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Bridge Substructure Concrete Deterioration

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BRIDGE SUBSTRUCTURE CONCRETE DETERIORATION

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16. Abstract

This report summarizes results of a reconnaissance survey of 45 bridges in NYSDOT Administrative Regions 1 (Albany), 4 (Rochester), 7 (Watertown), and 9 (Binghamton). They were inspected and reported by age group in 1979-80 under a previous study and discussed in Special Report 73. Visual inspections of the bridges began in the summer of 1988 and were completed in the summer of 1989. Included in this study is an analysis of mean ratings of bridge substructure elements from the Department's inventory of bridges in the same age categories. Ratings for epoxy-coated versus plain reinforcing bars in substructure concrete elements of similar age were compared. No attempt was made to determine causes of the distress observed except by inference. Problems most commonly encountered were closed cracks and spalling in splash zones, and open cracks in elements closer to the deck. Contrary to expectations based on Special Report 73, most substructure elements were found to be in good condition.

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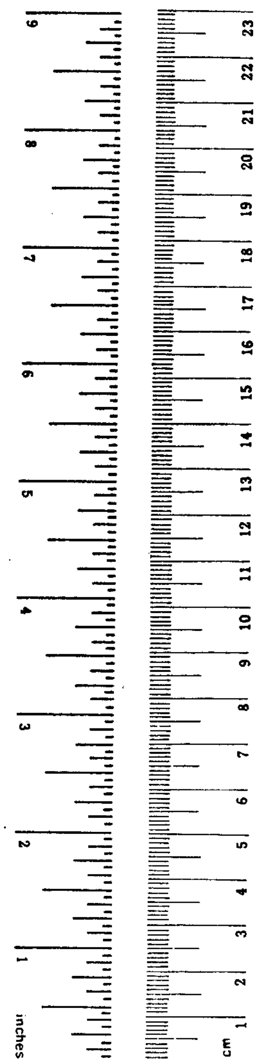
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

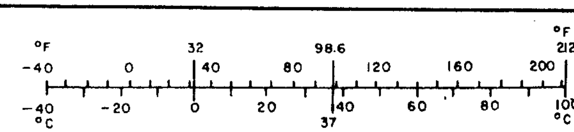
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I. INTRODUCTION

A. Background

Steel reinforcement embedded in concrete substructure elements of bridges is vulnerable to corrosion due to penetration of chlorides. Chloride concentration increases, due to repeated applications of deicing salts, result initially in cracking and eventually in spalling. Deterioration is also caused by faulty bridge deck drainage systems that permit contamination of structural members by brine runoff. Surfaces beneath deck joints (such as pier capbeams) or within the roadway splash zone (such as columns) are particularly vulnerable. The long-term effect of such deterioration is loss of carrying capacity.

In July 1983, Engineering Research and Development Bureau Special Report 73 (1) concluded that concrete in some substructure elements of 10-to-15-year-old bridges was beginning to exhibit damage, and predicted that the problem could become critical in the near future. Locations of specific bridges and total substructure members surveyed are listed in Table 1. Issued in November 1984, Engineering Instruction 84-60 (2) ordered use of epoxy-coated reinforcing steel in new substructure elements exposed to chloride, but had no provision to protect concrete in existing substructures (Appendix).

The potential severity of substructure deterioration due to corrosion caused by chloride warrants attention. Substructure elements have mostly vertical surfaces where ponding of brine will not occur. Thus even though chloride penetration rates are the same, corrosion damage develops in substructures at a slower rate than on decks, allowing more time to mobilize protective strategies. To address this issue, the Structures Design and Construction Division requested an update of the 1979-80 study, with the following specific objectives:

1. To determine the extent of change in condition of bridge substructure concrete by conducting a visual survey of the same bridges inspected in the 1979-80 study.

2. To determine the distribution of condition ratings for all bridge components (except decks) for those bridges that had 0-to-5, 6-to-10, and 11-to-15 years of service at the time of the 1979-80 survey. Currently they are 9-to-14, 15-to-19, and 20-to-24 years old, respectively.

3. To investigate the effectiveness of using epoxy-coated reinforcement instead of plain steel bars in reinforced concrete bridge substructures by comparing the condition ratings of all substructures in the 0-to-5-year age group built before and after issuance of EI 84-60.

Table 1. Substructure elements examined in the reconnaissance survey and condition notes.

BIN	Route, County, and Repair Contract Number [a]	Age Group, years	Elements[b]: Pier Columns	Pier Capbeams	Pier Pedestals	Bridge Seats and Pedestals	Backwalls	Wingwalls
REGION 1 (ALBANY)								
1030990	Rte 81, Catskill Creek Albany	9–14	—	—	—	10,0,0,0 EC	2,0,0,0 EC,WL	4,0,0,0
1094132	South Mall Arterial, Eagle St Albany	9–14	—	—	—	32,0,0,0 EC	2,0,0,0 EC	2,2,2,0
1092801	I 90 EB, Sand Rd Rensselaer	9–14	—	—	—	12,0,0,0 EC	2,0,0,0 EC	4,0,0,0 EC
1092802	I 90 WB, Sand Rd Rensselaer	9–14	—	—	—	12,0,0,1 EC	2,0,0,0 EC,WL	4,0,0,0 EC
1092480	Loudonville Rd, I 90 Albany	15–19	8,7,4,0 WL,SS,D	4,2,4,2 WL,S	32,1,0,0 SS	16,0,2,0 EC	2,1,1,0 EC,WL	4,1,2,0
1092691	I 90 EB, Miller Rd Rensselaer	15–19	—	—	—	14,0,0,0 EC	2,0,0,0 EC	4,0,0,0
1092692	I 90 WB, Miller Rd Rensselaer	15–19	—	—	—	14,0,0,0 EC	2,0,0,0 EC	4,0,0,0
1092269	Rte 7, I 787 Albany	15–19	—	—	—	42,0,0,0 EC	2,0,0,0 EC	4,0,1,0
1092600	Washington Ave, I 90 Rensselaer	20–24	2,1,0,0	1,2,0,0 D	6,0,0,0 EC	12,0,0,0 EC	2,2,1,0 EC	4,0,0,0
1034529	Everett Rd, I 90 Albany	20–24	18,4,2,1 P,D	6,6,6,2 D,S,SS	36,2,2,0 WL	24,2,1,0 EC,D,S	2,1,2,0 EC,WL	—
1033691	I 87 SB, Rte 74 Essex	20–24	1,0,1,0	1,0,1,0	4,0,0,0 EC	8,0,0,1 EC	2,0,1,1, EC	—
1033692	I 87 NB, Rte 74 Essex	20–24	2,0,0,0	1,0,1,0	5,0,0,0 EC	10,0,0,0 EC	2,0,0,0 EC,WL	—
REGION 4 (ROCHESTER)								
1069040	Rte 251, Genesee Exp Monroe	9–14	4,0,0,0	1,0,1,0 EC	8,0,0,0 EC	16,0,0,0 EC	2,1,2,0 EC,WL	4,0,0,0
1069050	Rte 15, Genesee Exp Monroe	9–14	8,0,1,0	1,0,0,0	8,0,0,0	16,0,0,0 EC	2,0,2,0 EC,WL	4,0,0,0
1069080	Erie Sta Rd, Genesee Exp Monroe	9–14	3,0,1,0	1,0,0,0	6,0,0,0 EC	12,0,0,0 EC	2,0,1,0 EC	4,0,0,0
1052200	Portland Ave, Rte 104 Monroe	15–19	15,8,6,3 D,WL	3,3,3,1 D	27,0,0,0 EC	18,0,0,0 EC	2,1,1,0 EC,WL	4,0,0,0
1052192	Rte 104, Carter St Monroe	15–19	6,3,0,0 D	2,2,0,1 D	12,0,0,0 EC	12,0,0,0 EC	2,0,2,0 EC	4,2,1,0 EC,D
1062491	Rte 390, Latona Rd Monroe, Repair Contract D250610	15–19	12,3,4,0 R,D,WL,P	2,0,0,0	12,0,0,0	12,0,0,0 EC	2,1,1,0 EC,D	4,1,0,1 D
1052160	Clinton Ave, Rte 104 Monroe, Repair Contract D500159	20–24	5,3,2,0 R,D,P	1,1,1,0 D	10,1,1,0	20,0,0,0 EC	2,0,0,0 EC,R	4,2,1,1 D,P
1025940	Edgewood Ave, I 590 Monroe, Repair Contract D500049	20–24	3,1,1,0, P	1,0,0,0 R,EC	6,0,0,0	10,0,0,0 EC	2,0,0,0 EC,R	4,0,0,0
1021662	I 590 NB, Monroe Ave Monroe, Repair Contract D500049	20–24	15,0,0,0 P	3,0,0,0 R	18,0,0,0	12,0,0,0 EC	2,0,2,0 EC,R	2,0,0,0
1063860	Hollenbeck St, Rte 104 Monroe, Repair Contract D500159	20–24	3,0,0,0 R	1,0,0,0 R	6,0,0,0 EC	12,0,0,0 EC	2,1,1,0 EC,R,WL	4,1,0,0

Table 1 (continued).

BIN	Route, County, and Repair Contract Number [a]	Age Group, years	Elements[b] Pier Columns	Pier Capbeams	Pier Pedestals	Bridge Seats and Pedestals	Backwalls	Wingwalls
REGION 7 (WATERTOWN)								
1009780	Rte 12, Otter Creek Jefferson	9–14	—	—	—	—	2,0,1,0	4,0,1,0
1023960	Rte 37, W Branch Little Salmon River Franklin	9–14	—	—	—	—	2,0,0,0 EC	4,0,0,0
2219660	Cornelia St, D&H Railroad Clinton	9–14	6,0,1,0	3,0,0,0	—	—	2,2,2,0 EC	4,1,2,0
1009610	Rte 12, Mill Creek Lewis	9–14	—	—	—	10,0,0,0 EC	2,0,2,0 EC	4,0,1,0
1010020	Rte 12D, Sugar River Lewis	15–19	4,0,0,0 P	2,0,1,0	12,0,0,0 EC	12,0,0,0 EC	2,0,2,0 EC	4,0,0,0
1032230	Co. Rd 16, I 81 Jefferson	20–24	12,0,0,0	4,0,0,1	20,0,0,0 EC	10,0,0,0 EC	2,0,2,0 EC	4,0,1,0 EC
1032241	I 81 SB, Perch Lake Rd Jefferson	20–24	6,0,0,0	2,2,2,1 WL	10,0,0,0 EC	10,0,0,0 EC	2,0,1,0 EC	4,0,0,0 EC
1032242	I 81 NB, Perch Lake Rd Jefferson	20–24	6,0,0,0	2,1,2,2 SS	10,0,0,0 EC	10,0,0,0 EC	2,0,2,0 EC	4,0,2,0 EC
1052251	I 81 SB, Rte 411 Jefferson	20–24	6,1,6,1	2,1,2,1	10,0,0,0 EC	10,0,0,0 EC	2,0,0,0 EC	—
1032252	I 81 NB, Rte 411 Jefferson	20–24	6,0,5,1 S	2,2,2,1	10,0,0,0 EC	10,0,0,0 EC,S	2,0,1,0 EC	—
REGION 9 (BINGHAMTON)								
1007880	Rte 10, Brimstone Creek Schoharie	9–14	—	—	—	—	2,1,1,0	4,0,2,0
1007890	Rte 10, Brimstone Creek Schoharie	9–14	—	—	—	—	2,1,1,0	4,0,1,0
1007900	Rte 10, Brimstone Creek Schoharie	9–14	—	—	—	—	2,2,2,0	4,1,2,0
1095241	I 88 WB, D&H Railroad Otsego	15–19	12,0,0,0 S	—	—	12,0,0,0 EC	2,0,2,0 EC	4,0,1,0
1095242	I 88 EB, D&H Railroad Otsego	15–19	12,0,0,0	—	—	12,0,0,0 EC	2,0,2,0 EC	4,0,0,0
1063189	Rte 201, Rte 17 Broome	15–19	6,1,0,0 D	2,1,0,1 D,S	12,0,0,0 EC	24,0,1,0 EC	2,1,1,0 EC,WL	4,1,4,1 S,SS,P,WL,D
1054911	Rte 17 WB, Beaverkill River Delaware South	20–24	6,0,0,1 D	6,0,0,0	30,0,0,0 EC	10,0,0,0 EC	2,0,0,0 EC	4,0,0,0
1054912	Rte 17 EB, Beaverkill River Delaware South	20–24	6,0,0,0 D,WL	6,0,0,1 D	30,0,1,1 EC	10,0,0,0 EC	2,0,1,0 EC	4,0,0,2 P,D
1054961	Rte 17 WB, Russell Brook Rd Delaware South	20–24	4,0,0,0	2,0,0,0	10,0,0,0 EC	10,0,0,0 EC	2,1,0,1 EC,D	4,0,0,0
1054962	Rte 17 EB, Russell Brook Rd Delaware South	20–24	4,0,0,0	2,0,0,0	10,0,0,0 EC	10,0,0,0 EC	2,1,0,1 EC,D,WL	4,0,1,0
1012999	Rte 26, Rte 434 Broome, Repair Contract D500522	20–24	32,0,0,0 R	8,0,0,0 R	56,0,0,0 R	28,0,0,0 R	2,0,0,0 R	4,0,0,0 R
1013529	Rte 17, DeBruce Rd Sullivan	20–24	32,4,1,1 D	8,1,4,1 D,SS,RS	112,0,0,0 EC,WL	28,2,1,0 EC,D,WL,P	2,0,2,1 EC,D,WL,P	4,0,1,0
1013539	Rte 17, Service Road Sullivan	20–24	—	—	—	28,13,0,13 EC	2,1,1,2 EC,WL	4,0,4,2 P

[a] First line of each entry lists route carried by the bridge, followed by feature the bridge crosses; second line lists county maintenance residency responsible for the bridge and repair contract number (if any).
[b] First line of each entry lists number of substructure elements, number with open cracks, number with closed cracks, and number with spalls; second line lists condition abbreviations: R = major repair (these elements have not been included in further data analysis), EC = epoxy coating, D = delaminations, WL = water leakage, S = scaling, P = patching, SS = salt-stained, RS = rust-stained.

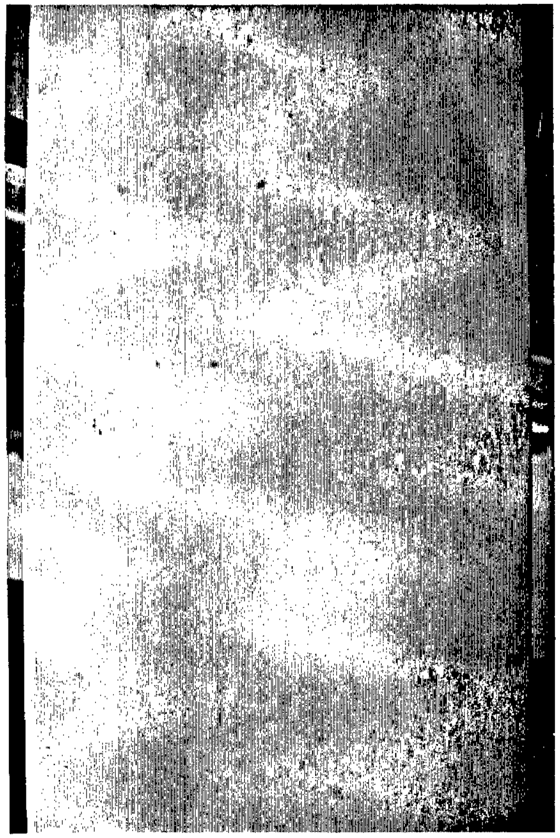
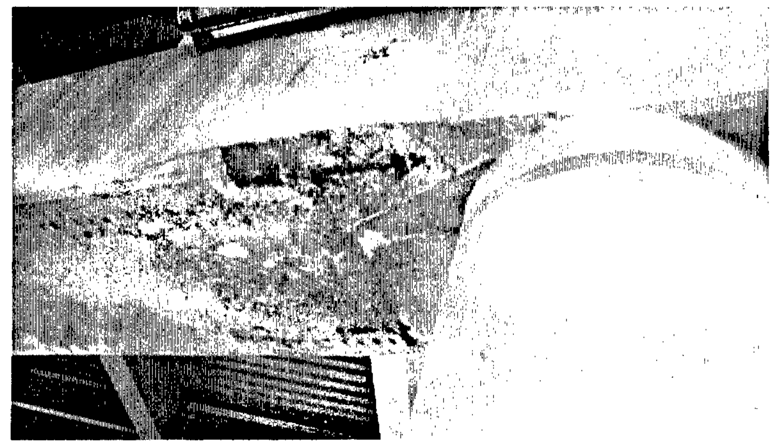


Figure 1 (far left). Pier column with closed cracking.

Figure 2 (near left). Pier column with open vertical cracking.



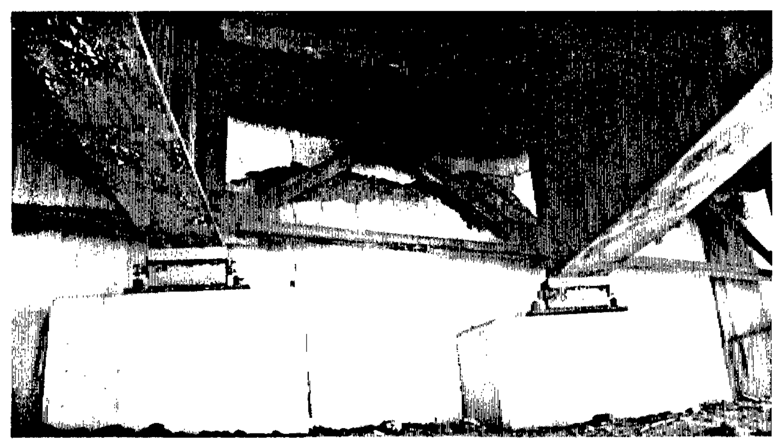


Figure 3 (top right). Spalling in capbeam.

Figure 4 (bottom right). Open horizontal cracking and spalling in backwall.

The purpose of this report is to document the findings from this work and to draw appropriate conclusions. To draw such conclusions, the survey was conducted in a manner similar to the prior survey. Consequently, in preparing this report liberal use has been made of Special Report 73.

B. Procedures

1. Reconnaissance Survey

The 45 bridges in the original survey were examined to determine the kinds and frequencies of distress occurring in different substructure elements. One bridge (No. 1012999) in the 20-to-24 age group from Region 9 had undergone major rehabilitation and thus was dropped from the survey. Several others had undergone contract repairs, with elements identified as repaired removed from further consideration in the analysis (as noted in Table 1). As in the original survey, the structural elements examined were pier columns, pier capbeams, pier pedestals, bridge seats and pedestals, backwalls, and wingwalls.

The survey was restricted to visual inspection aided by such simple expedients as sounding in-place concrete with a hammer or examination with a 10x hand lens, in the same manner on the first survey.

The presence of cracks in concrete can contribute to deterioration of structures because they facilitate entry of moisture, oxygen, and chlorides. In this study, cracking was classified as "open" or "closed," depending on whether a safety pin (0.03 in. diam.) could be inserted. The general direction of cracking (horizontal or vertical) was noted. Examples of closed and open, vertical cracking are shown in Figures 1 and 2.

Spalls are depressions caused by separation and removal of surface concrete. Spalling is related to age of the structure because major causes of spalling are corrosion of the reinforcing steel and overstressing. A spall is usually quite noticeable, but it may start as a delamination in the concrete and thus not be visible. Delaminations are separations along a plane parallel to the surface of the concrete (3), and are detected by sounding. Both spalls and delaminations were classified as "small" (<5 sf), "medium" (5 to 10 sf), or "large" (>10 sf). Examples of spalling are shown in Figures 3 and 4.

Observations of cracking, spalling, staining, and other manifestations of weakness or distress, where apparent, are summarized in Table 1. Sounding of concrete with a hammer was useful in detecting areas where the concrete was delaminating. In addition, water leakage through deck joints was noted. Identification numbers of rehabilitation contracts that include substructure work are also noted. Cracks were counted, but crack length was not measured. No attempt was made to measure the percentage of the surface area of a given element that was cracked or spalled.

2. Ratings of Substructure Concrete Members

Estimates of the overall condition of bridge substructures and changes in that condition with time were obtained from the Department's biennial bridge inspection and condition inventory. This inventory uses a numerical rating system to describe condition of individual bridge elements, and inspection report summaries can be obtained for individual bridges or structural elements and summarized by age, region, or other categories of interest. The condition of each bridge element is rated numerically and assigned to one of the following categories:

Rating number	Description
1	Potentially hazardous.
2	Used to shade between Ratings 1 and 3.
3	Serious deterioration or not functioning as originally designed.
4	Used to shade between Ratings 3 and 5.
5	Minor deterioration and functioning as originally designed.
6	Used to shade between Ratings 5 and 7.
7	New condition.

Although information from inventory files is useful in providing an overview of relative condition of various bridge elements, it does not identify specific conditions leading to a low rating nor contributing factors associated with any deterioration.

The inventory files were used to determine the distribution of ratings for each element of interest for bridges in 9-to-14, 15-to-19, and 20-to-24 year age groups, and by NYSDOT region. The elements considered included those inspected as part of the reconnaissance survey as well as abutment stems, solid pier stems, primary members, and secondary members.

The mean rating of each of these 11 structural elements was calculated by region and age group. Ratings for all substructure elements in bridges built after EI 84-60 was issued (the 0-to-5 year group) were compared by region to ratings of all substructures of similar age built before with plain steel reinforcement before adopting EI 84-60.

II. RESULTS AND DISCUSSION

A. Survey Analysis

In general, the level of deterioration observed in the field reconnaissance survey was less than had been anticipated, based on extrapolation of findings summarized in Special Report 73. The principal modes of distress were cracking and spalling in pier columns and capbeams, and vertical cracks in abutment backwalls. Small areas of scaling were present in many of the structures examined, but appeared to be only cosmetic in nature.

The following discussion addresses the major types of defects encountered for each of the substructure elements examined. The frequency of both types of cracking (open and closed) and spalling was summarized for the three age groups in each of the four regions surveyed and is given in Tables 2 through 7. Additional condition information is presented in Table 1.

1. Pier Columns

Condition of pier columns varies widely from region to region as seen in Table 2. Pier columns in the 9-to-14 year age group were generally free of deterioration, but cracking and delaminations were observed in the 15-to-19 and 20-to-24 year groups. Most cracks were closed and vertical. Delaminations were found in all regions except Region 7 as noted in Table 1, but were generally small. Spalls were very infrequent and small when found. There were small increases in percentages of columns with open and closed cracks between the two surveys, but spalls decreased because of repairs. As can be seen in Table 1, pier columns were the most frequently repaired element in the survey, usually with shotcrete patches. As can also be seen in Table 1, two bridges (BINs 1092480 in Region 1 and 1052200 in Region 4) have most of the reported damage. Correlation of distress with distance from the road shoulder to the column was not attempted.

2. Pier Capbeams

Deterioration of pier capbeams generally increased with time and was observed in all regions, as can be seen in Table 3. Bridges in the 9-to-14 age group show little distress. Open and closed cracks occurred with about the same frequency. Spalls observed were accompanied by cracks of both types as well as rust and salt staining, and were generally small. A number of delaminations of various sizes were observed as noted in Table 1. Rust stains were found quite often. Open cracks appeared on a smaller percentage of pier capbeams than in the previous survey, but closed cracks and spalls

Table 2. Pier Column cracks and spalls.

Age Group, years	Feature	Region 1 N	Region 1 n	Region 1 %	Region 4 N	Region 4 n	Region 4 %	Region 7 N	Region 7 n	Region 7 %	Region 9 N	Region 9 n	Region 9 %	Totals by Age N	Totals by Age n	Totals by Age %
1979-80 Survey																
0-5	Open Cracks	0	-	---	15	0	0.0	6	0	0.0	24	0	0.0	45	0	0.0
	Closed Cracks	0	-	---	15	0	0.0	6	0	0.0	24	0	0.0	45	0	0.0
	Spalling	0	-	---	15	0	0.0	6	0	0.0	24	0	0.0	45	0	0.0
6-10	Open Cracks	8	8	100.0	26	4	15.4	4	1	25.0	26	1	3.8	64	14	21.9
	Closed Cracks	8	7	87.5	26	0	0.0	4	0	0.0	26	3	11.5	64	10	15.6
	Spalling	8	0	0.0	26	5	19.2	4	0	0.0	26	1	3.8	64	6	9.4
11-15	Open Cracks	24	0	0.0	33	8	24.2	36	1	2.8	64	12	18.8	157	21	13.4
	Closed Cracks	24	3	12.5	33	6	18.2	36	1	2.8	64	3	4.7	157	13	8.3
	Spalling	24	3	12.5	33	6	18.2	36	1	2.8	64	9	14.1	157	19	12.1
Totals by Region	Open Cracks	32	8	25.0	74	12	16.2	46	2	4.3	114	13	11.4	266	35	13.2
	Closed Cracks	32	10	31.3	74	6	8.1	46	1	2.2	114	6	5.3	266	23	8.6
	Spalling	32	3	9.4	74	11	14.9	46	1	2.2	114	10	8.8	266	25	9.4
1988-89 Survey																
9-14	Open Cracks	0	-	---	15	0	0.0	6	0	0.0	0	-	---	21	0	0.0
	Closed Cracks	0	-	---	15	2	13.3	6	1	16.7	0	-	---	21	3	14.3
	Spalling	0	-	---	15	0	0.0	6	0	0.0	0	-	---	21	0	0.0
15-19	Open Cracks	8	7	87.5	27	14	51.9	4	0	0.0	30	1	3.3	69	22	31.9
	Closed Cracks	8	4	50.0	27	10	37.0	4	0	0.0	30	0	0.0	69	14	20.3
	Spalling	8	0	0.0	27	3	11.1	4	0	0.0	30	0	0.0	69	3	4.3
20-24	Open Cracks	23	5	21.7	18	1	5.6	36	1	2.8	52	4	7.7	129	11	8.5
	Closed Cracks	23	3	13.0	18	1	5.6	36	11	30.6	52	1	1.9	129	16	12.4
	Spalling	23	1	4.3	18	0	0.0	36	2	5.6	52	2	3.8	129	5	3.9
Totals by Region	Open Cracks	31	12	38.7	60	15	25.0	46	1	2.2	82	5	6.1	219	33	15.1
	Closed Cracks	31	7	22.6	60	13	21.7	46	12	26.1	82	1	1.2	219	33	15.1
	Spalling	31	1	3.2	60	3	5.0	46	2	4.3	82	2	2.4	219	8	3.7

NOTE: N = number of elements examined, n = number of elements in which feature occurs.
Elements that have had major repairs are not included in the second part of this table.

Table 3. Pier Cap Beam cracks and spalls.

Age Group, years	Feature	Region 1 N	Region 1 n	Region 1 %	Region 4 N	Region 4 n	Region 4 %	Region 7 N	Region 7 n	Region 7 %	Region 9 N	Region 9 n	Region 9 %	Totals by Age N	Totals by Age n	Totals by Age %
1979-80 Survey																
0-5	Open Cracks	0	-	---	2	0	0.0	3	0	0.0	0	-	---	5	0	0.0
	Closed Cracks	0	-	---	2	0	0.0	3	0	0.0	0	-	---	5	0	0.0
	Spalling	0	-	---	2	0	0.0	3	0	0.0	0	-	---	5	0	0.0
6-10	Open Cracks	4	3	75.0	6	6	100.0	2	0	0.0	18	0	0.0	30	9	30.0
	Closed Cracks	4	0	0.0	6	1	16.7	2	0	0.0	18	0	0.0	30	1	3.3
	Spalling	4	0	0.0	6	2	33.3	2	0	0.0	18	0	0.0	30	2	6.7
11-15	Open Cracks	9	4	44.4	5	5	100.0	12	4	33.3	16	9	56.3	42	22	52.4
	Closed Cracks	9	2	22.2	5	2	40.0	12	3	25.0	16	9	56.3	42	16	38.1
	Spalling	9	0	0.0	5	0	0.0	12	0	0.0	16	0	0.0	42	0	0.0
Totals by Region	Open Cracks	13	7	53.8	13	11	84.6	17	4	23.5	34	9	26.5	77	31	40.3
	Closed Cracks	13	2	15.4	13	3	23.1	17	3	17.6	34	9	26.5	77	17	22.1
	Spalling	13	0	0.0	13	2	15.4	17	0	0.0	34	0	0.0	77	2	2.6
1988-89 Survey																
9-14	Open Cracks	0	-	---	3	0	0.0	3	0	0.0	0	-	---	6	0	0.0
	Closed Cracks	0	-	---	3	1	33.3	3	0	0.0	0	-	---	6	1	16.7
	Spalling	0	-	---	3	0	0.0	3	0	0.0	0	-	---	6	0	0.0
15-19	Open Cracks	4	2	50.0	7	5	71.4	2	0	0.0	2	1	50.0	15	8	53.3
	Closed Cracks	4	4	100.0	7	3	42.9	2	1	0.0	2	0	0.0	15	8	53.3
	Spalling	4	2	50.0	7	2	28.6	2	0	0.0	2	1	50.0	15	5	33.3
20-24	Open Cracks	9	8	88.9	1	1	100.0	12	6	50.0	24	1	4.2	46	16	34.8
	Closed Cracks	9	8	88.9	1	1	100.0	12	8	66.7	24	4	16.7	46	21	45.7
	Spalling	9	2	22.2	1	0	0.0	12	6	50.0	24	2	8.3	46	10	21.7
Totals by Region	Open Cracks	13	10	76.9	11	6	54.5	17	6	35.3	26	2	7.7	67	24	35.8
	Closed Cracks	13	12	92.3	11	5	45.5	17	9	52.9	26	4	15.4	67	30	44.8
	Spalling	13	4	30.8	11	2	18.2	17	6	35.3	26	3	11.5	67	15	22.4

NOTE: N = number of elements examined, n = number of elements in which feature occurs.
Elements that have had major repairs are not included in the second part of this table.

Table 4. Pier Pedestal cracks and spalls.

Age Group, years	Feature	Region 1 N	Region 1 n	Region 1 %	Region 4 N	Region 4 n	Region 4 %	Region 7 N	Region 7 n	Region 7 %	Region 9 N	Region 9 n	Region 9 %	Totals by Age N	Totals by Age n	Totals by Age %
1979-80 Survey																
0-5	Open Cracks	0	-	---	14	0	0.0	0	-	---	0	-	---	14	0	0.0
	Closed Cracks	0	-	---	14	0	0.0	0	-	---	0	-	---	14	0	0.0
	Spalling	0	-	---	14	0	0.0	0	-	---	0	-	---	14	0	0.0
6-10	Open Cracks	32	0	0.0	49	0	0.0	12	0	0.0	92	0	0.0	185	0	0.0
	Closed Cracks	32	0	0.0	49	0	0.0	12	0	0.0	92	0	0.0	185	0	0.0
	Spalling	32	0	0.0	49	0	0.0	12	0	0.0	92	0	0.0	185	0	0.0
11-15	Open Cracks	51	0	0.0	30	0	0.0	60	1	1.7	142	0	0.0	283	1	0.4
	Closed Cracks	51	0	0.0	30	0	0.0	60	0	0.0	142	0	0.0	283	0	0.0
	Spalling	51	0	0.0	30	0	0.0	60	0	0.0	142	0	0.0	283	0	0.0
Totals by Region	Open Cracks	83	0	0.0	93	0	0.0	72	1	1.4	234	0	0.0	482	1	0.2
	Closed Cracks	83	0	0.0	93	0	0.0	72	0	0.0	234	0	0.0	482	0	0.0
	Spalling	83	0	0.0	93	0	0.0	72	0	0.0	234	0	0.0	482	0	0.0
1988-89 Survey																
9-14	Open Cracks	0	-	---	22	0	0.0	0	-	---	0	-	---	22	0	0.0
	Closed Cracks	0	-	---	22	0	0.0	0	-	---	0	-	---	22	0	0.0
	Spalling	0	-	---	22	0	0.0	0	-	---	0	-	---	22	0	0.0
15-19	Open Cracks	32	1	3.1	51	0	0.0	12	0	0.0	12	0	0.0	107	1	0.9
	Closed Cracks	32	0	0.0	51	0	0.0	12	0	0.0	12	0	0.0	107	0	0.0
	Spalling	32	0	0.0	51	0	0.0	12	0	0.0	12	0	0.0	107	0	0.0
20-24	Open Cracks	51	2	3.9	40	1	2.5	60	0	0.0	192	0	0.0	343	3	0.9
	Closed Cracks	51	2	3.9	40	1	2.5	60	0	0.0	192	1	0.5	343	4	1.2
	Spalling	51	0	0.0	40	0	0.0	60	0	0.0	192	1	0.5	343	1	0.3
Totals by Region	Open Cracks	83	3	3.6	113	1	0.9	72	0	0.0	204	0	0.0	472	4	0.8
	Closed Cracks	83	2	2.4	113	1	0.9	72	0	0.0	204	1	0.5	472	4	0.8
	Spalling	83	0	0.0	113	0	0.0	72	0	0.0	204	1	0.5	472	1	0.2

NOTE: N = number of elements examined, n = number of elements in which feature occurs.
Elements that have had major repairs are not included in the second part of this table.

increased substantially. Repairs were few and overall condition of this element was better than expected, based on extrapolation of Special Report 73 findings. As can be seen in Table 1, however, damage has occurred on a substantial number of pier capbeams in all regions and all age groups. These beams were generally in the poorest condition of all substructure elements surveyed.

3. Pier Pedestals and Bridge Seat Pedestals

Pier pedestals and bridge seat pedestals exhibited the least amount of deterioration (Tables 4 and 5) in all regions and age groups. This was also true of the first survey, where percentages were low in all categories. Evidence of distress was generally in the form of either open or closed cracks and was limited to the older bridges. Table 1 shows that one bridge (BIN 1013539 in Region 9) has sustained almost all the damage in these two element categories. This lack of distress may be attributable to fact that the vast majority of the pedestals surveyed had been sealed with an epoxy coating at some point, as indicated in Table 1.

4. Backwalls

Closed vertical cracks were the predominant mode of distress in the backwalls surveyed. This type of damage may have increased substantially since the prior survey, but this is an area of subjective judgment by the different observers as to whether the cracks are due to corrosion. Relative frequencies of the types of distress are summarized in Table 6. Many backwalls had horizontal cracks. The most severe damage noted was open, horizontal cracking extending the entire length of one backwall (BIN 1054961 in Region 9), shown in Figure 4. There was no indication that this was due to deterioration caused by chloride infiltration. Spalls and delaminations were observed infrequently and were generally limited to the 20-to-24 age group. Many backwalls had also been sealed with an epoxy coating.

5. Wingwalls

Wingwalls were found to be in generally good condition, although relative percentages of damage are higher than in the previous survey (Table 7). Numerous small cracks were observed, with a few instances of small spalls and delaminations. Several wingwalls were repaired with shotcrete. In addition, some wingwalls had been sealed with an epoxy coating. "U-type" wingwalls were considered a continuation of the backwall and reported in that category.

B. Inventory Analysis

1. Element Rating Comparison by Region and Age

Bridge inspection personnel from the Main Office and regions rate individual

Table 5. Bridge Seat and Pedestal cracks and spalls.

Age Group, years	Feature	Region 1 N	n	%	Region 4 N	n	%	Region 7 N	n	%	Region 9 N	n	%	Totals by Age N	n	%
1979-80 Survey																
0-5	Open Cracks	42	0	0.0	44	0	0.0	0	-	---	24	0	0.0	110	0	0.0
	Closed Cracks	42	0	0.0	44	0	0.0	0	-	---	24	0	0.0	110	0	0.0
	Spalling	42	0	0.0	44	0	0.0	0	-	---	24	0	0.0	110	0	0.0
6-10	Open Cracks	110	0	0.0	50	0	0.0	12	0	0.0	64	0	0.0	236	0	0.0
	Closed Cracks	110	0	0.0	50	0	0.0	12	0	0.0	64	0	0.0	236	0	0.0
	Spalling	110	0	0.0	50	0	0.0	12	0	0.0	64	0	0.0	236	0	0.0
11-15	Open Cracks	54	0	0.0	46	0	0.0	60	0	0.0	70	9	12.9	230	9	3.9
	Closed Cracks	54	0	0.0	46	0	0.0	60	0	0.0	70	0	0.0	230	0	0.0
	Spalling	54	0	0.0	46	0	0.0	60	0	0.0	70	5	7.1	230	5	2.2
Totals by Region	Open Cracks	206	0	0.0	140	0	0.0	72	0	0.0	158	9	5.7	576	9	1.6
	Closed Cracks	206	0	0.0	140	0	0.0	72	0	0.0	158	0	0.0	576	0	0.0
	Spalling	206	0	0.0	140	0	0.0	72	0	0.0	158	5	3.2	576	5	0.9
1988-89 Survey																
9-14	Open Cracks	66	0	0.0	44	0	0.0	10	0	0.0	0	-	---	120	0	0.0
	Closed Cracks	66	0	0.0	44	0	0.0	10	0	0.0	0	-	---	120	0	0.0
	Spalling	66	1	0.0	44	0	0.0	10	0	0.0	0	-	---	120	1	0.8
15-19	Open Cracks	86	0	0.0	42	0	0.0	12	0	0.0	48	0	0.0	188	0	0.0
	Closed Cracks	86	2	2.3	42	0	0.0	12	0	0.0	48	1	2.1	188	3	1.6
	Spalling	86	0	0.0	42	0	0.0	12	0	0.0	48	0	0.0	188	0	0.0
20-24	Open Cracks	54	2	3.7	46	0	0.0	50	0	0.0	82	15	18.3	232	17	7.3
	Closed Cracks	54	1	1.9	46	0	0.0	50	0	0.0	82	2	2.4	232	3	1.3
	Spalling	54	1	1.9	46	0	0.0	50	0	0.0	82	13	15.9	232	14	6.0
Totals by Region	Open Cracks	206	2	1.0	132	0	0.0	72	0	0.0	130	15	11.5	540	17	3.1
	Closed Cracks	206	3	1.5	132	0	0.0	72	0	0.0	130	3	2.3	540	6	1.1
	Spalling	206	2	1.0	132	0	0.0	72	0	0.0	130	13	10.0	540	15	2.8

NOTE: N = number of elements examined, n = number of elements in which feature occurs.
Elements that have had major repairs are not included in the second part of this table.

Table 6. Backwall cracks and spalls.

Age Group, years	Feature	Region 1 N	Region 1 n	Region 1 %	Region 4 N	Region 4 n	Region 4 %	Region 7 N	Region 7 n	Region 7 %	Region 9 N	Region 9 n	Region 9 %	Totals by Age N	Totals by Age n	Totals by Age %
1979-80 Survey																
0-5	Open Cracks	4	0	0.0	6	0	0.0	6	1	16.7	10	4	40.0	26	5	19.2
	Closed Cracks	4	0	0.0	6	0	0.0	6	0	0.0	10	0	0.0	26	0	0.0
	Spalling	4	0	0.0	6	0	0.0	6	0	0.0	10	0	0.0	26	0	0.0
6-10	Open Cracks	12	0	0.0	6	4	66.7	2	1	0.0	10	5	50.0	30	10	33.3
	Closed Cracks	12	0	0.0	6	0	0.0	2	0	0.0	10	0	0.0	30	0	0.0
	Spalling	12	0	0.0	6	1	16.7	2	0	0.0	10	3	30.0	30	4	13.3
11-15	Open Cracks	8	3	37.5	8	3	37.5	12	0	0.0	6	0	0.0	34	6	17.6
	Closed Cracks	8	2	25.0	8	0	0.0	12	0	0.0	6	0	0.0	34	2	5.9
	Spalling	8	1	12.5	8	0	0.0	12	0	0.0	6	1	16.7	34	2	5.9
Totals by Region	Open Cracks	24	3	12.5	20	7	35.0	20	2	10.0	26	9	34.6	90	21	23.3
	Closed Cracks	24	2	8.3	20	0	0.0	20	0	0.0	26	0	0.0	90	2	2.2
	Spalling	24	1	4.2	20	1	5.0	20	0	0.0	26	4	15.4	90	6	6.7
1988-89 Survey																
9-14	Open Cracks	8	0	0.0	6	1	16.7	8	2	25.0	6	4	0.0	28	7	25.0
	Closed Cracks	8	0	0.0	6	5	83.3	8	5	62.5	6	4	0.0	28	14	50.0
	Spalling	8	0	0.0	6	0	0.0	8	0	0.0	6	0	0.0	28	0	0.0
15-19	Open Cracks	8	1	12.5	6	2	33.3	2	0	0.0	6	1	16.7	22	4	18.2
	Closed Cracks	8	1	12.5	6	4	66.7	2	2	0.0	6	5	83.3	22	12	54.5
	Spalling	8	0	0.0	6	0	0.0	2	0	0.0	6	0	0.0	22	0	0.0
20-24	Open Cracks	8	2	25.0	0	-	--	10	0	0.0	12	3	25.0	30	5	16.7
	Closed Cracks	8	4	50.0	0	-	--	10	6	60.0	12	4	33.3	30	14	46.7
	Spalling	8	1	12.5	0	-	--	10	0	0.0	12	5	41.7	30	6	20.0
Totals by Region	Open Cracks	24	3	12.5	12	3	25.0	20	2	10.0	24	8	33.3	80	16	20.0
	Closed Cracks	24	5	20.8	12	9	75.0	20	13	65.0	24	13	54.2	80	40	50.0
	Spalling	24	1	4.2	12	0	0.0	20	0	0.0	24	5	20.8	80	6	7.5

NOTE: N = number of elements examined, n = number of elements in which feature occurs.
Elements that have had major repairs are not included in the second part of this table.

Table 7. Wingwall cracks and spalls.

Age Group, years	Feature	Region 1 N	Region 1 n	Region 1 %	Region 4 N	Region 4 n	Region 4 %	Region 7 N	Region 7 n	Region 7 %	Region 9 N	Region 9 n	Region 9 %	Totals by Age N	Totals by Age n	Totals by Age %
1979-80 Survey																
0-5	Open Cracks	6	0	0.0	12	0	0.0	12	0	0.0	20	0	0.0	50	0	0.0
	Closed Cracks	6	0	0.0	12	0	0.0	12	0	0.0	20	0	0.0	50	0	0.0
	Spalling	6	0	0.0	12	0	0.0	12	1	8.3	20	0	0.0	50	1	2.0
6-10	Open Cracks	24	11	45.8	12	1	8.3	4	0	0.0	20	0	0.0	60	12	20.0
	Closed Cracks	24	7	29.2	12	0	0.0	4	1	25.0	20	0	0.0	60	8	13.3
	Spalling	24	0	0.0	12	0	0.0	4	0	0.0	20	0	0.0	60	0	0.0
11-15	Open Cracks	8	2	25.0	14	2	14.3	12	0	0.0	12	1	8.3	46	5	10.9
	Closed Cracks	8	2	25.0	14	1	7.1	12	0	0.0	12	0	0.0	46	3	6.5
	Spalling	8	0	0.0	14	0	0.0	12	0	0.0	12	0	0.0	46	0	0.0
Totals by Region	Open Cracks	38	13	34.2	38	3	7.9	28	0	0.0	52	1	1.9	156	17	10.9
	Closed Cracks	38	9	23.7	38	1	2.6	28	1	3.6	52	0	0.0	156	11	7.1
	Spalling	38	0	0.0	38	0	0.0	28	1	3.6	52	0	0.0	156	1	0.6
1988-89 Survey																
9-14	Open Cracks	14	2	0.0	12	0	0.0	16	1	6.3	12	1	0.0	54	4	7.4
	Closed Cracks	14	2	0.0	12	0	0.0	16	4	25.0	12	5	0.0	54	11	20.4
	Spalling	14	0	0.0	12	0	0.0	16	0	0.0	12	0	0.0	54	0	0.0
15-19	Open Cracks	16	1	6.3	12	3	25.0	4	0	0.0	12	1	8.3	44	5	11.4
	Closed Cracks	16	3	18.8	12	1	8.3	4	0	0.0	12	5	41.7	44	9	20.5
	Spalling	16	0	0.0	12	1	8.3	4	0	0.0	12	3	25.0	44	4	9.1
20-24	Open Cracks	4	0	0.0	14	3	21.4	12	0	0.0	24	0	0.0	54	3	5.6
	Closed Cracks	4	0	0.0	14	1	7.1	12	3	25.0	24	5	20.8	54	9	16.7
	Spalling	4	0	0.0	14	1	7.1	12	0	0.0	24	1	4.2	54	2	3.7
Totals by Region	Open Cracks	34	3	8.8	38	6	15.8	32	1	3.1	48	2	4.2	152	12	7.9
	Closed Cracks	34	5	14.7	38	2	5.3	32	7	21.9	48	15	31.3	152	29	19.1
	Spalling	34	0	0.0	38	2	5.3	32	0	0.0	48	4	8.3	152	6	3.9

NOTE: N = number of elements examined, n = number of elements in which feature occurs.
Elements that have had major repairs are not included in the second part of this table.

substructure elements biennially on a per-span basis as mandated by the 1978 Surface Transportation Act. When more than a single element is present in a span (i.e., multiple pier columns), the rating of the member in the worst condition determines that for the group. Ratings were analyzed for ten substructure elements. Mean ratings were calculated for all members of all highway bridges in the same three age groups examined in the reconnaissance survey. A one-way analysis of variance or ANOVA, (4) was performed at the 99-percent confidence level to determine uniformity of ratings among regions. As shown in Figure 5, based on ANOVA region-to-region differences are significant for all three age groups.

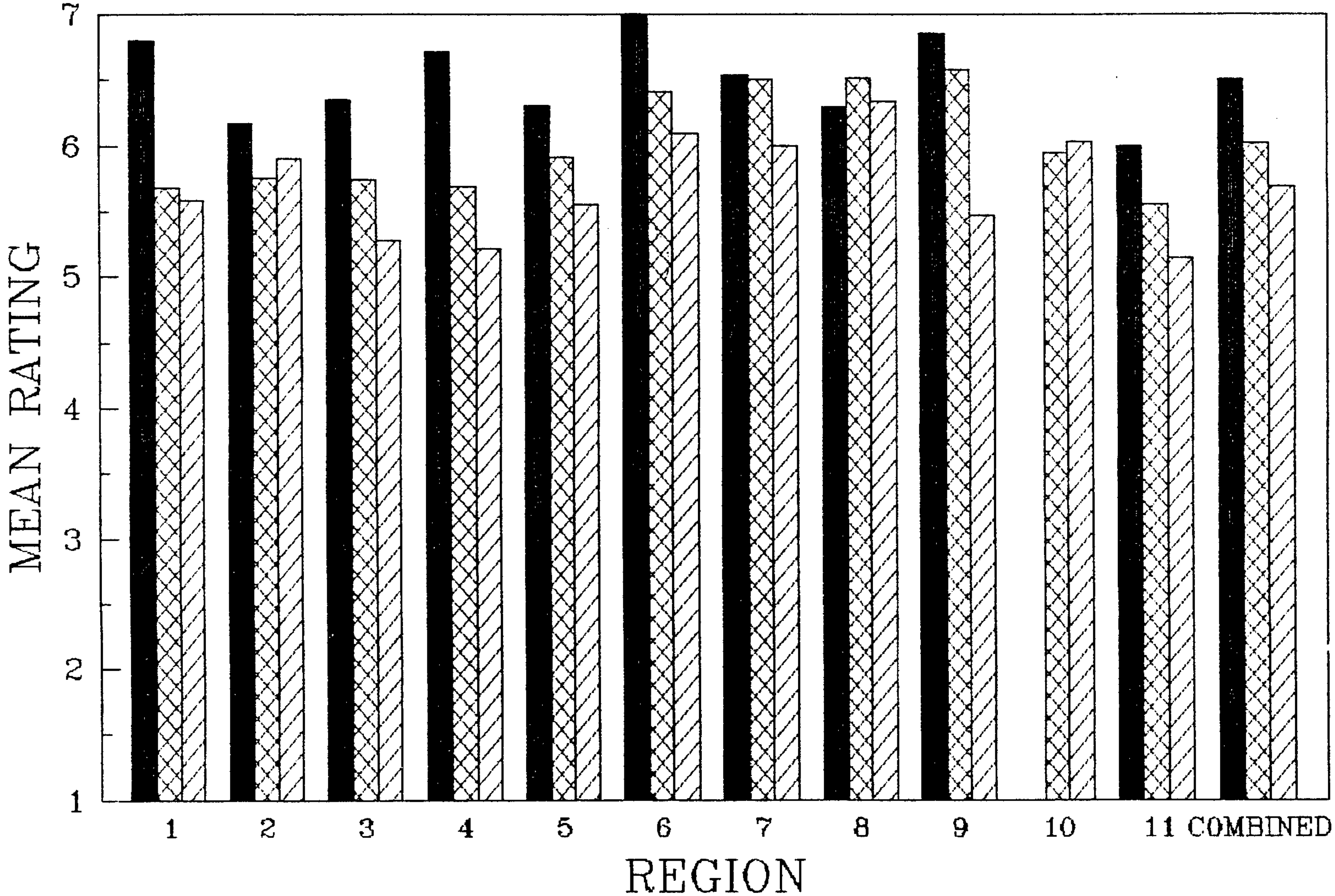
In general, ratings decreased with age for all elements. Most condition ratings were between 6 and 7 regardless of age in the original survey, and they are now between 5.5 and 6.75. An exception is in Region 4, where element ratings indicate that substructures have improved relative to the other regions. A possible explanation is that all the older bridges had undergone some degree of rehabilitation. Another possible explanation is variation among regions in prioritization and performance of routine monitoring and maintenance.

Pier columns and pier capbeams have tended to deteriorate at a somewhat faster rate than other substructure elements, but not at such a rate that they have reached a critical condition. Special Report 73 predicted these elements would do so and attributed this to exposure to saltwater seeping through deck joints or from traffic spray. Ratings of pier pedestals, which are particularly susceptible to leakage from faulty deck joints, have also decreased at a faster rate. Ratings of substructure elements in Region 11 have deteriorated to a lower value than those of the state as a whole, although in the first survey their ratings were represented by mean bridge condition.

2. Epoxy-Coated Versus Plain Reinforcement

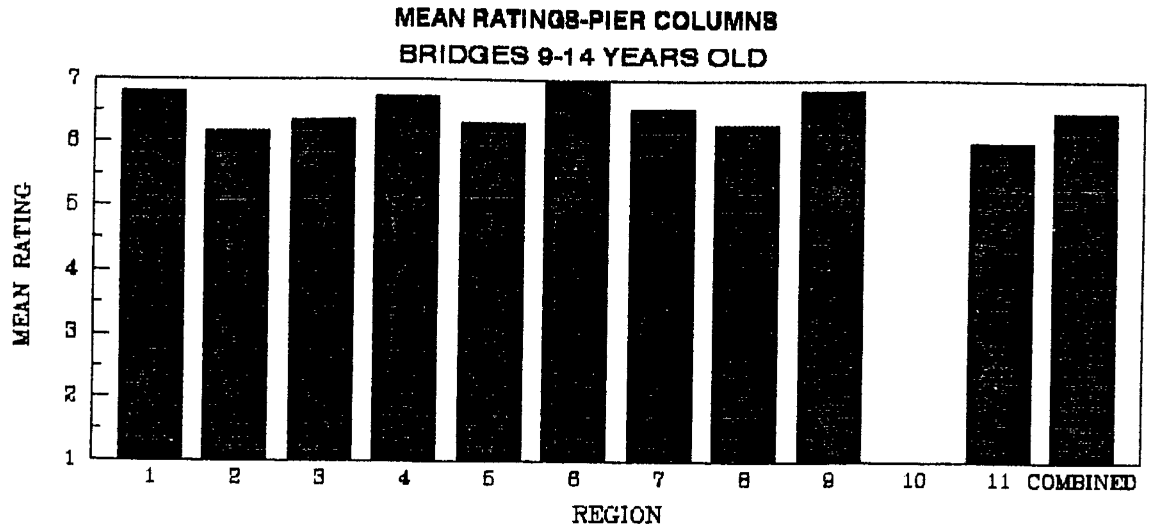
Mean ratings for the ten substructure elements in the 0-to-5 year age group from the previous report are compared to mean ratings of all bridges now 0-to-5 years old in Figure 6. Bridges currently in this age group were built since the issuance of EI 84-60. As would be anticipated, there is no difference among bridges in these groups. The rating of substructure elements containing epoxy-coated bars 0 to 5 years old form the base line for measurement of the effectiveness of epoxy coating of reinforcing bars at some future time.

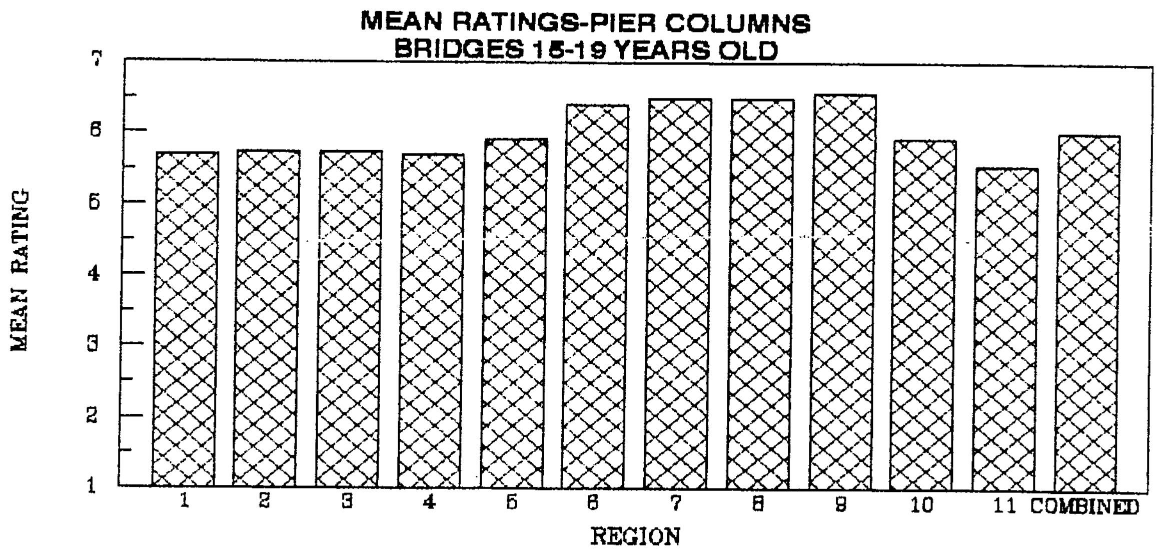
Figure 5a. MEAN RATINGS-PIER COLUMNS



AGE GROUP	F	SIGNIFICANT DIFFERENCE
9–14 YEARS	2.89	YES
15–19 YEARS	7.40	YES
20–24 YEARS	13.00	YES

Figure 5a. Continued





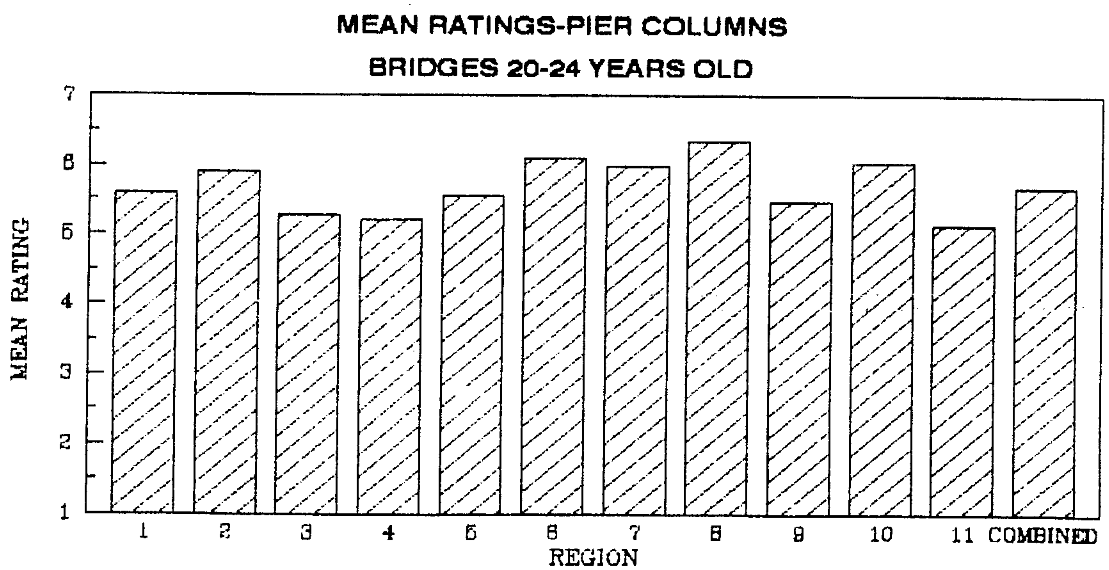


Figure 5b. MEAN RATINGS-PIER CAP BEAMS

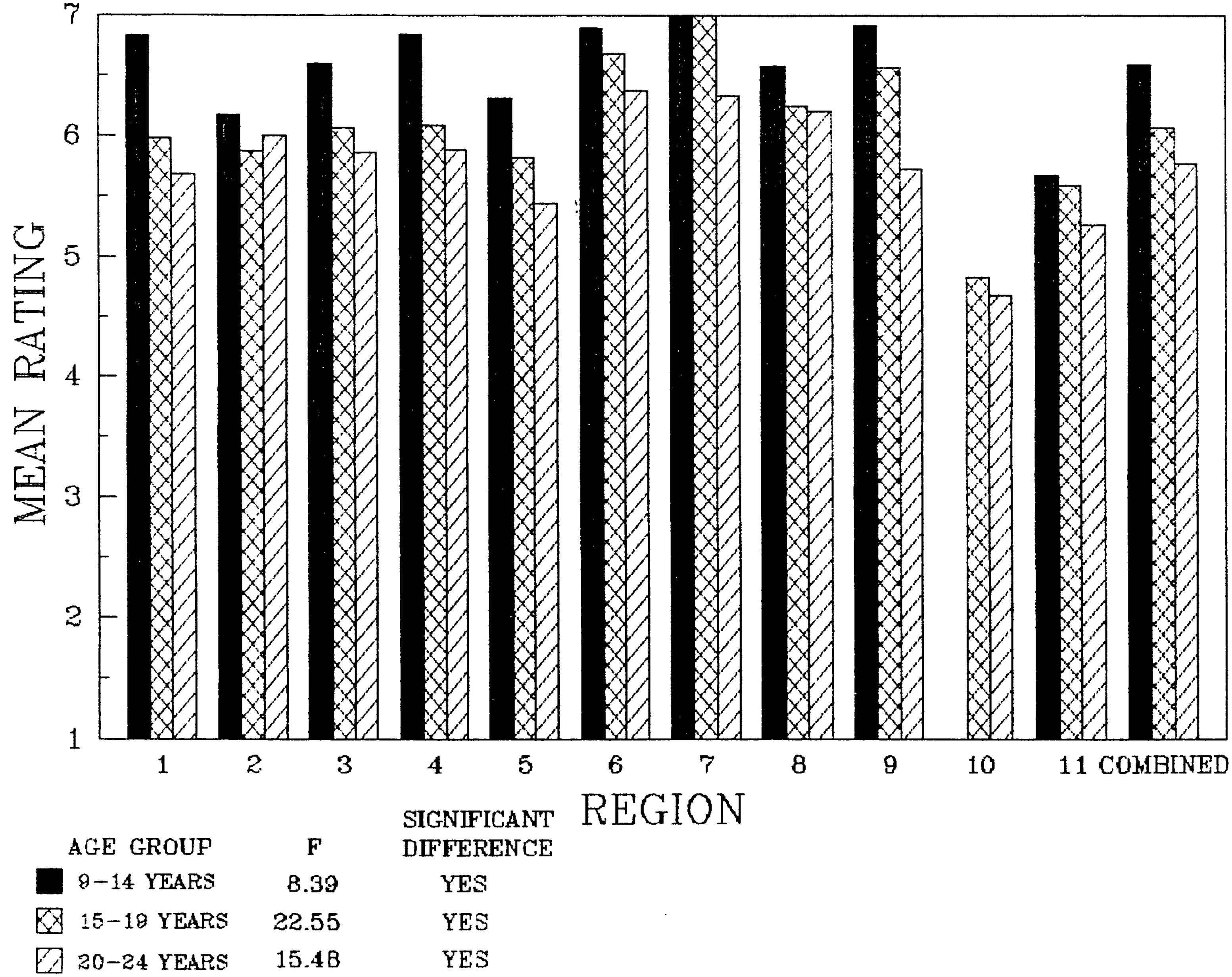
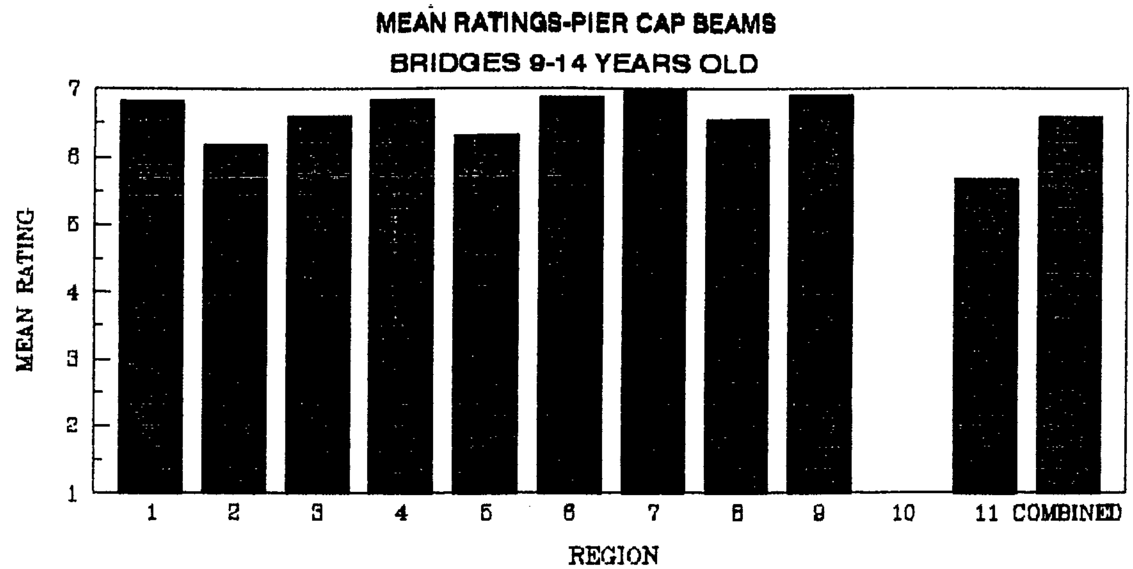
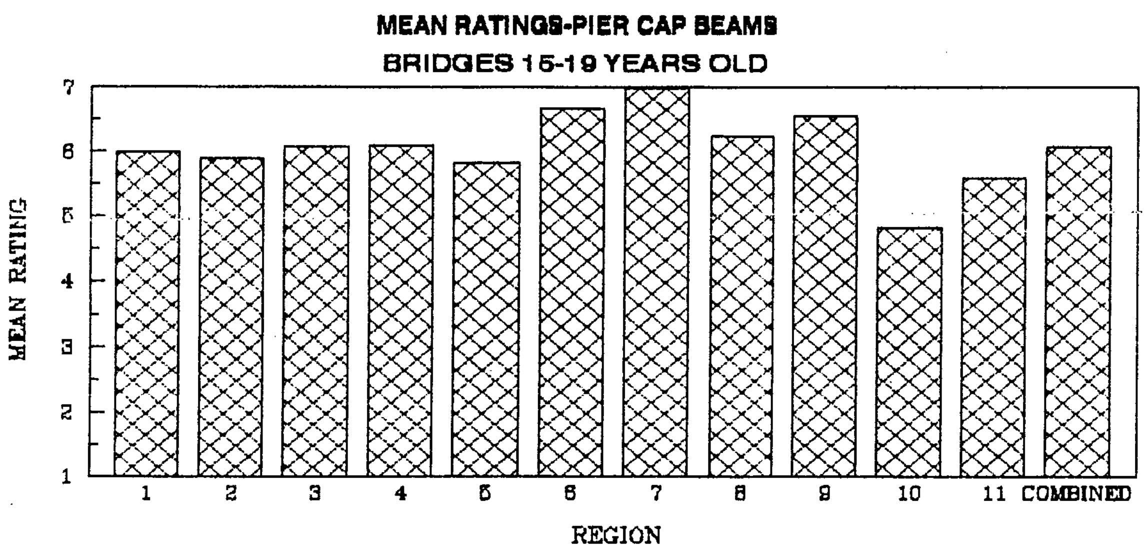


Figure 5b. Continued





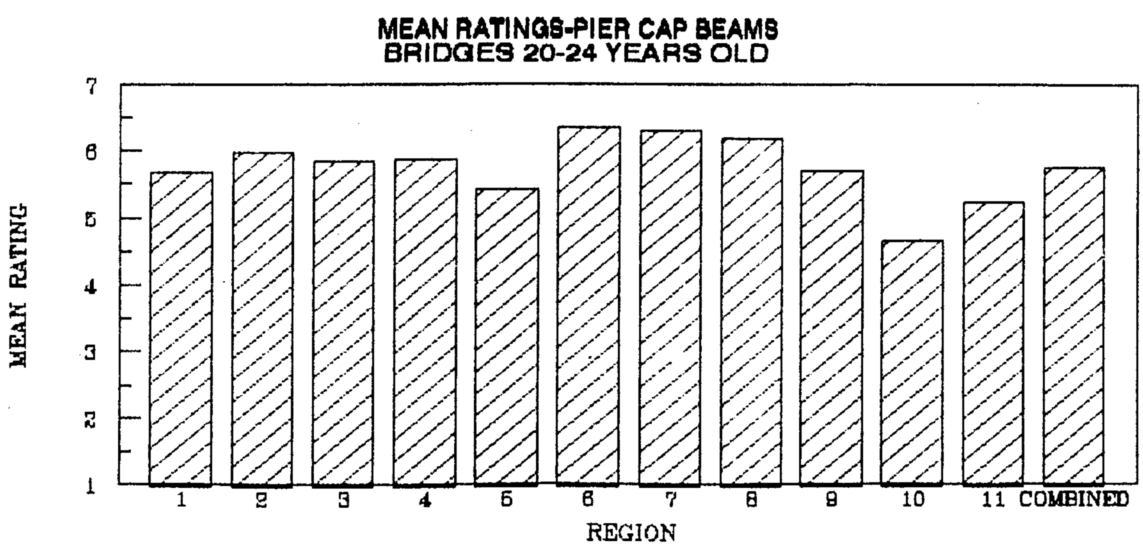
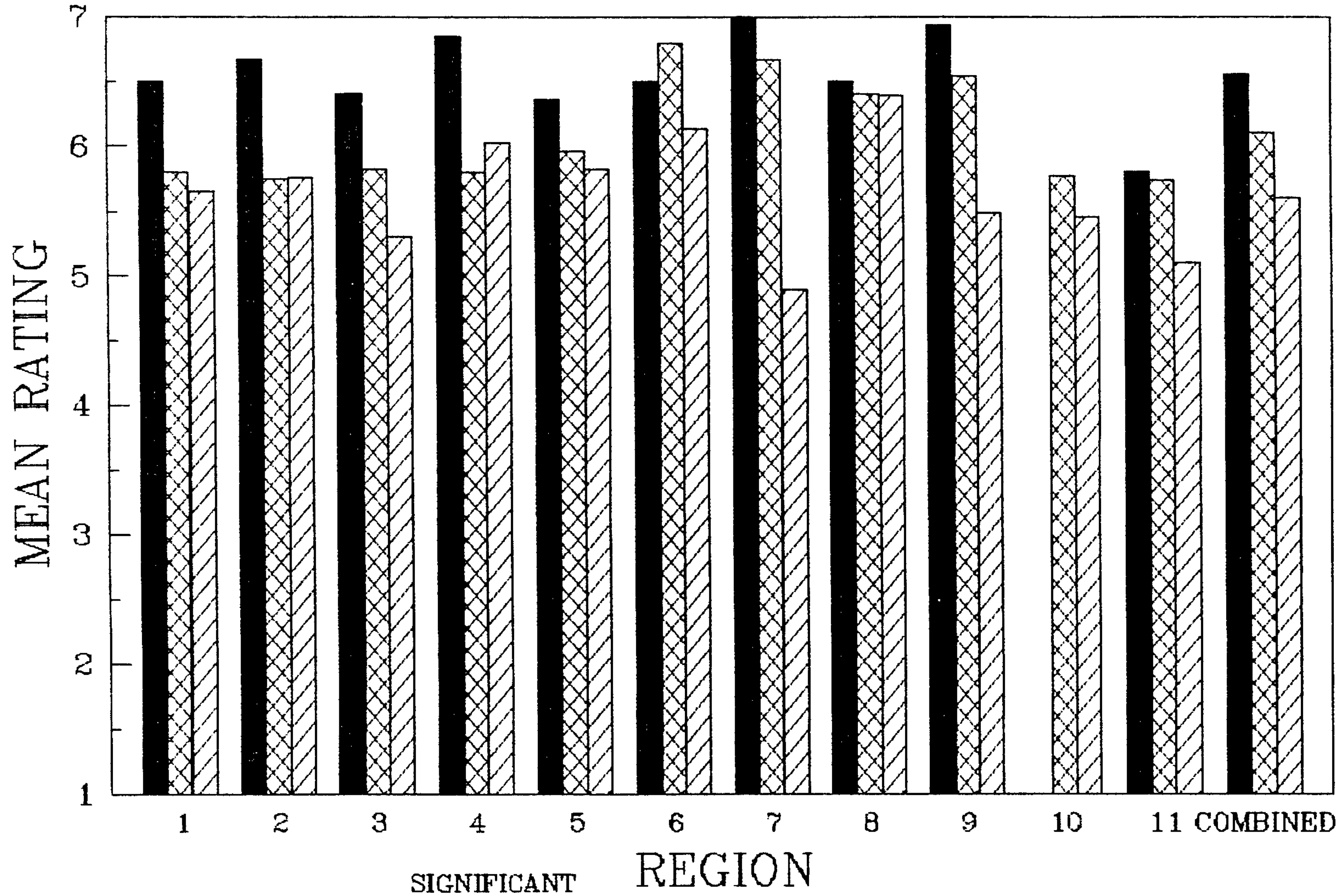


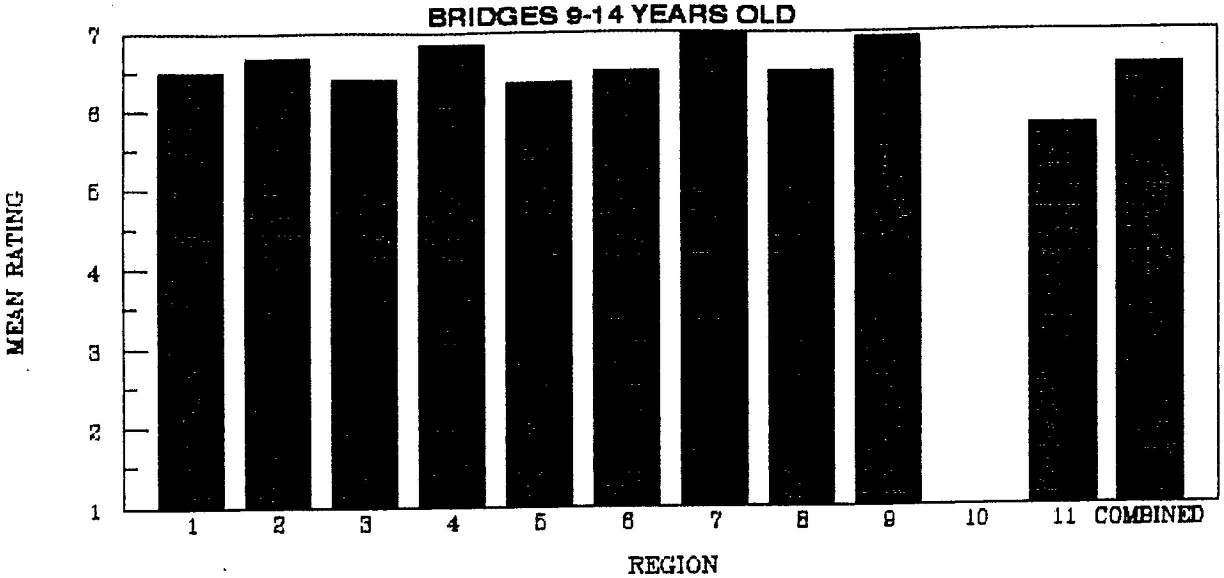
Figure 5c. MEAN RATINGS-PIER PEDESTALS



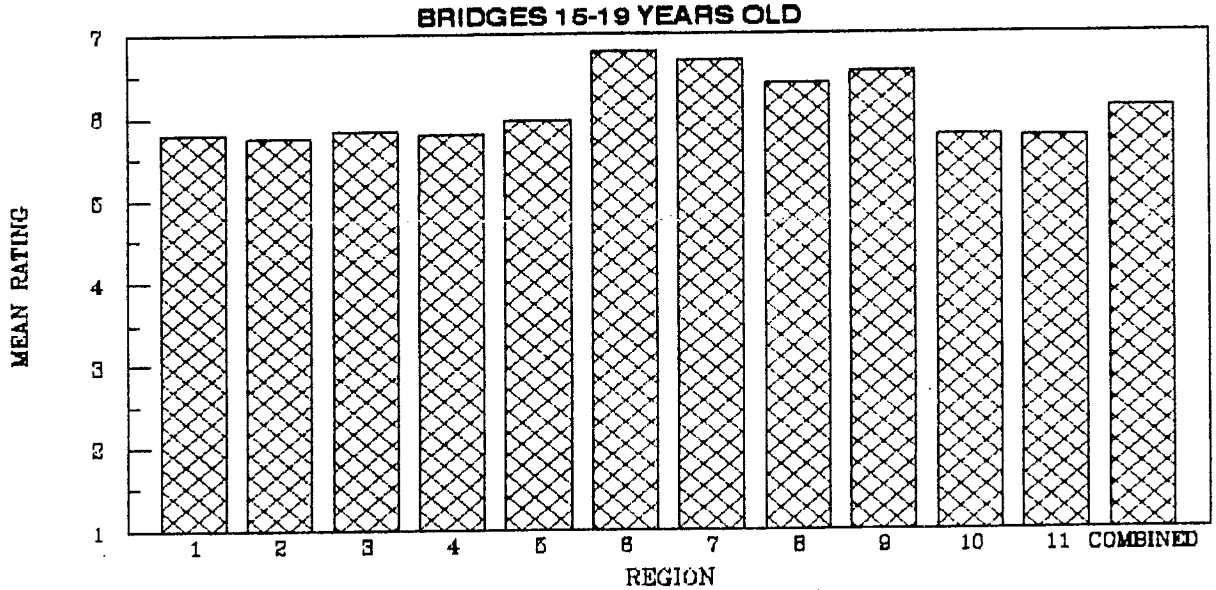
AGE GROUP	F	SIGNIFICANT DIFFERENCE
9-14 YEARS	4.87	YES
15-19 YEARS	11.87	YES
20-24 YEARS	13.04	YES

Figure 5c. Continued

MEAN RATINGS-PIER PEDESTALS
BRIDGES 9-14 YEARS OLD



MEAN RATINGS-PIER PEDESTALS
BRIDGES 15-19 YEARS OLD



MEAN RATINGS-PIER PEDESTALS
BRIDGES 20-24 YEARS OLD

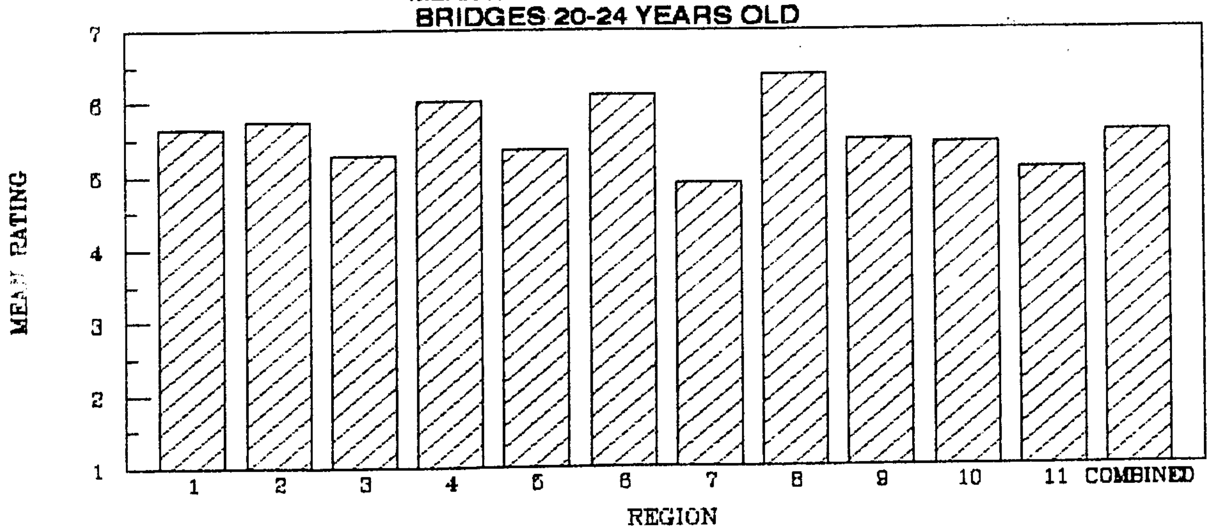
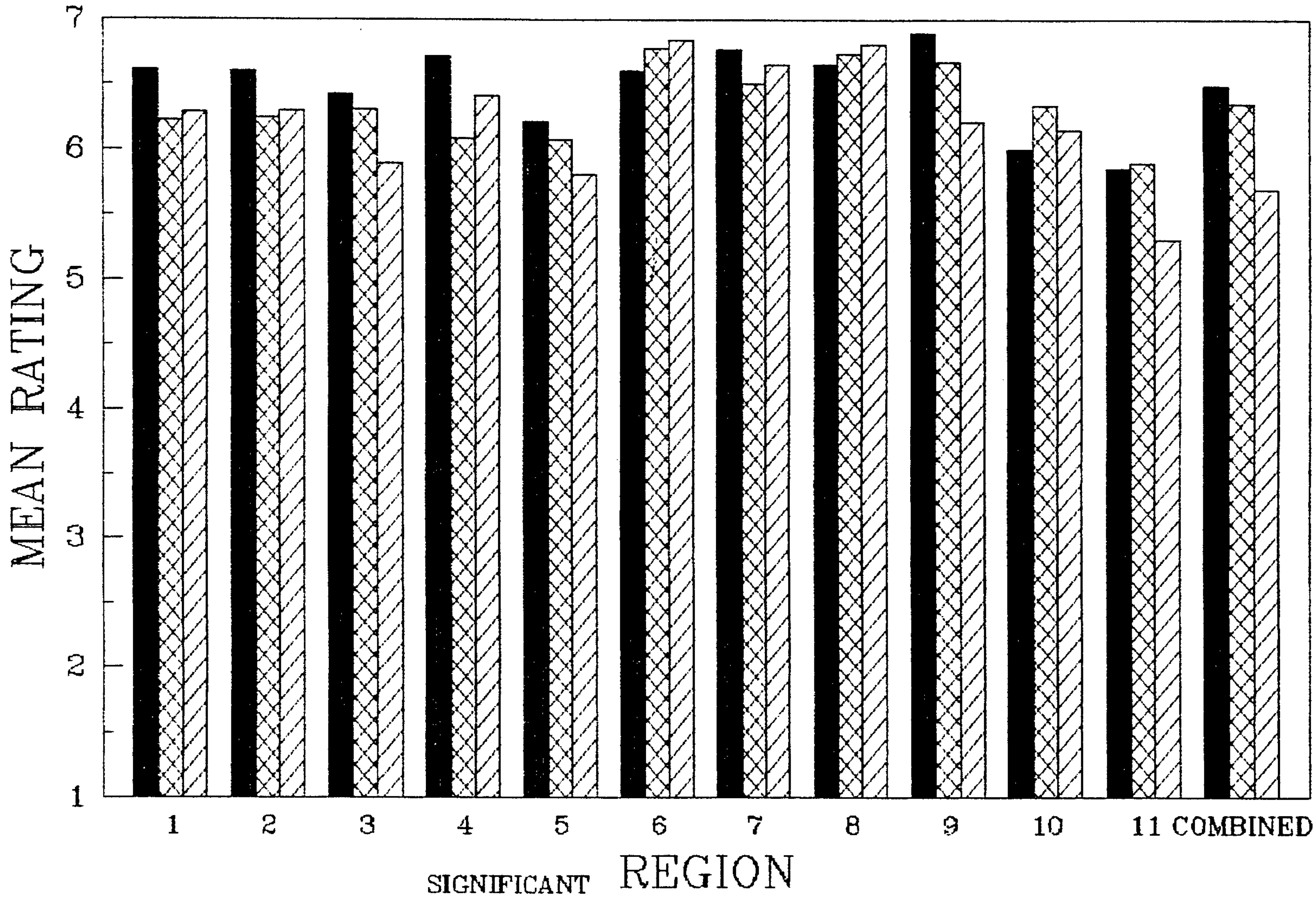
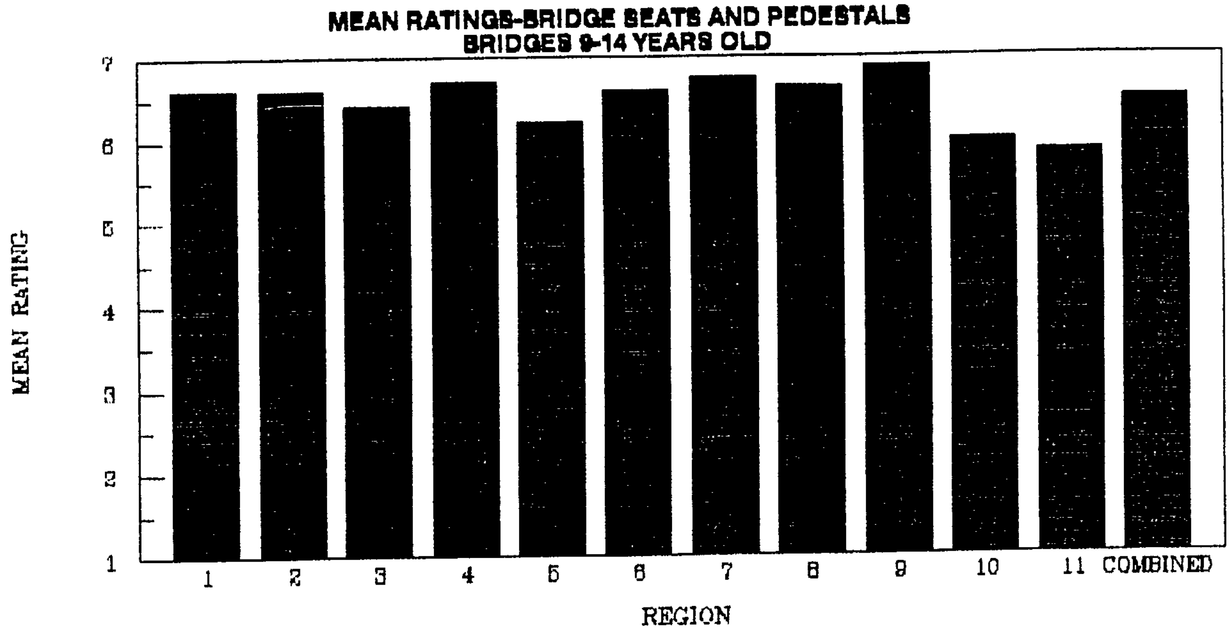


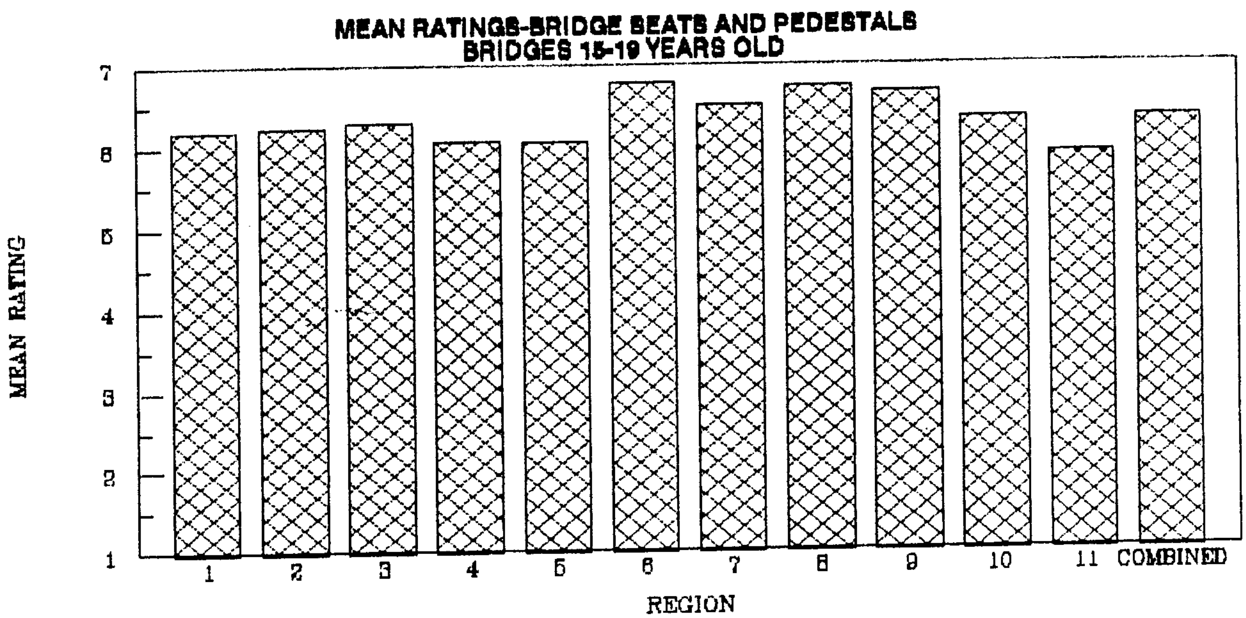
Figure 5d. MEAN RATINGS-BRIDGE SEATS & PEDESTALS



AGE GROUP	F	SIGNIFICANT DIFFERENCE
9–14 YEARS	14.83	YES
15–19 YEARS	44.52	YES
20–24 YEARS	94.00	YES

Figure 5d. Continued





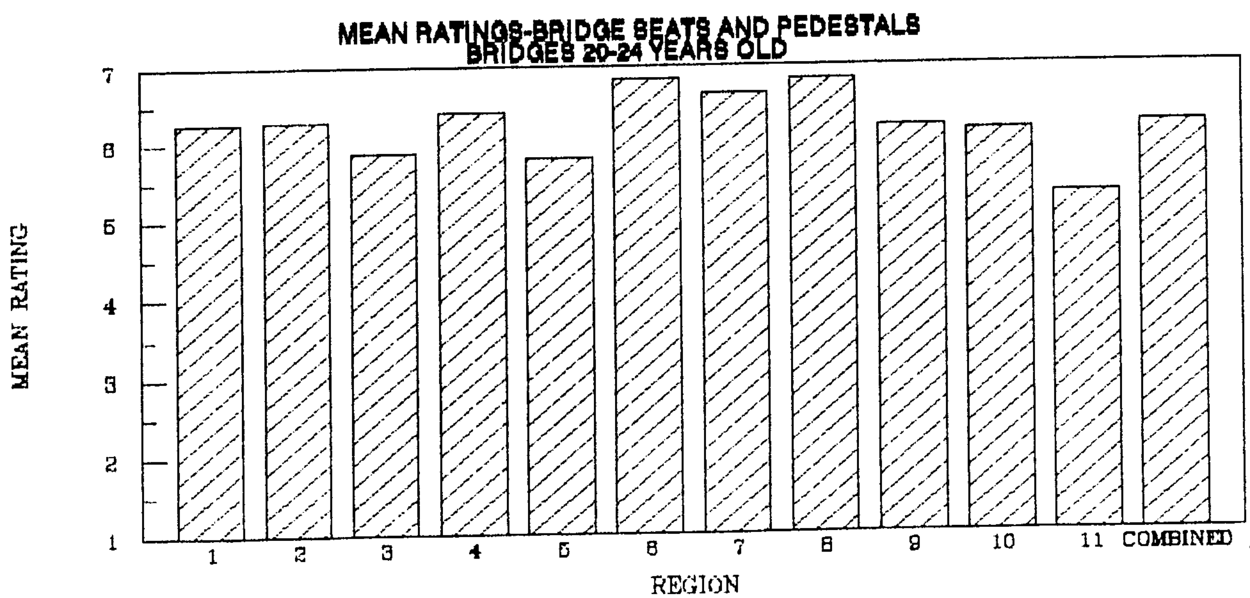
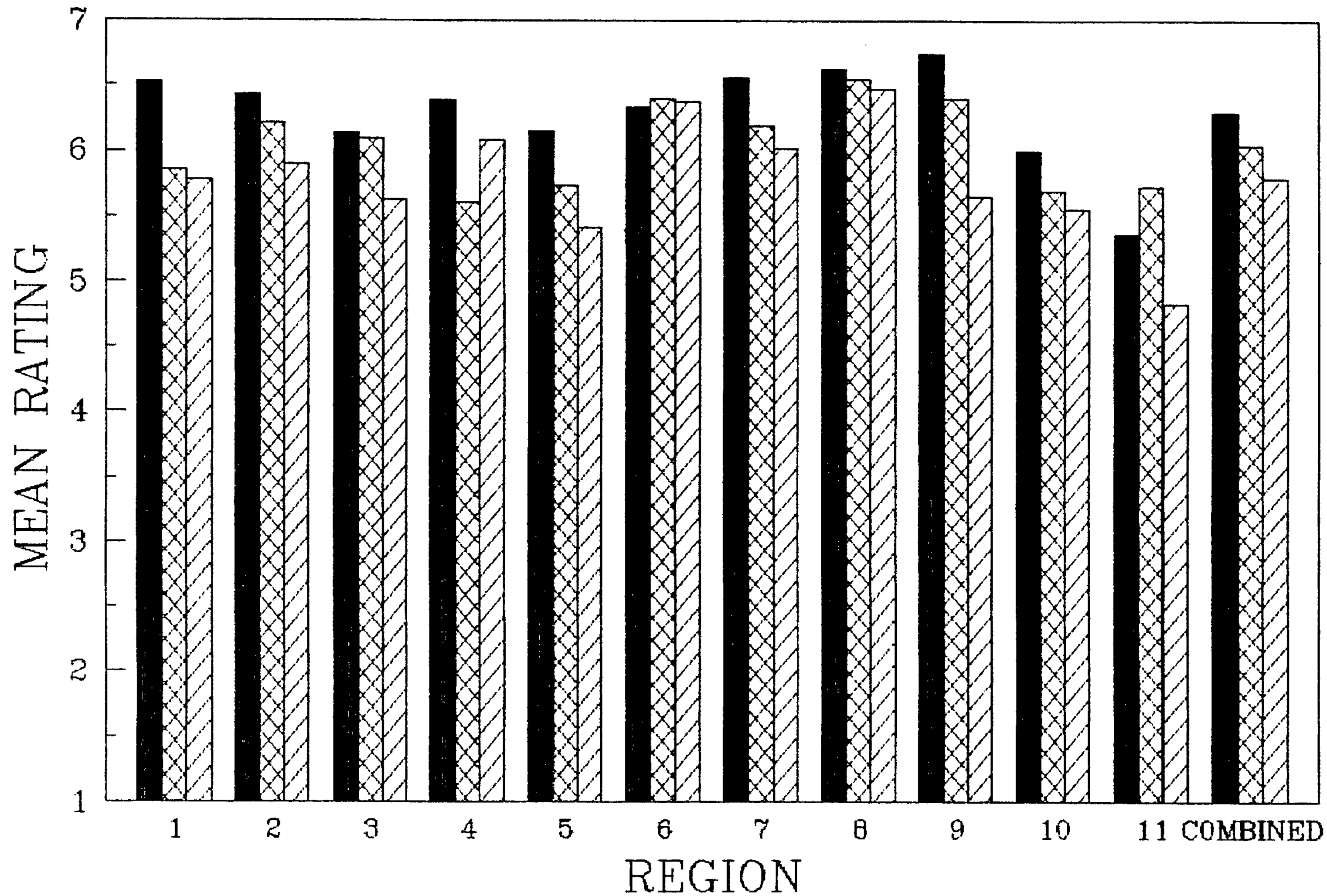
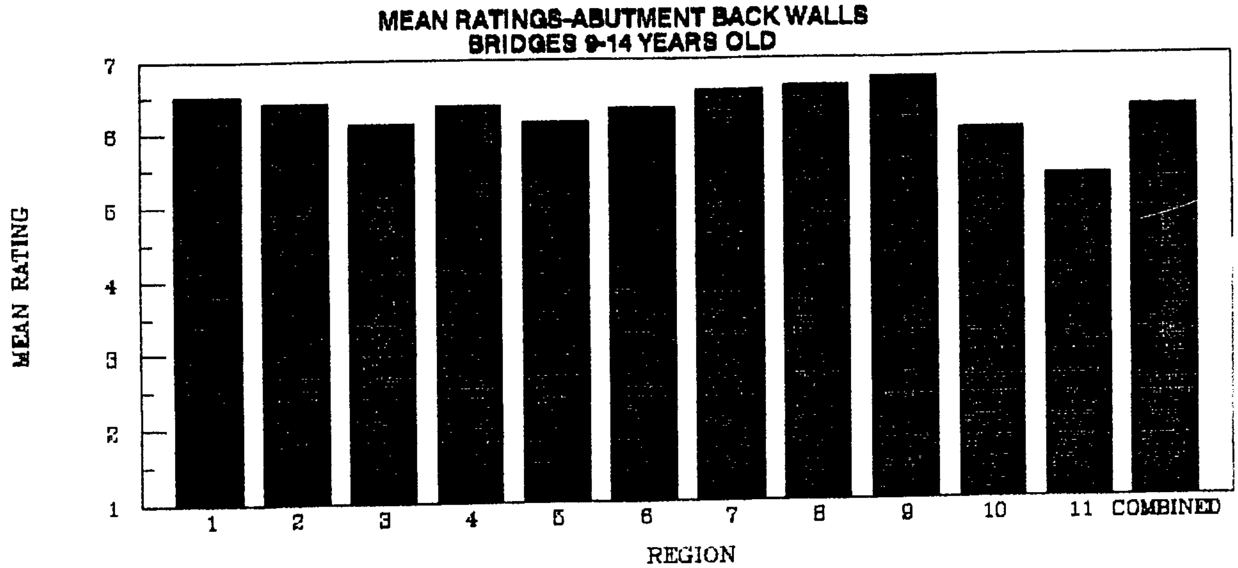


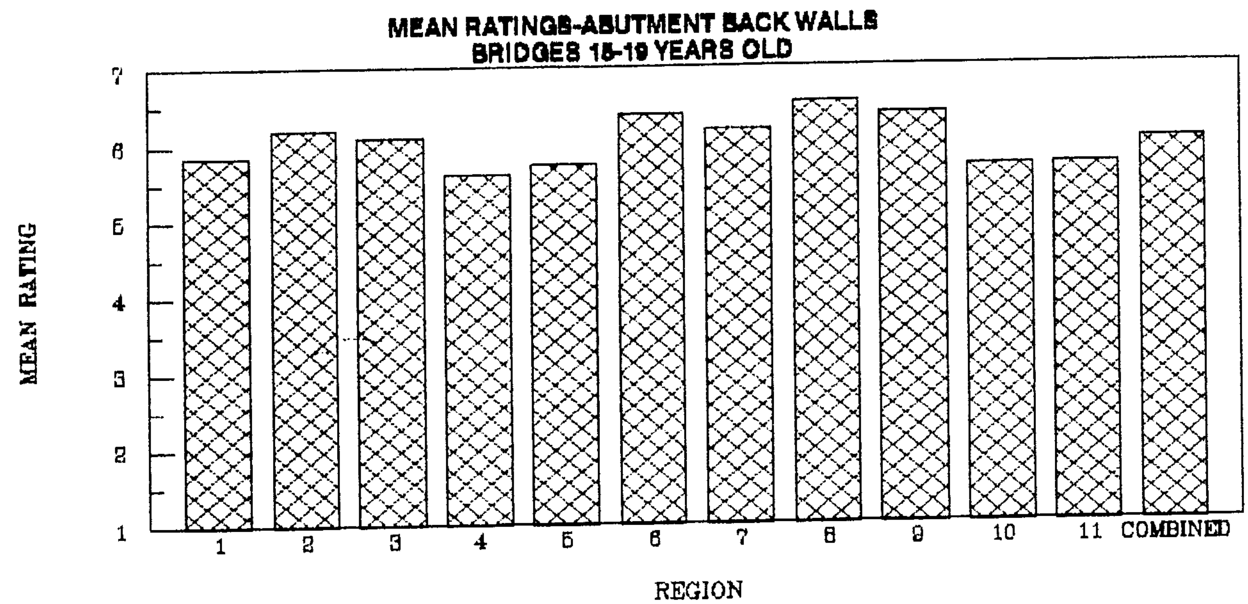
Figure 5e. MEAN RATINGS-ABUTMENT BACK WALLS



AGE GROUP	F	SIGNIFICANT DIFFERENCE
9-14 YEARS	34.90	YES
15-19 YEARS	40.74	YES
20-24 YEARS	57.12	YES

Figure 5e. Continued





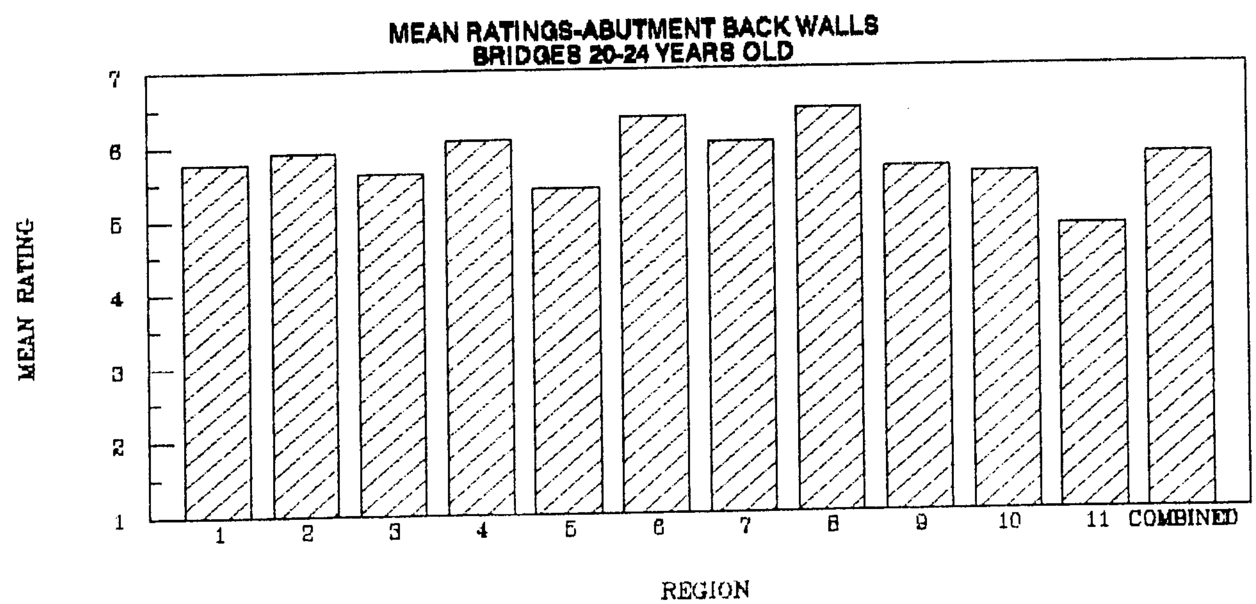
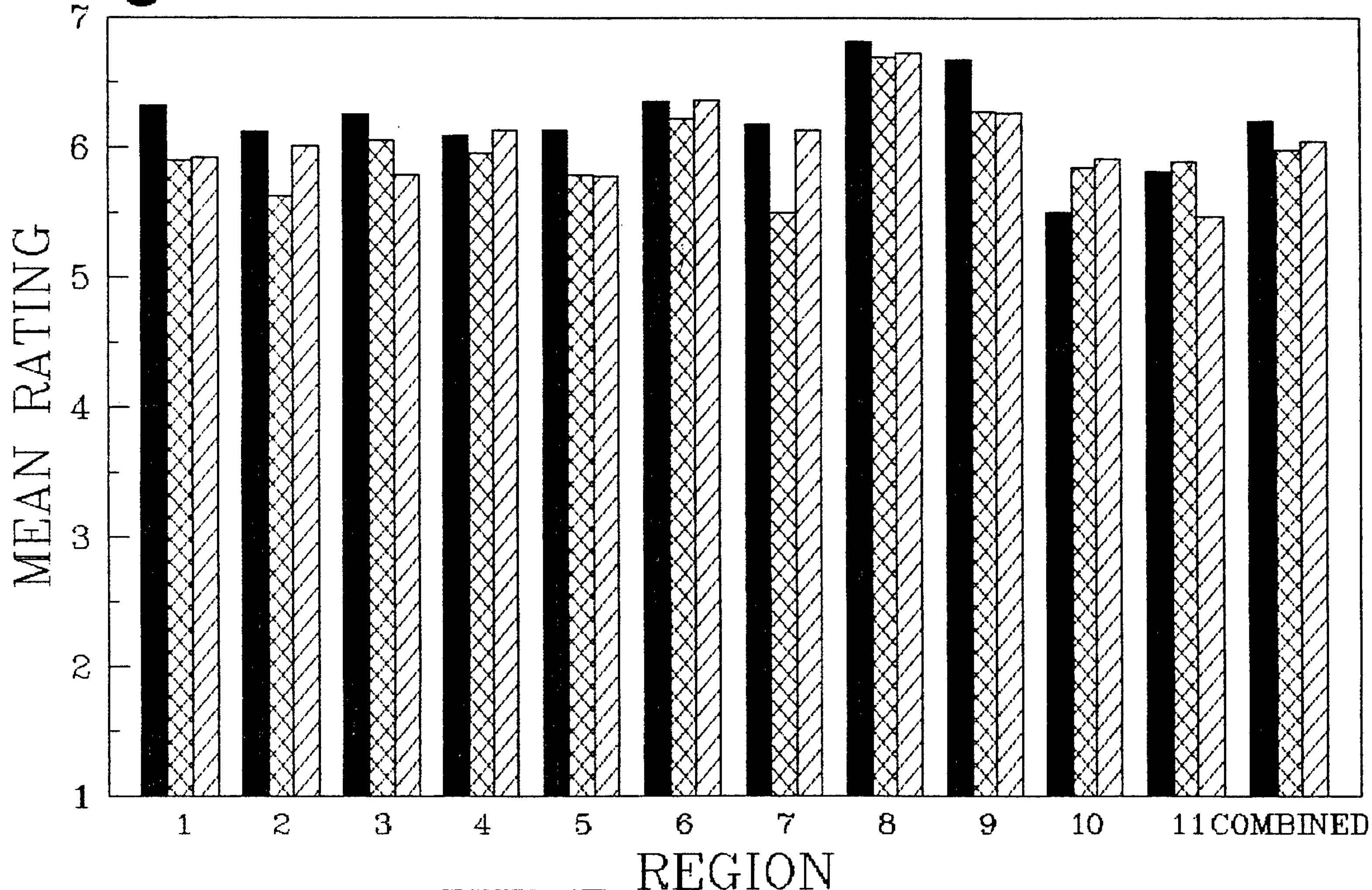
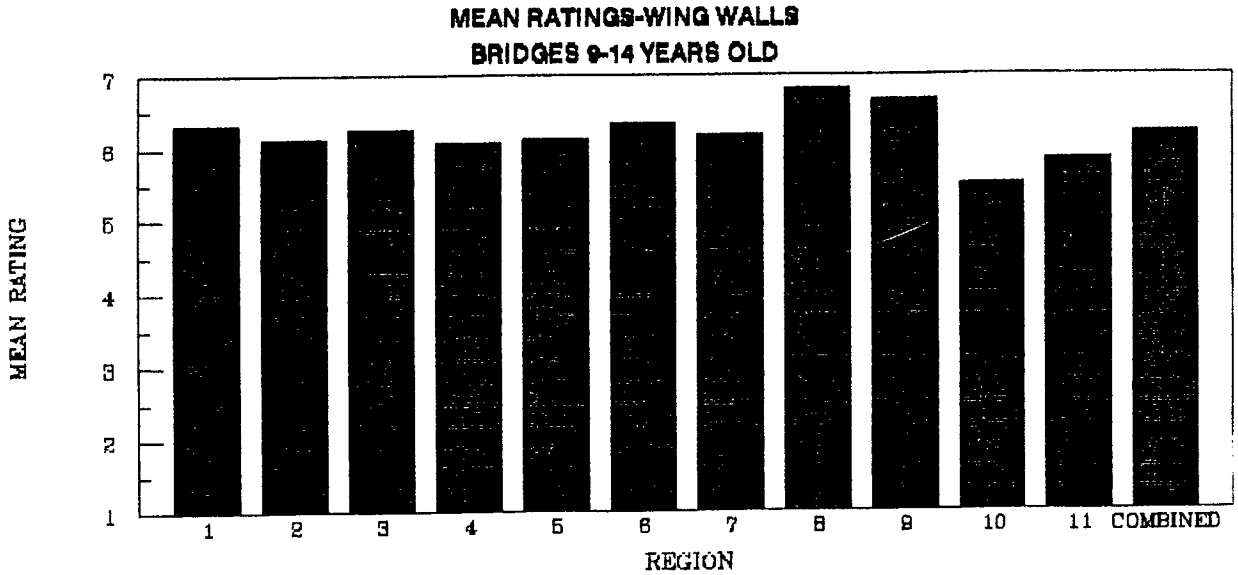


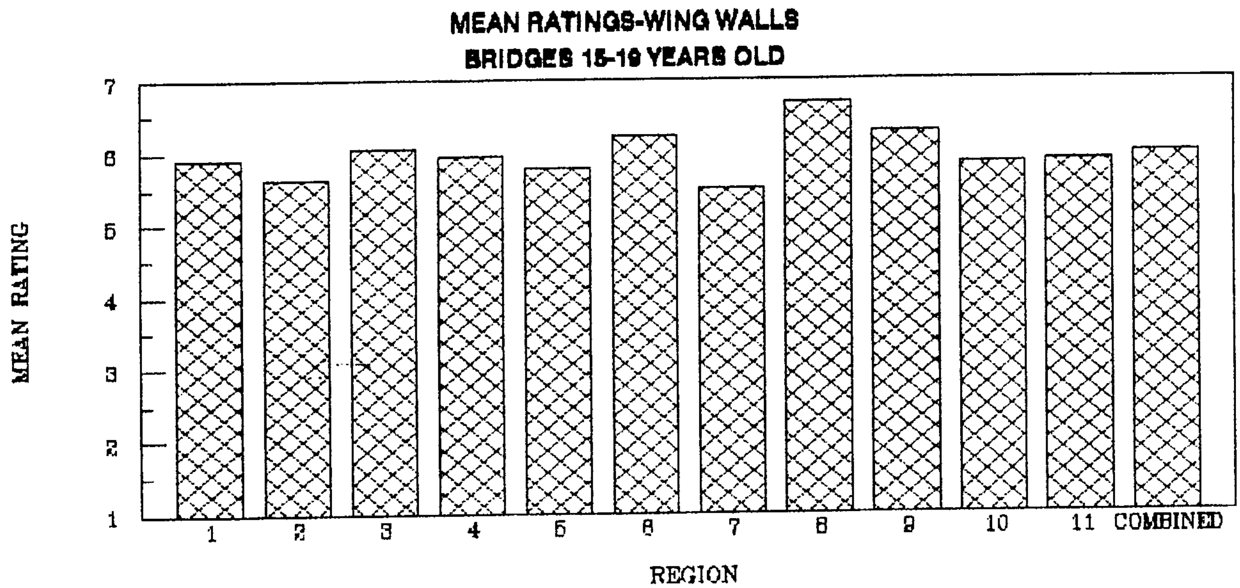
Figure 5f. MEAN RATINGS-WING WALLS



AGE GROUP	F	SIGNIFICANT DIFFERENCE
9–14 YEARS	14.01	YES
15–19 YEARS	32.38	YES
20–24 YEARS	81.60	YES

Figure 5f. Continued





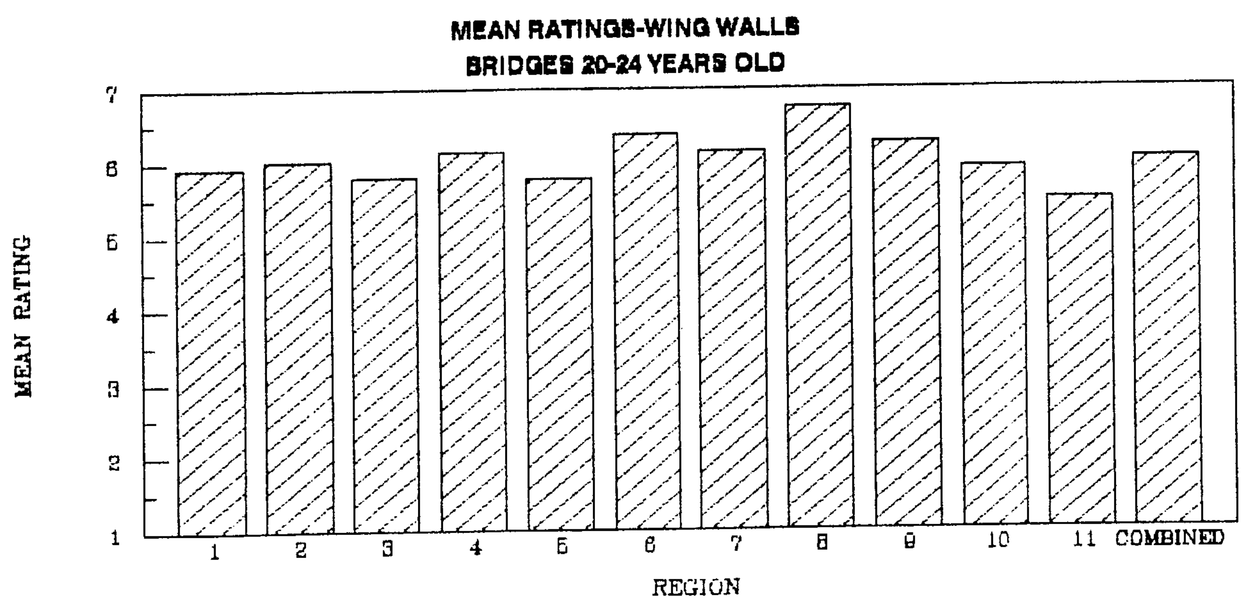
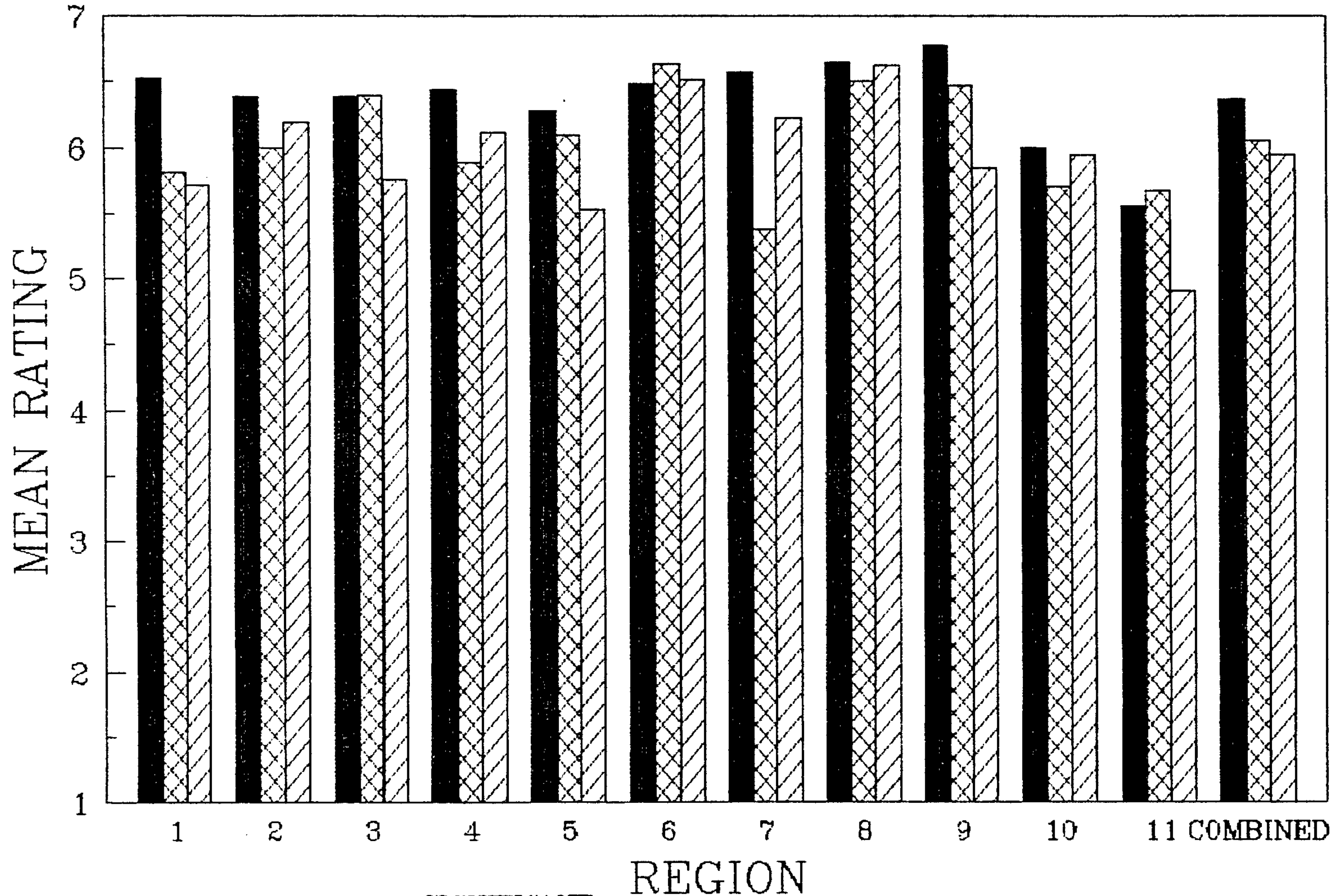
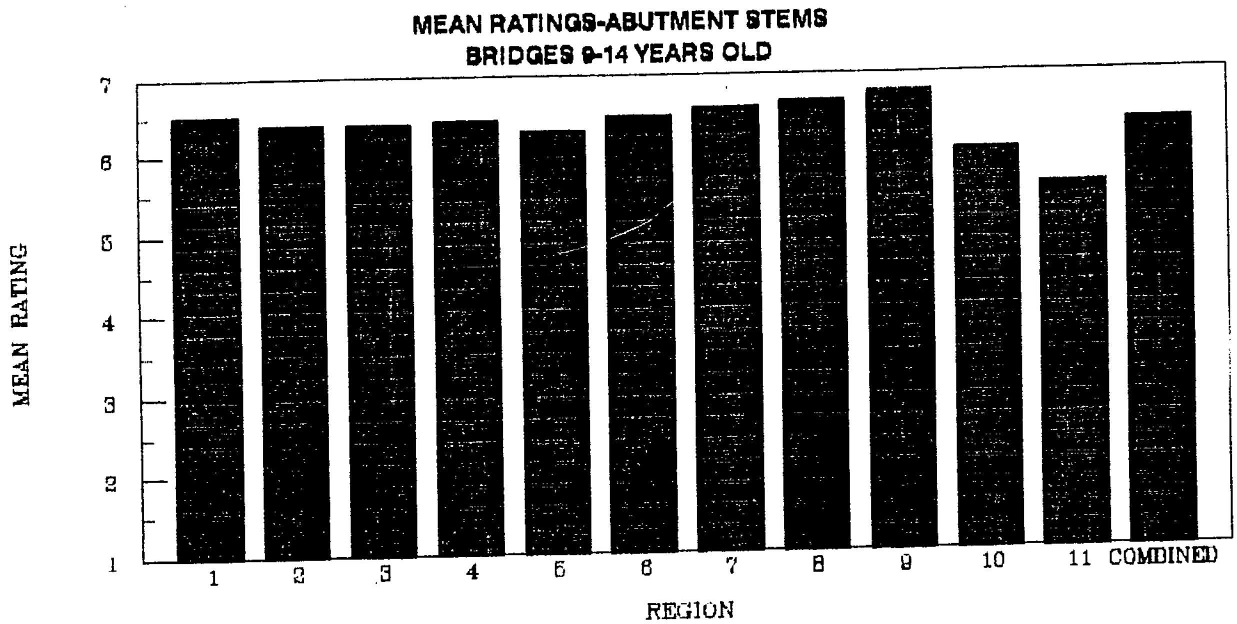


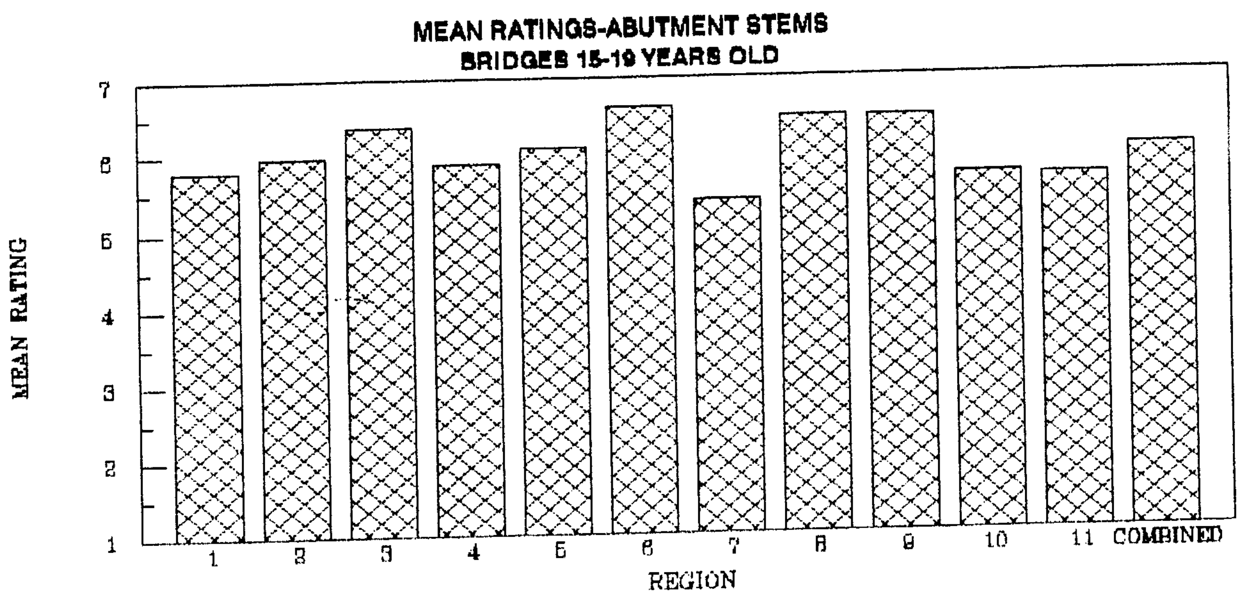
Figure 5g. MEAN RATINGS-ABUTMENT STEMS



AGE GROUP	F	SIGNIFICANT DIFFERENCE
9-14 YEARS	7.94	YES
15-19 YEARS	98.74	YES
20-24 YEARS	57.45	YES

Figure 5g. Continued





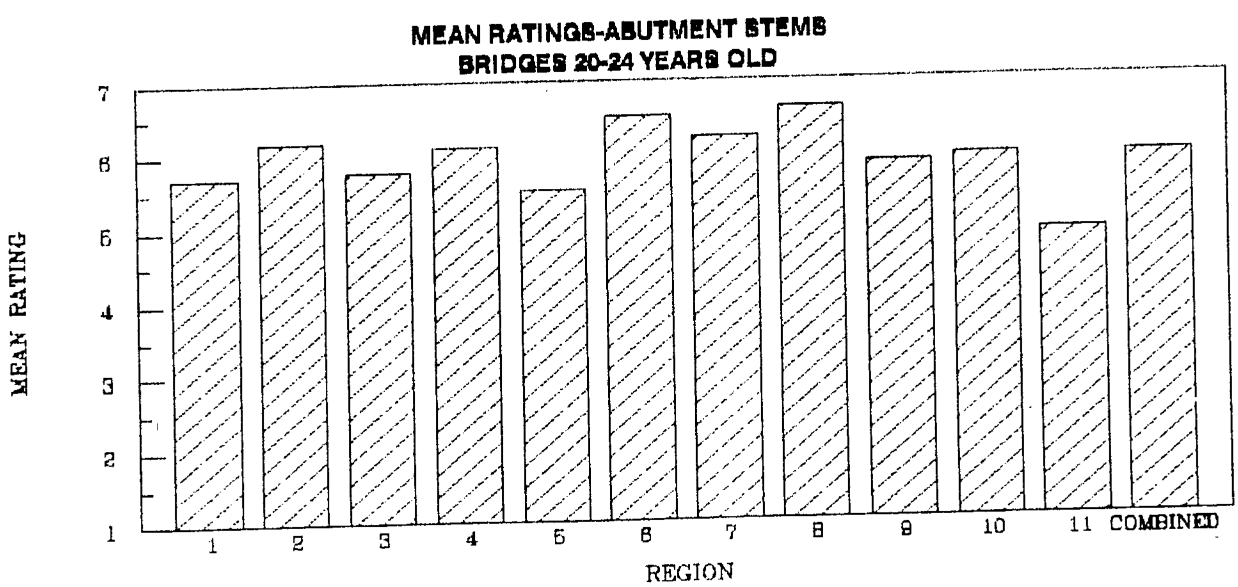
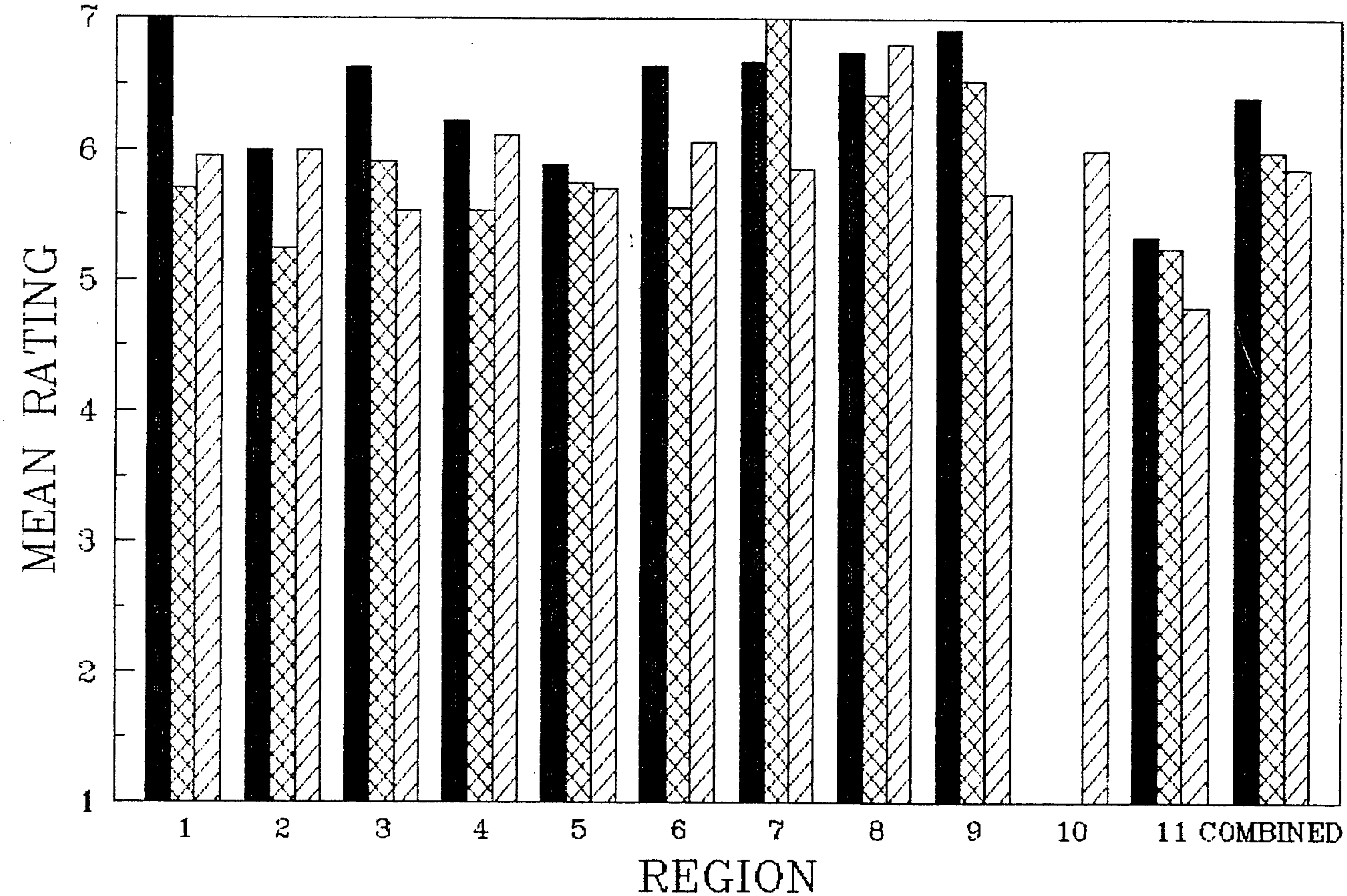


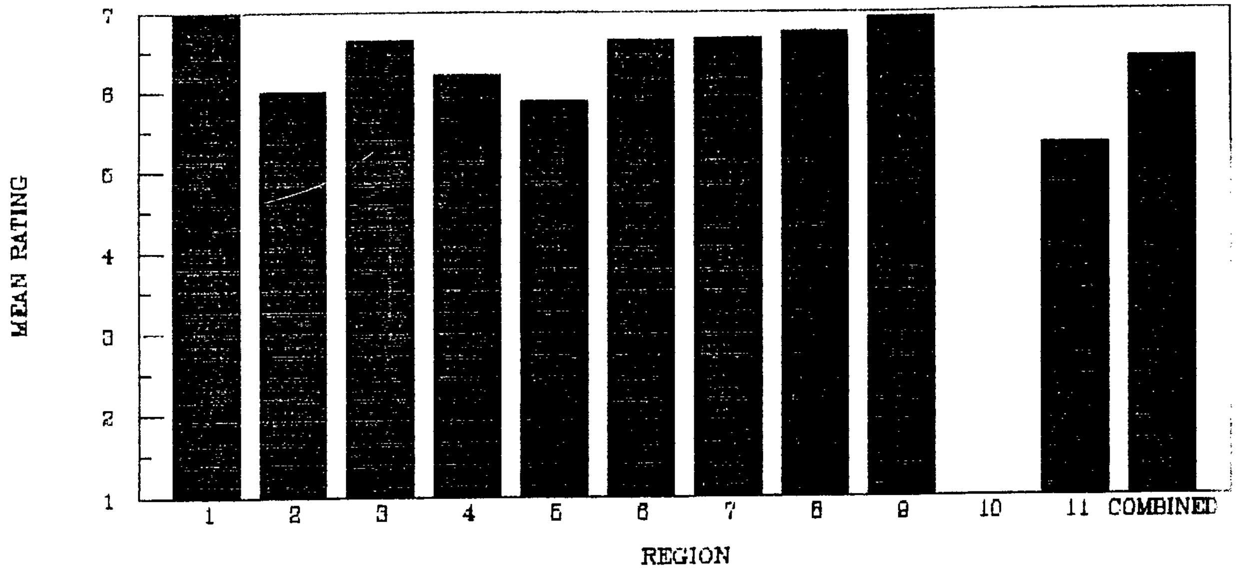
Figure 5h. MEAN RATINGS-SOLID PIER STEMS



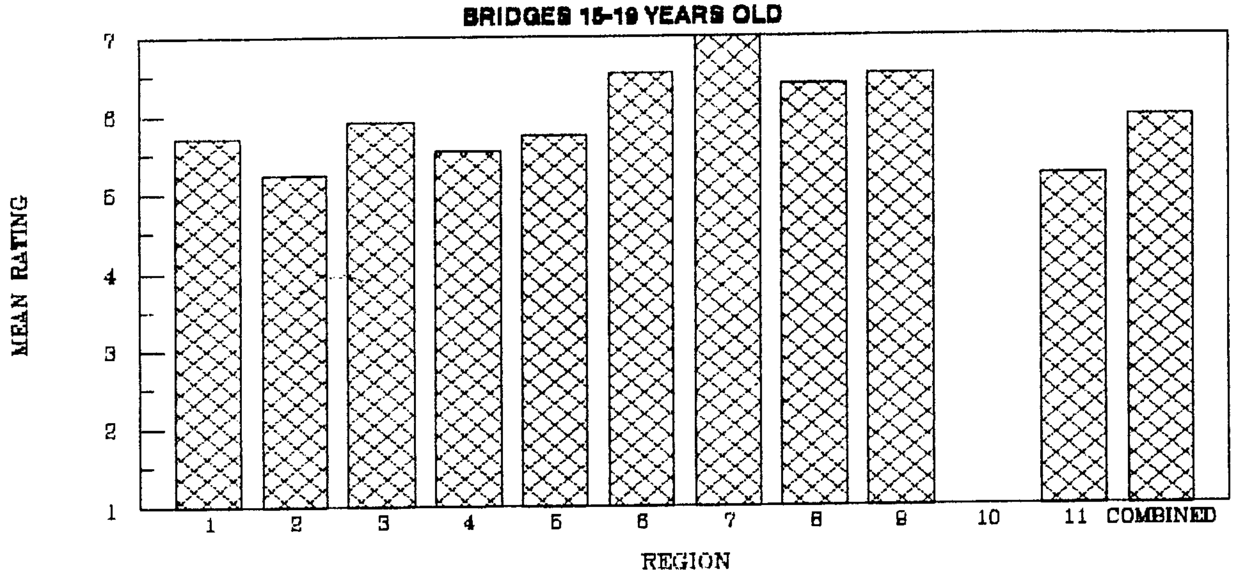
AGE GROUP	F	SIGNIFICANT DIFFERENCE
9–14 YEARS	2.35	YES
15–19 YEARS	8.25	YES
20–24 YEARS	12.23	YES

Figure 5h. Continued

MEAN RATINGS-SOLID PIER STEMS
BRIDGES 9-14 YEARS OLD



MEAN RATINGS-SOLID PIER STEMS
BRIDGES 15-19 YEARS OLD



MEAN RATINGS-SOLID PIER STEMS
BRIDGES 20-24 YEARS OLD

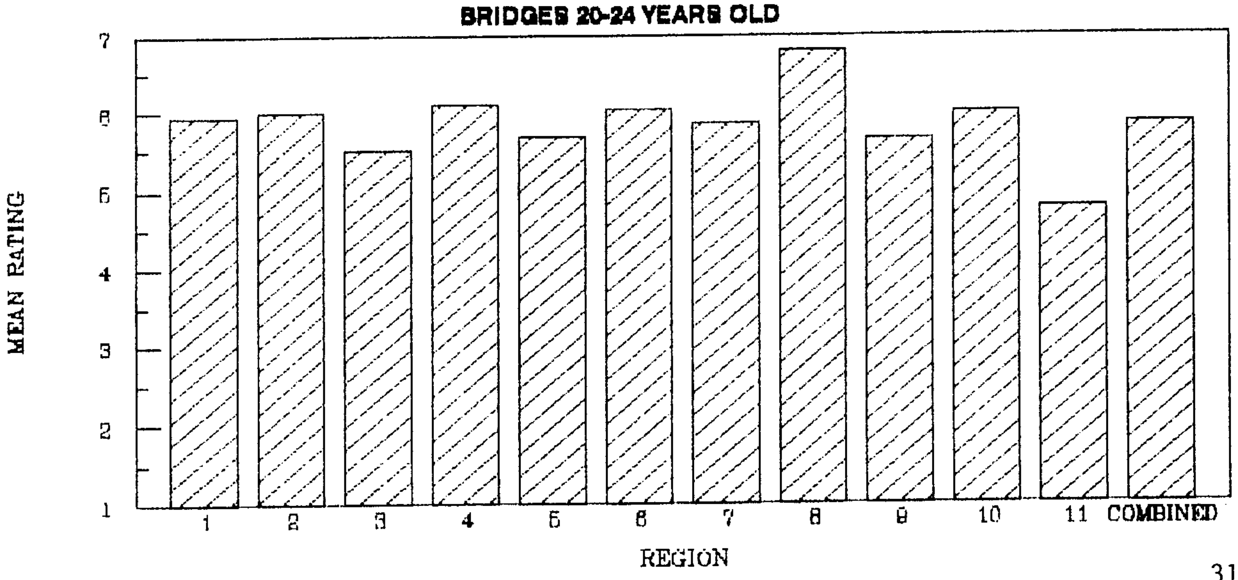
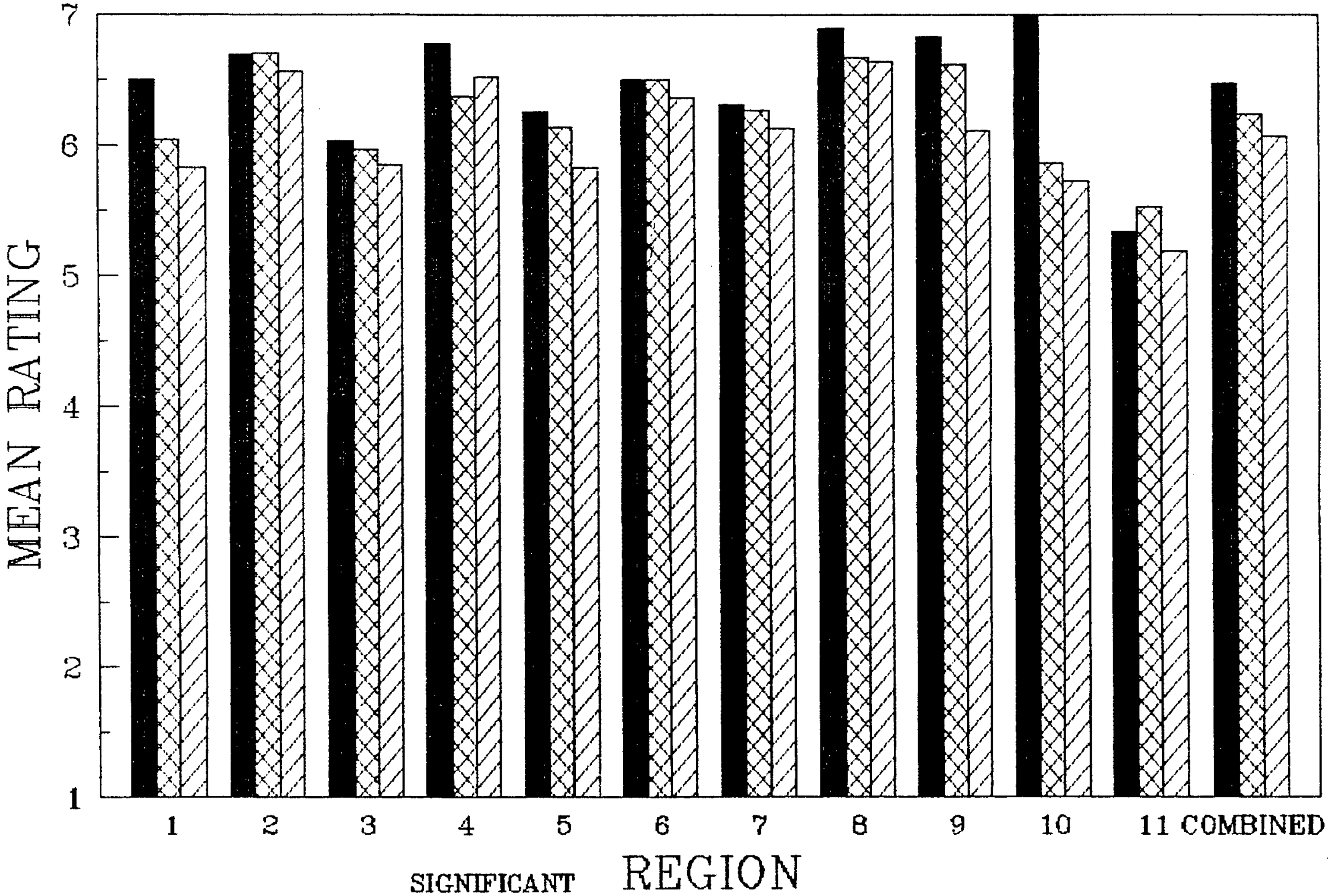


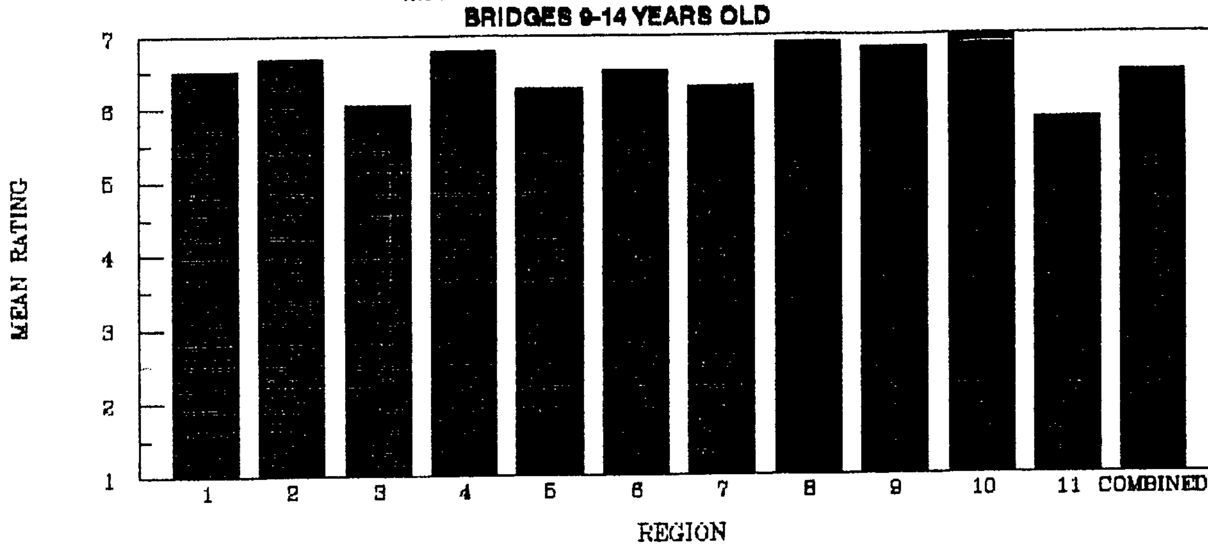
Figure 5i. MEAN RATINGS-PRIMARY MEMBERS



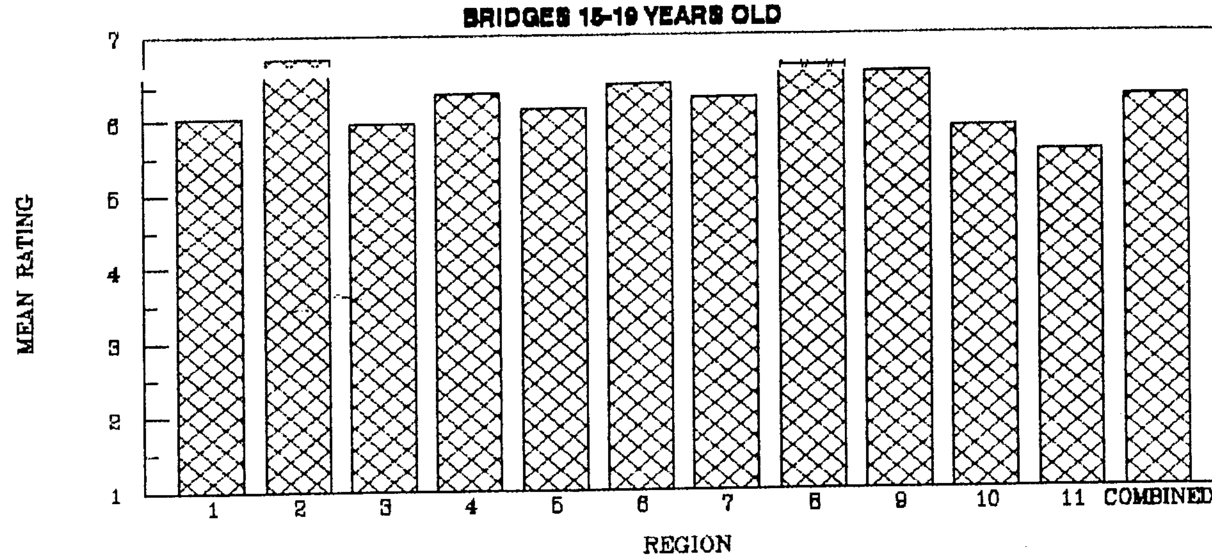
AGE GROUP	F	SIGNIFICANT DIFFERENCE
9-14 YEARS	12.03	YES
15-19 YEARS	17.04	YES
20-24 YEARS	43.20	YES

Figure 5I. Continued

MEAN RATINGS-PRIMARY MEMBERS
BRIDGES 9-14 YEARS OLD



MEAN RATINGS-PRIMARY MEMBERS
BRIDGES 15-19 YEARS OLD



MEAN RATINGS-PRIMARY MEMBERS
BRIDGES 20-24 YEARS OLD

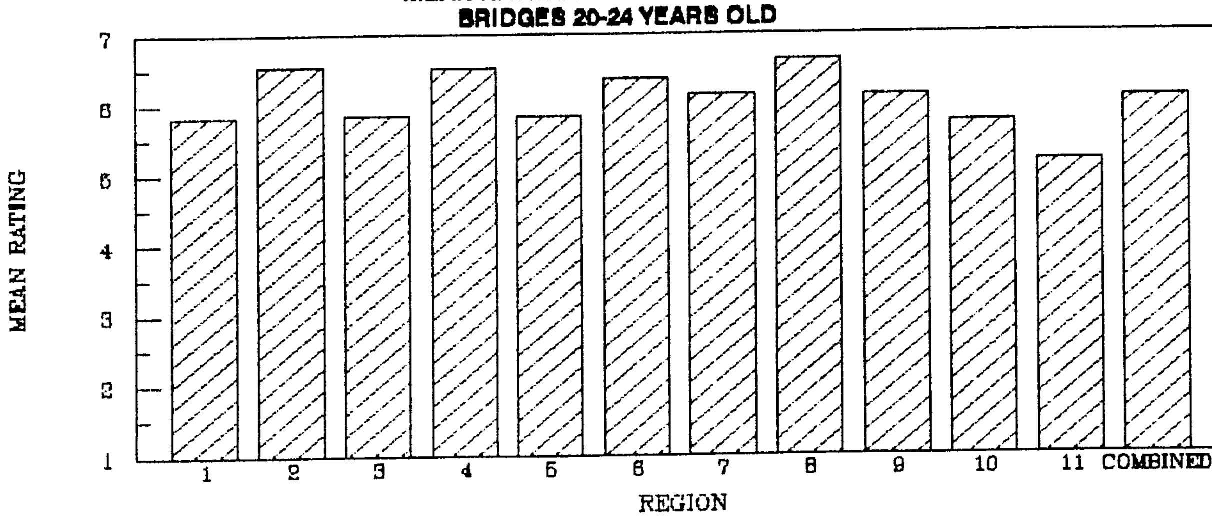
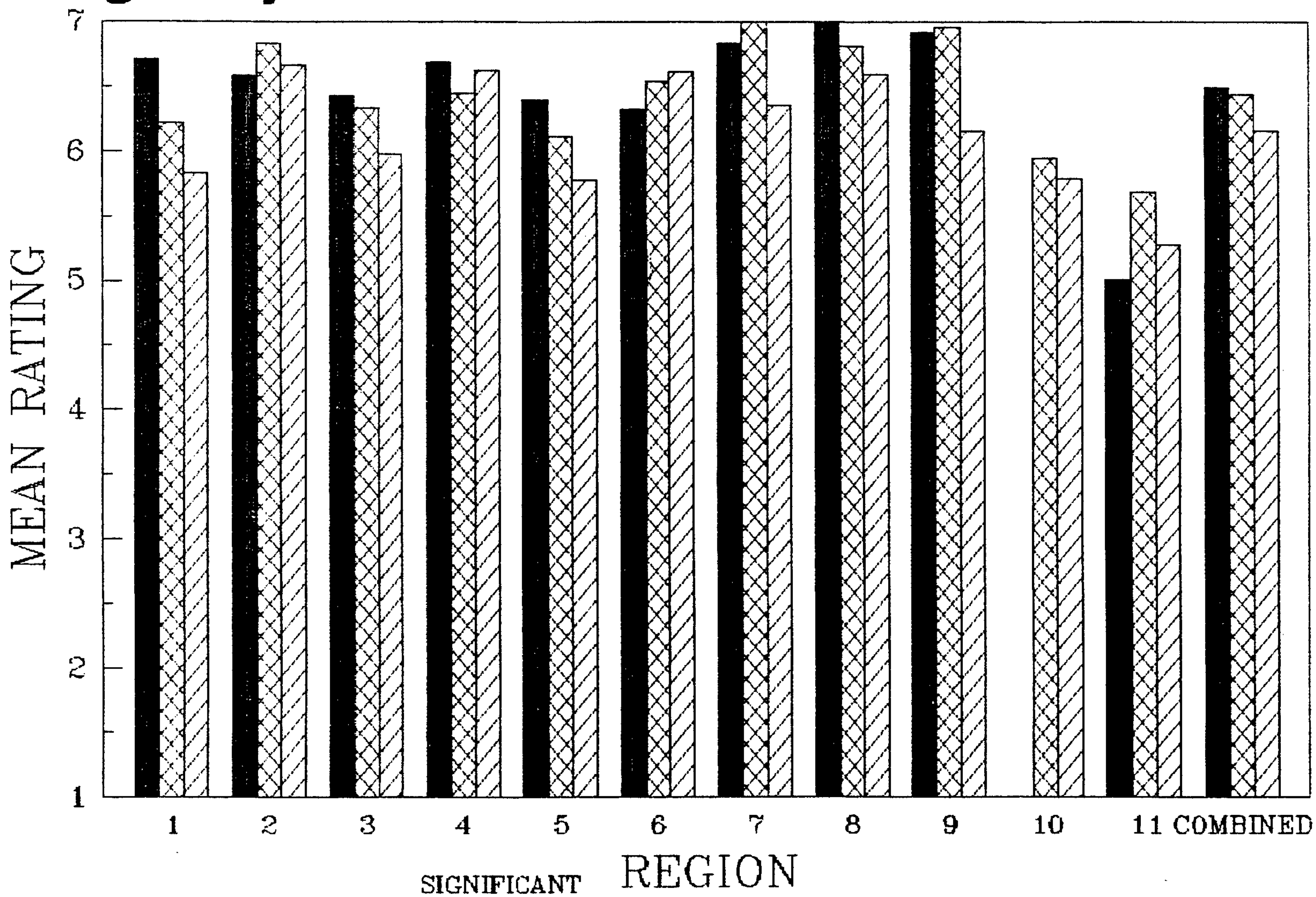
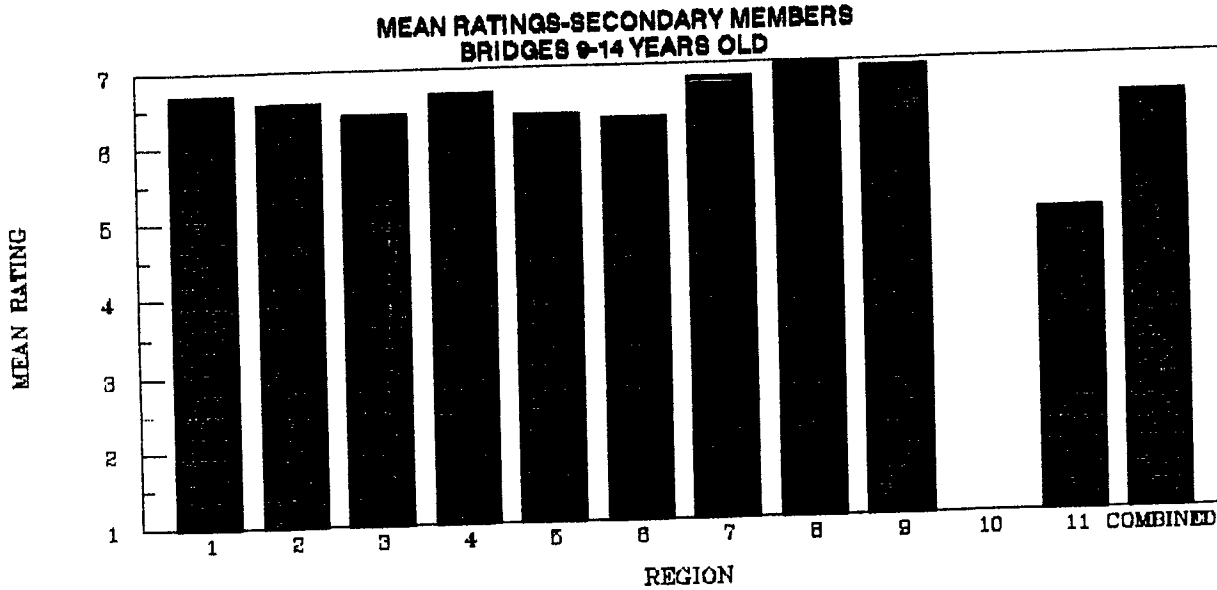


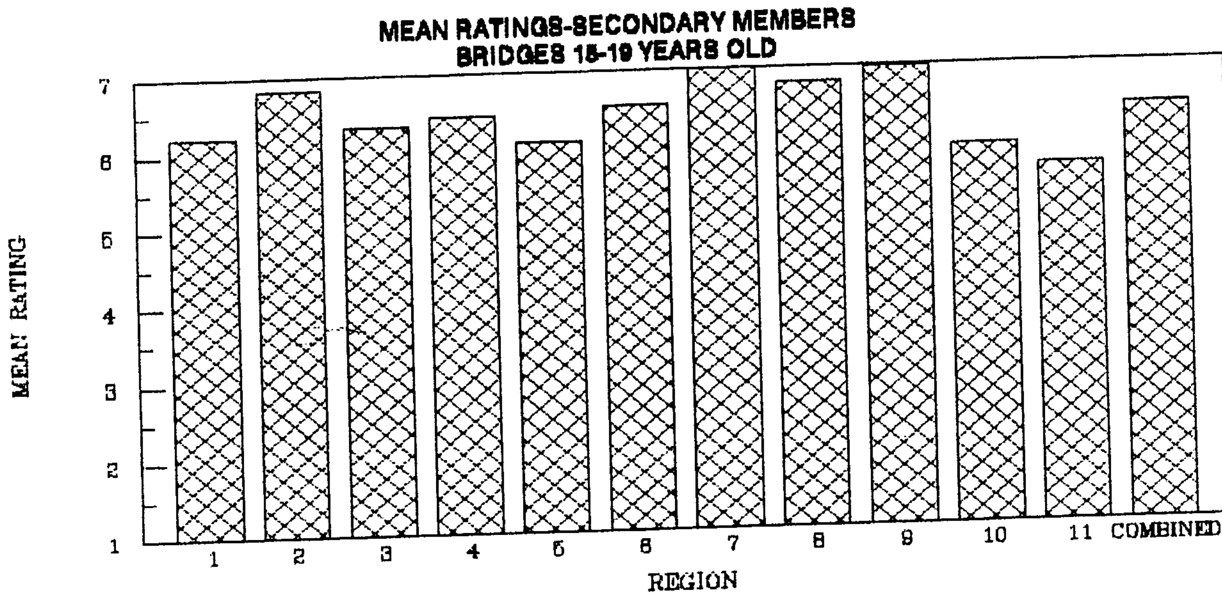
Figure 5j. MEAN RATINGS-SECONDARY MEMBERS



AGE GROUP	F	SIGNIFICANT DIFFERENCE
9-14 YEARS	8.91	YES
15-19 YEARS	18.08	YES
20-24 YEARS	25.17	YES

Figure 5j. Continued





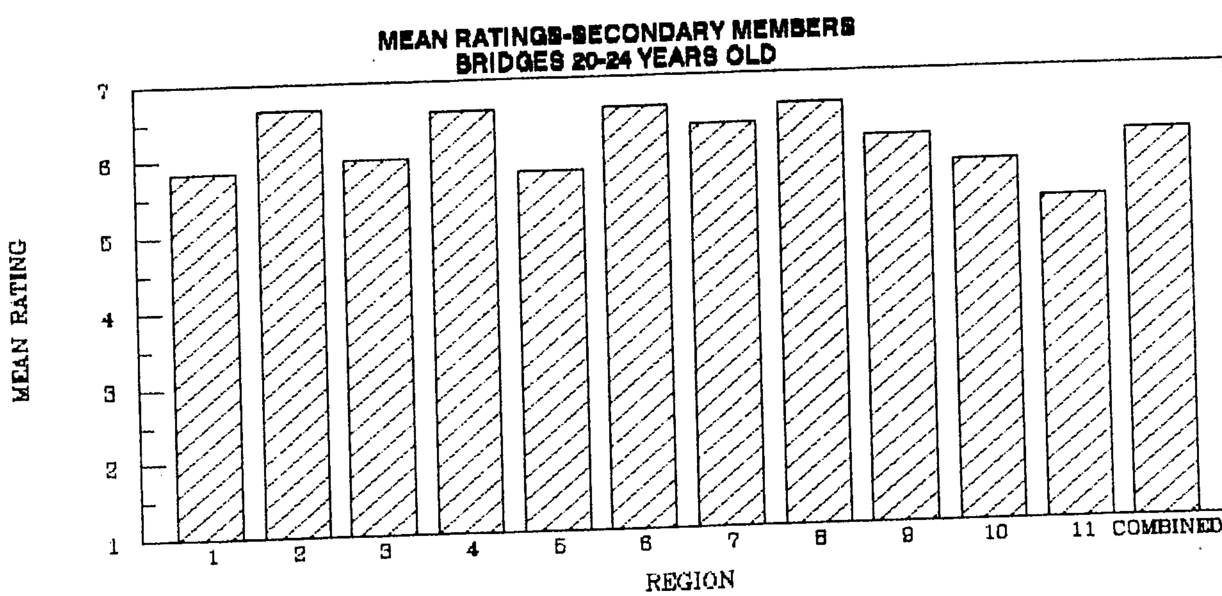


Figure 6a. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Pier Columns

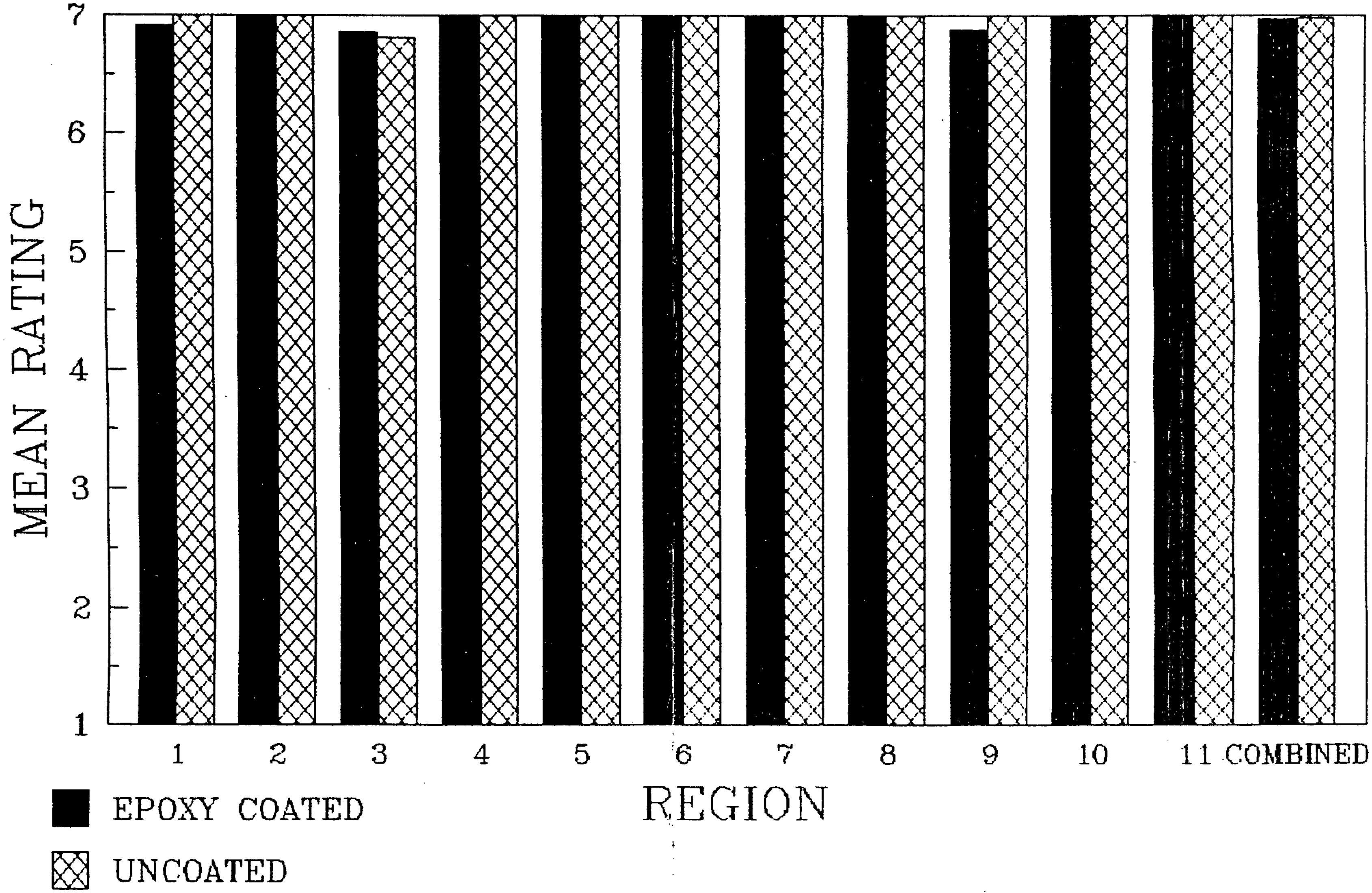


Figure 6b. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Pier Cap Beams

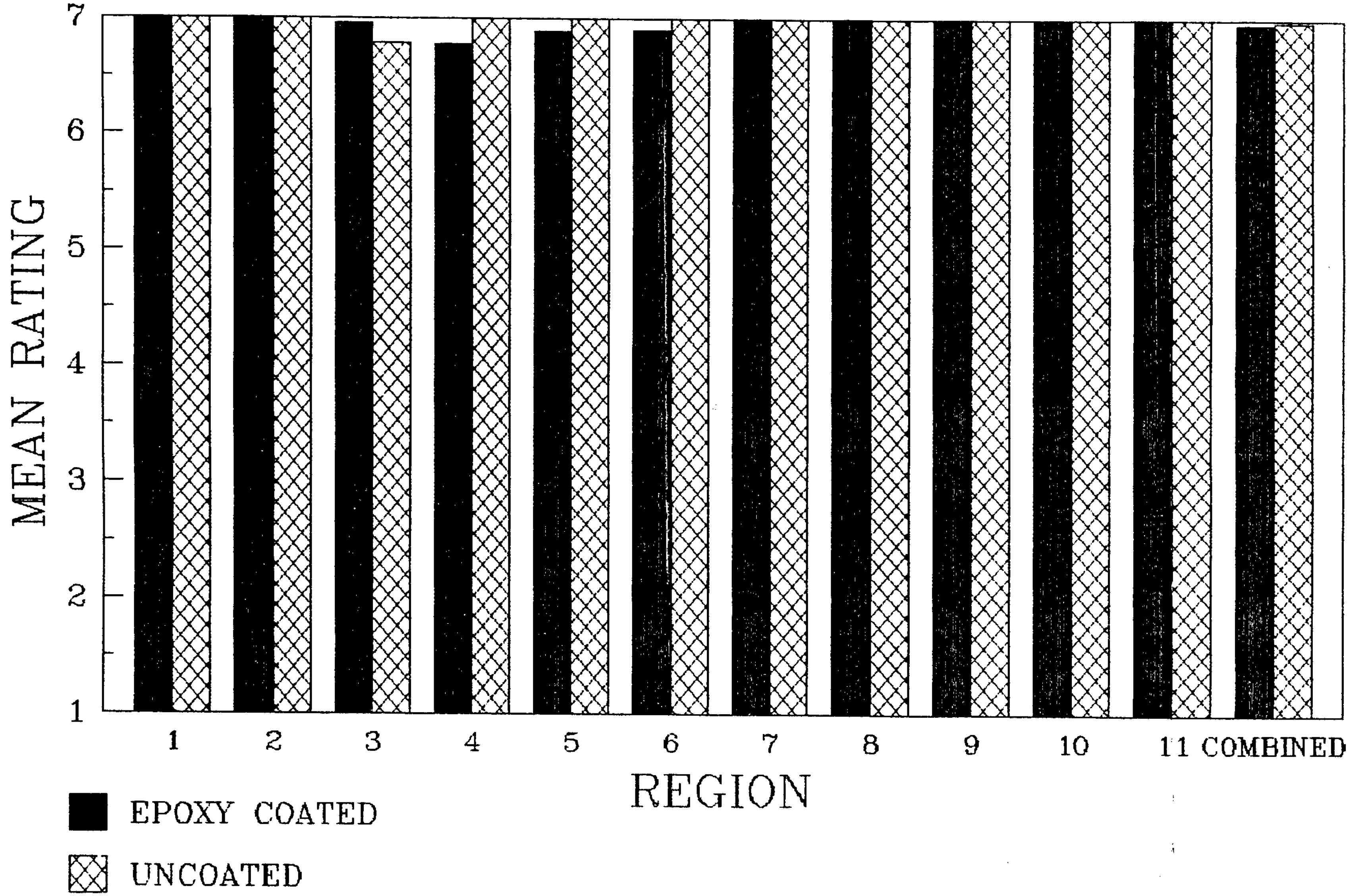


Figure 6c. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Pier Pedestals

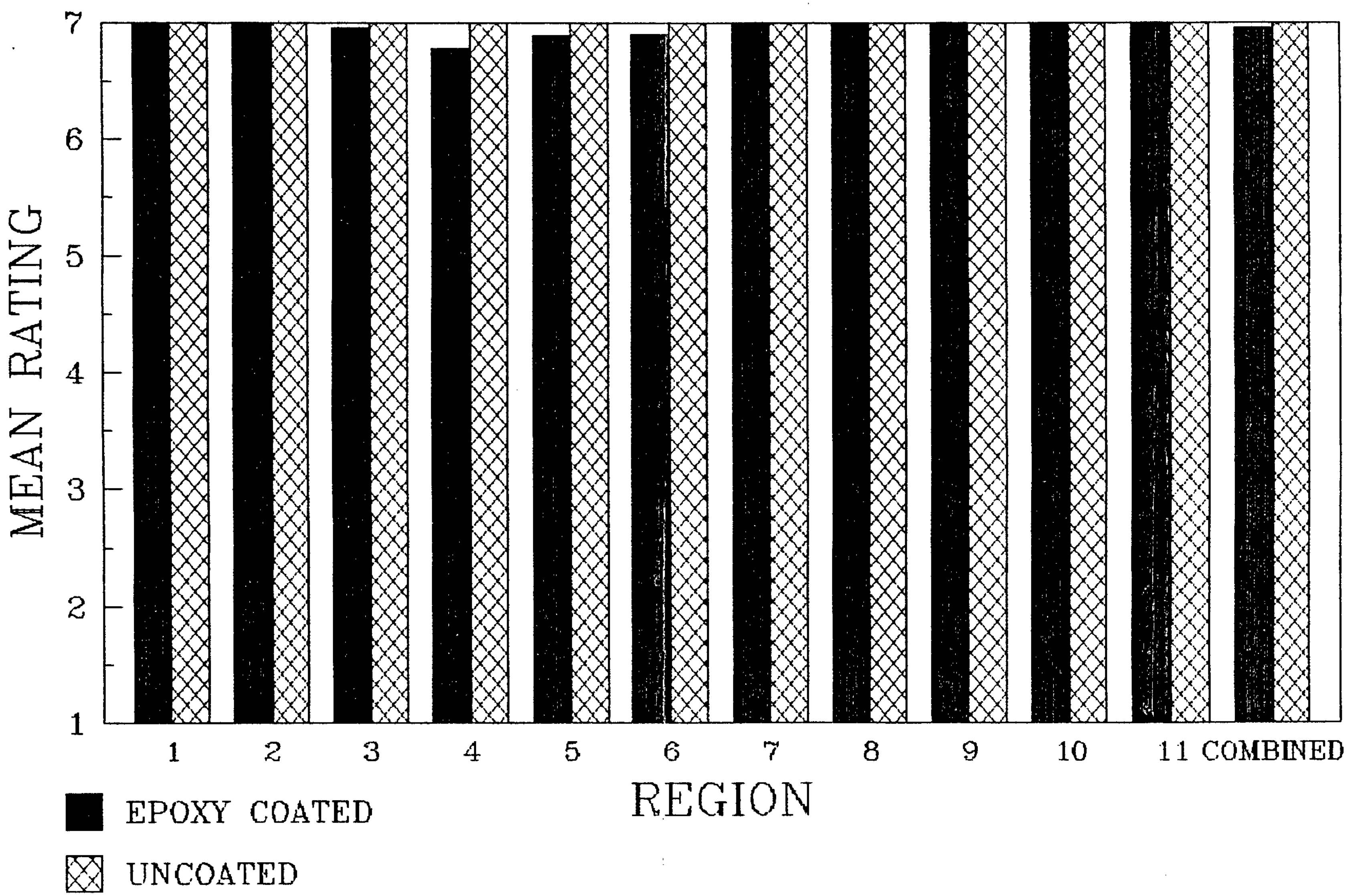


Figure 6d. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Bridge Seats and Pedestals

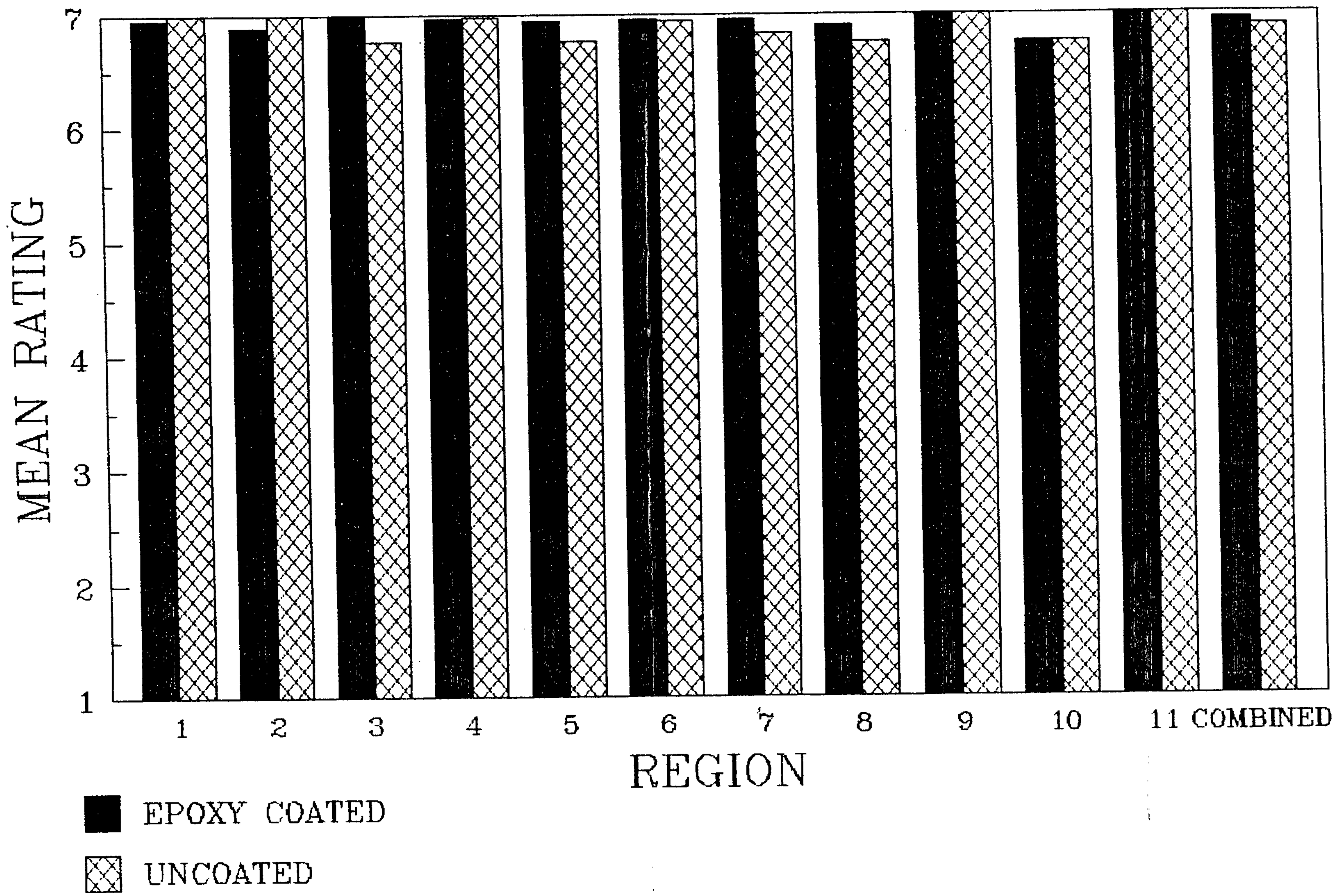


Figure 6e. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Abutment Back Walls

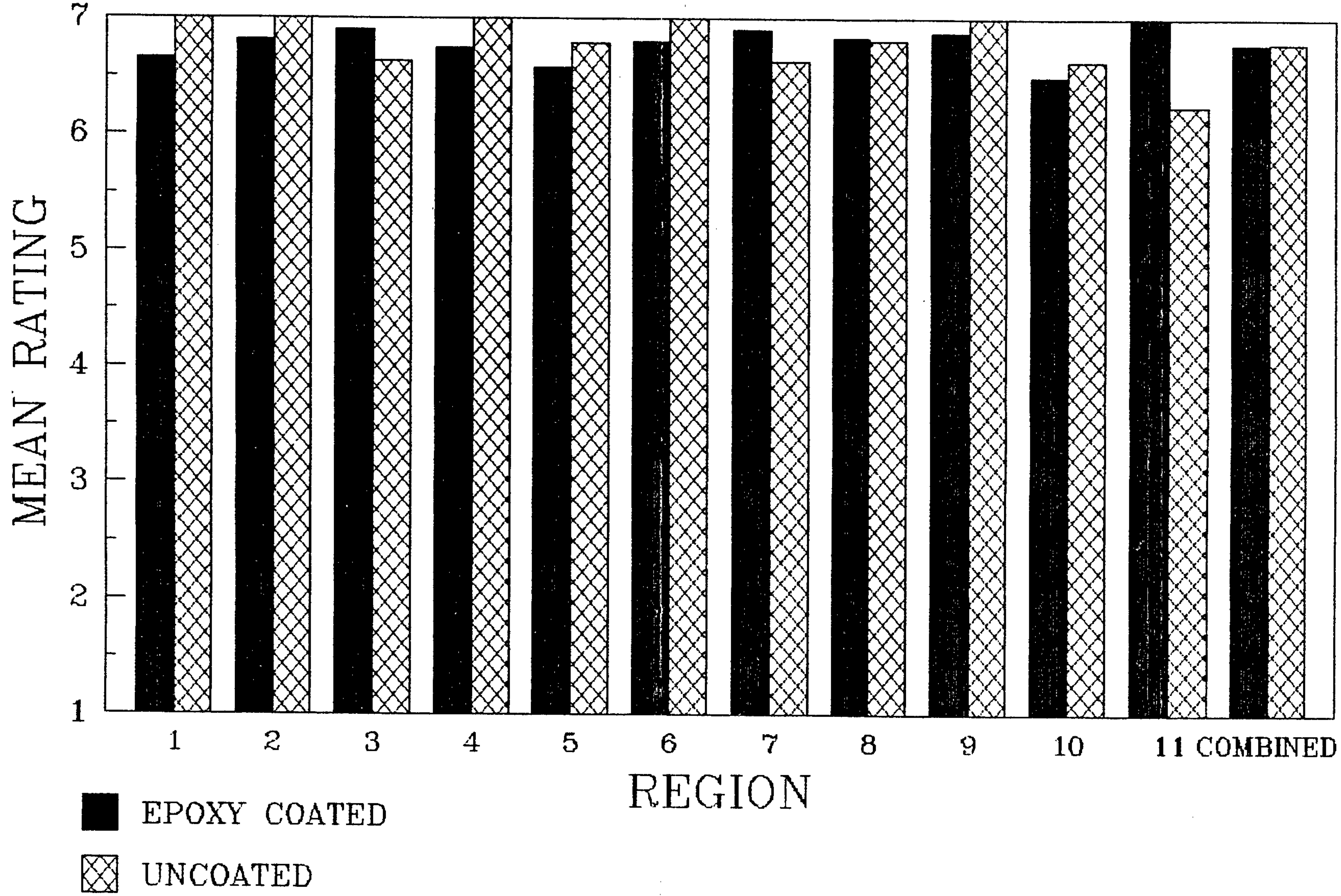


Figure 6f. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Wing Walls

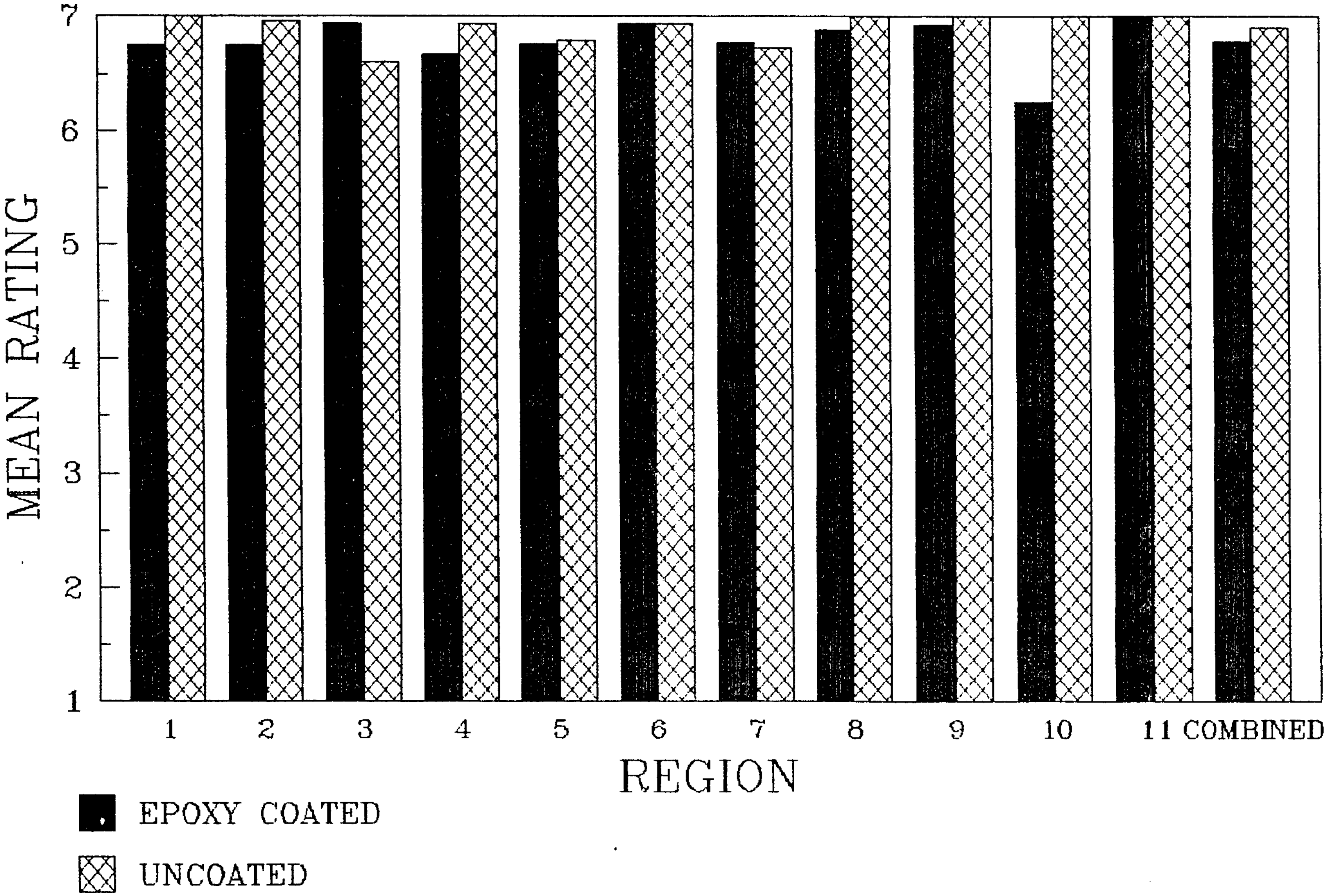


Figure 6g. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Abutment Stems

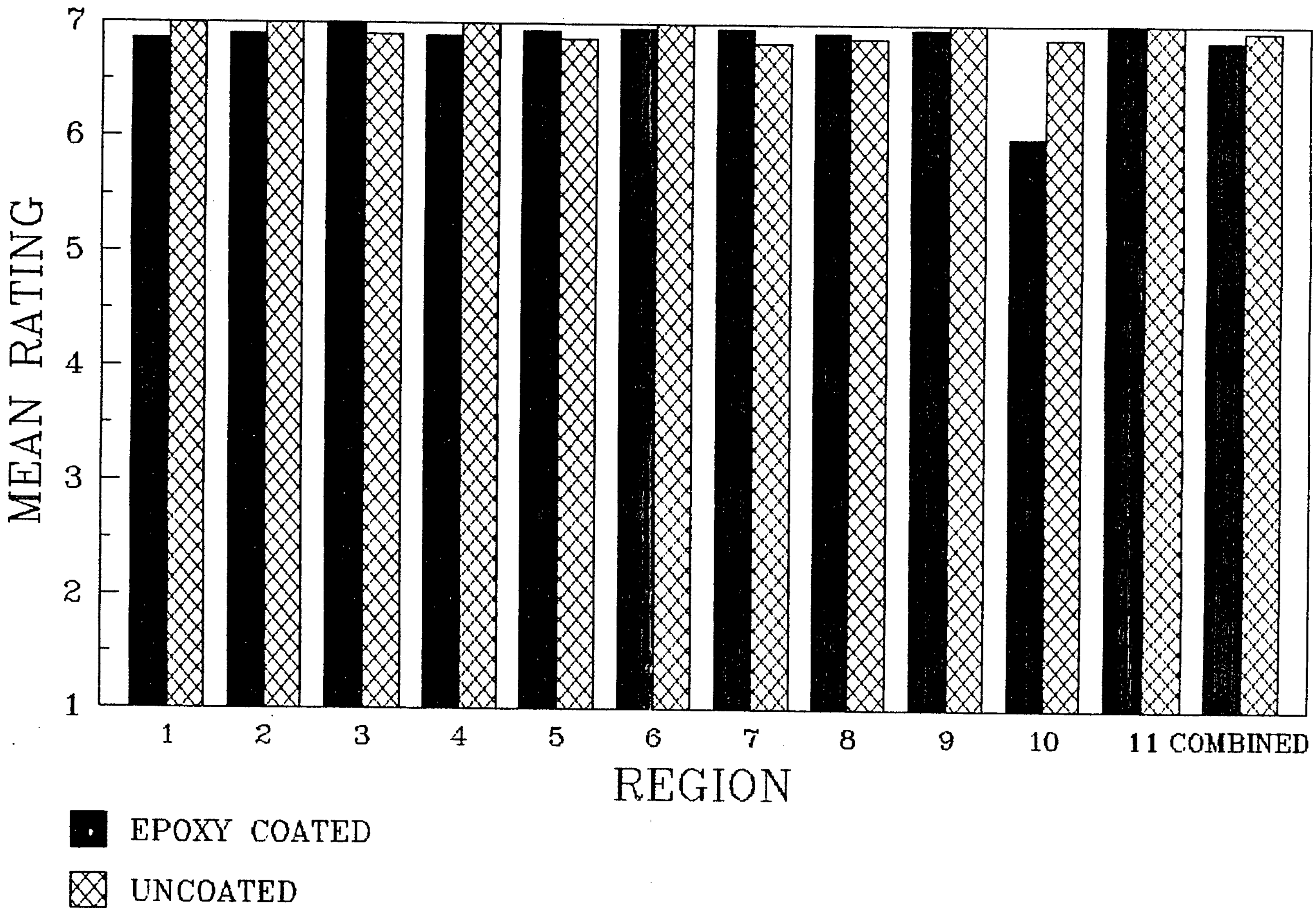


Figure 6h. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Solid Pier Stems

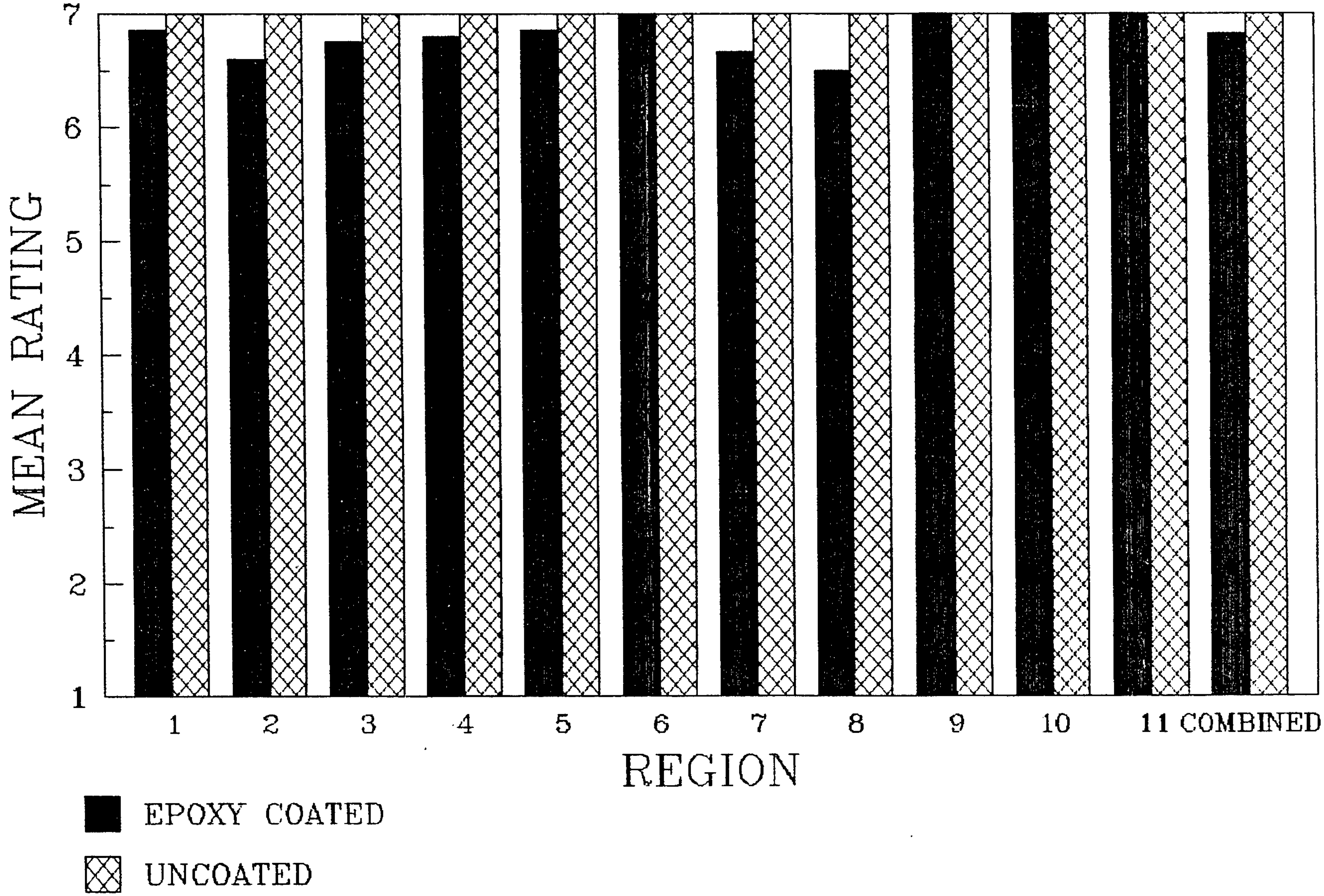


Figure 6i. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Primary Members

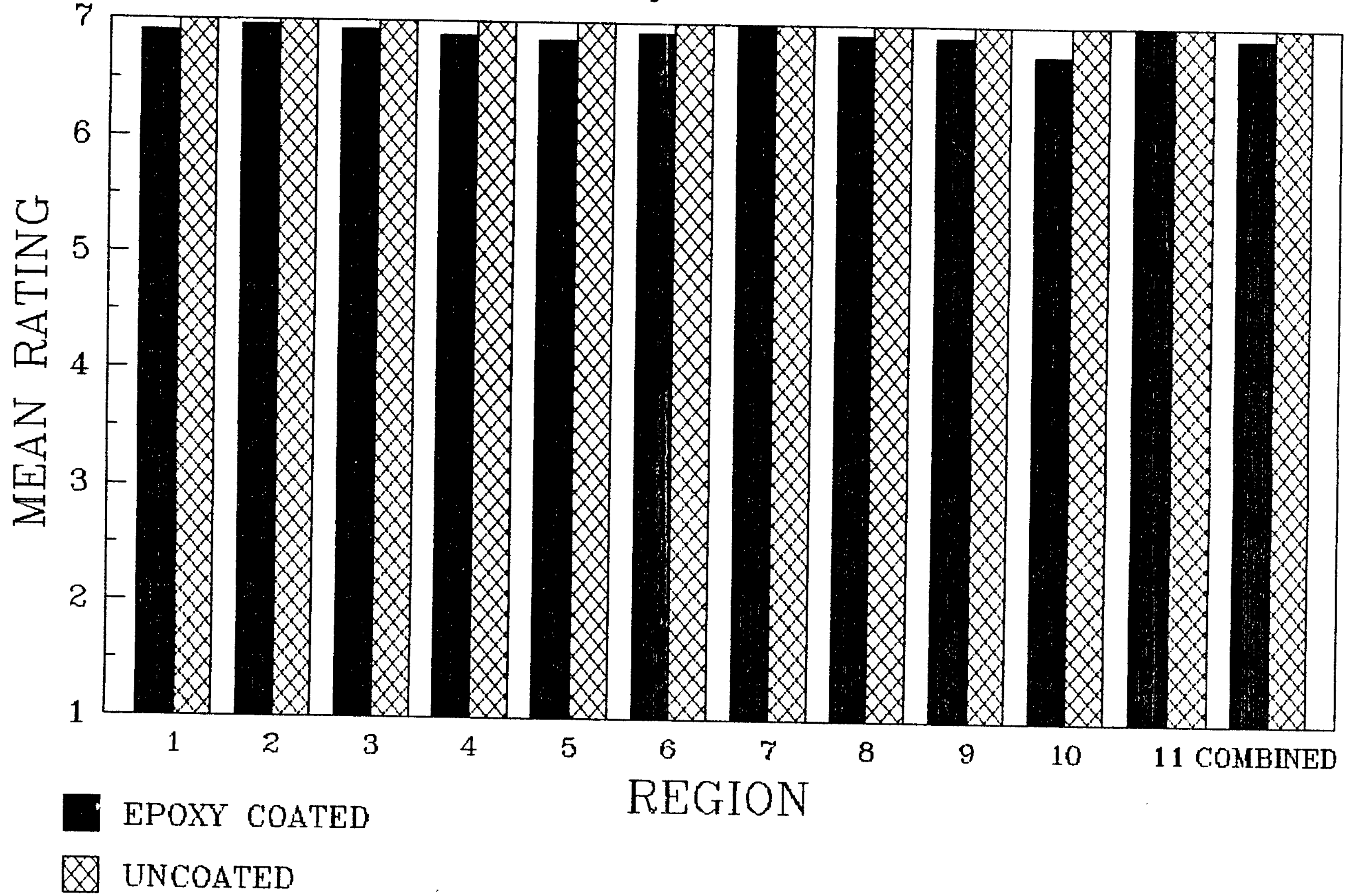
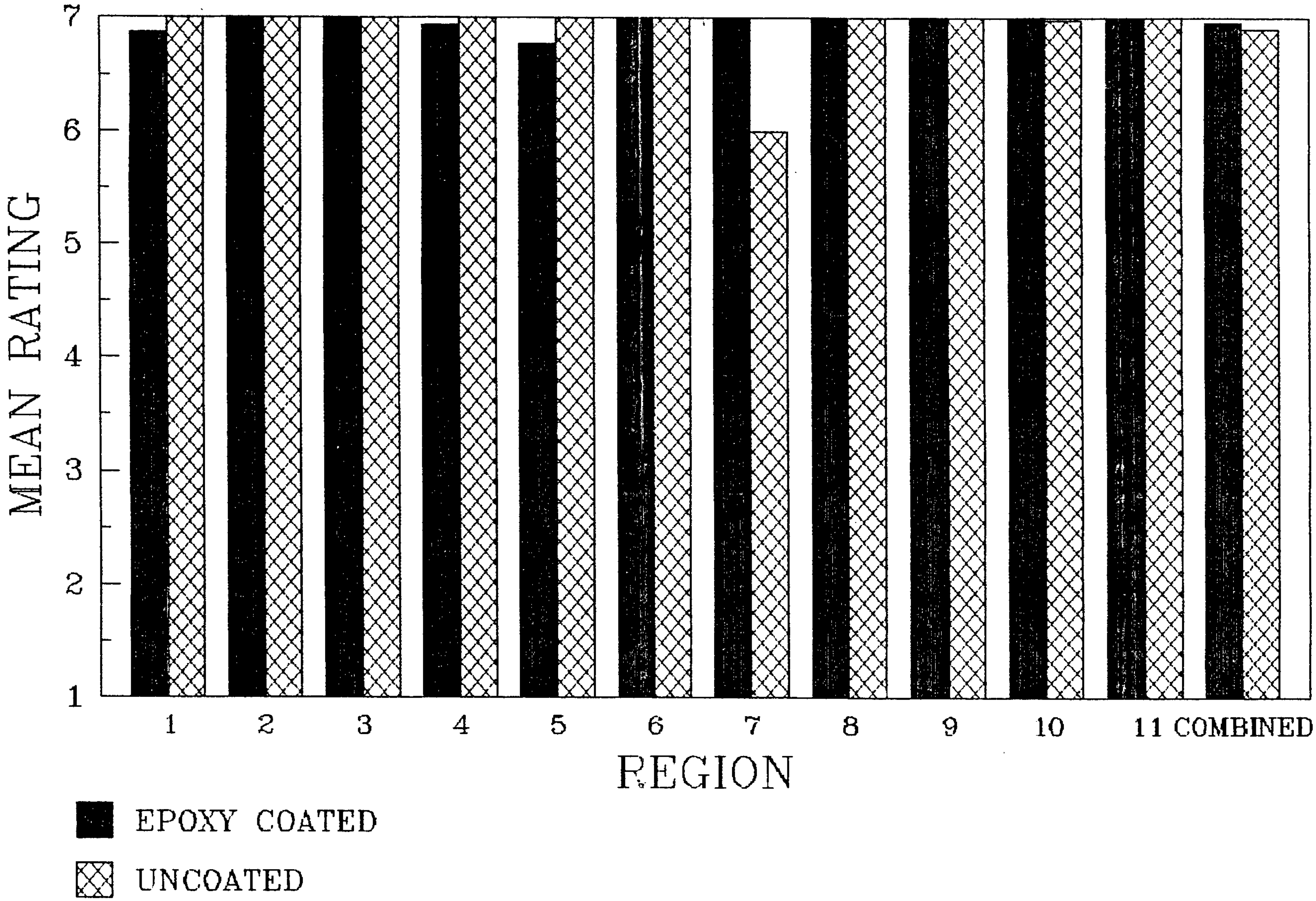


Figure 6j. MEAN RATINGS-BRIDGES 0-5 YEARS OLD

Epoxy Coated VS Unprotected Rebars

Secondary Members



III. CONCLUSIONS

As a result of continuing concern over deteriorating structural concrete, a reconnaissance survey of 45 bridges in four DOT administrative regions (Nos. 1, 4, 7, and 9) and an analysis of mean element ratings of substructures throughout the state were performed. For the survey and the analysis, the bridges were grouped into three age categories -- 9 to 14 years, 15 to 19 years, and 20 to 24 years. This work updated a similar study done 9 years ago and reported in Special Report 73. In addition, element ratings of bridges currently 0 to 5 years old were compared to bridges 0 to 5 years old at the time of the first survey, to study the effect of epoxy coating of reinforcing steel in substructure elements.

Based on the findings of this study the following conclusions are drawn:

1. The current study indicates additional deterioration of substructures as expected, but apparently less than predicted in Special Report 73. It must be noted that the bridges reviewed are relatively young. Furthermore, harsher environments (as in Regions 10 and 11) were not part of the reconnaissance survey.

2. Most substructures in these age groupings are still in satisfactory condition and pose no immediate concern. The inventory analysis revealed possible problems in pier capbeams in Region 10, and stems, solid pier stems, primary members, and abutment backwalls in Region 11 (Fig. 5). The survey analysis revealed possible problems in pier pedestals in Region 7 in the 20-to-24 age group. Conditions of these elements may become critical in the near future.

3. Consistent with Special Report 73, pier columns and pier capbeams were observed to suffer from deterioration in the forms of spalling and open cracking due to corrosion of embedded steel reinforcement.

4. Epoxy coating appears effective in preventing damage to bridge seat pedestals and pier pedestals, most of which were in excellent condition.

5. At this time, no conclusions can be drawn concerning the value of epoxy coating of reinforcing steel in substructure elements. A base line of information has been developed for a similar investigation of element rating data in the future.

6. Based on the reconnaissance survey update, it appears that construction practices and current preventive and corrective maintenance programs of the various regions are sufficient. Substructures of most bridges included in the survey can be expected to provide quality service for several years to come.

REFERENCES

1. Gupta, P.K. A Survey of Concrete Deterioration in Bridge Substructures. Special Report 73, Engineering Research and Development Bureau, New York State Department of Transportation, July 1983.

2. "Bridge Design Manual; Design Criteria for Bridges, Protection of Substructure Concrete. Subject Code: 7.35-4." Engineering Instruction 84-60, Structures Design and Construction Division, New York State Department of Transportation, November 27, 1984.

3. Minor J., White, K.R., and Busch, R.S. Condition Surveys of Concrete Bridge Components -- User's Manual. Report 312, National Cooperative Highway Research Program, Transportation Research Board, December 1988.

4. Dixon, W.J., and Massey, F.J., Jr. Introduction to Statistical Analysis. New York: McGraw-Hill Book Company, 1969 (3rd ed.).

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APPENDIX

Protection of Substructure Concrete
Engineering Instruction 84-60

TO:	**ENGINEERING INSTRUCTION** NEW YORK STATE DEPARTMENT OF TRANSPORTATION
	SUBJECT: Bridge Design Manual; Design Criteria For Bridges, Protection of Substructure Concrete Subject Code: 7.35-4

Distribution:	31 [X] Main Office	33 [X] Regions	34 [X] Special	Code: E.I. 84-60 Date: 11/27/84
APPROVED: E. V. HOURIGAN, Deputy Chief Engineer (Structures)				Supersedes:

The following criteria shall be used to determine where steel reinforcing bars in concrete should be protected from chlorides.

RATIONALE

Much attention has been given to understanding the effects of chlorides on reinforced concrete and to developing measures to prevent the undesirable effects caused by the corrosion of reinforcing bars. The Department's major effort has been directed to bridge decks up to this time, but with increased understanding of the nature of the problem, it has become apparent that attention must also be given to the effect of chlorides on substructure concrete elements.

Substructure concrete is directly exposed to chlorides in the following ways:

1. salt water passing through bridge deck openings or bridge deck joints.
2. salt water running or dripping over deck fascias.
3. salt water splash resulting from moving vehicles.
4. immersion in seawater.
5. splashing of seawater.

The result of this exposure is the same as that which occurs in bridge decks. Spalling, delamination and cracking of concrete may be expected as a result of the corrosion of unprotected reinforcing bars. The elapsed time to the appearance of these problems in substructure concrete is normally greater than for a bridge deck because the exposure is generally less concentrated and traffic loads are not a factor. However, some substructure situations may be as severe as with a bridge deck, such as exposure to seawater, or a high concentration of chlorides in water passing through an open bridge deck joint.

Just as the cause and symptoms of the problem are the same as with bridge decks, the corrective measures are also the same. Epoxy coated reinforcing bars, increased concrete cover, and surface coatings are measures that can be taken to reduce or eliminate the corrosion problem. Because of the positive protection provided, the small extra cost and the confidence in the quality of the protection provided, this criteria statement will only consider the use of epoxy coated reinforcing bars. Epoxy protective coating for concrete has been effective in preventing the ingress of chlorides in concrete on backwalls, pier caps, and bearing seats. However, it is not as cost effective as epoxy coated reinforcing bars and extends the construction schedule for a structure. The protective coating is not required to protect properly air entrained concrete. In addition, the entrained air requirements for all classes of concrete have been increased by 1% to provide a greater degree of confidence that the minimum air contents will provide satisfactory protection against freeze-thaw damage. For this reason, the use of epoxy protective coating for concrete on these elements will be discontinued. The development of improved bridge joint sealing systems has also substantially reduced the potential for chloride laden water to reach these elements.

WARRANTS FOR PROTECTION OF REINFORCED CONCRETE SUBSTRUCTURE ELEMENTS DIRECTLY EXPOSED TO CHLORIDES

Reinforcing bars used in the faces of substructure concrete elements which are directly exposed to chlorides shall be epoxy coated to prevent corrosion of the steel. Sources of chlorides include roadway drainage and spray from traffic due to deicing salt, splash and spray from seawater, and immersion in seawater. The exposed reinforced concrete elements generally include abutments, backwalls, bridge seats, bearing pedestals, columns, cap beams, stems of solid piers, wingwalls and retaining walls.

POLICY

1. Epoxy Protective Coating for Concrete
   Section 559 - Protective Coatings For Concrete shall not be used on bridges designed and built under this policy. However, for bridges not built under this policy, Note 36 of Section 21.21 of the Standard Details For Highway Bridges shall apply where appropriate.

2. <u>Elements Exposed to Roadway Drainage</u>
   The faces of substructure elements shall be considered directly exposed to roadway drainage and require epoxy coated reinforcing bars when they are located as follows:
   a. under an open steel grating deck.
   b. under any bridge joint.
   c. under or adjacent to a bridge deck with an open bridge railing.

   Footings are not directly exposed. However, any reinforcing bars extending from the footing into an exposed substructure element shall be epoxy coated.

   The need for protecting the elements beneath open steel gratings and open bridge joints is obvious. Bridge joints with "watertight" seals should protect the substructure, however, "watertight" seals may leak after a few years of service. Protecting the substructure concrete against the problems caused by leaking joints assures a long service life of the element. Water running or dripping over the fascia of the bridge deck usually finds its way to the substructure element. It is very difficult to differentiate between elements or portions of elements which would be affected. Even if portions of elements could be identified, it would be a burden to construct the element with a mixture of plain and epoxy coated reinforcing bars. Therefore, all substructure elements, except footings, under a bridge deck with an open railing shall utilize epoxy coated reinforcing bars. This includes U-wingwalls.

   Bridges with parapets keep the roadway drainage on the deck, therefore, the substructure does not require epoxy coated reinforcing bars due to roadway drainage over the fascias.

3. <u>Elements Exposed to Salt Splash or Spray</u>
   The faces of substructure elements shall be considered directly exposed to salt splash or spray and require epoxy coated reinforcing bars when they are located as follows:

   a. within 30 feet horizontally of the edge of the roadway pavement.
   b. within 30 feet horizontally of the edge of seawater at mean high water. If the structure is located in a seawater area where large waves frequently exceed the mean high water level, the distance from the edge of seawater shall be increased to 100 feet.

   The limits of seawater shall be all tidal waters of New York State, except those of the Hudson River and its tributaries north of the Newburgh-Beacon Bridge.

Footings are not directly exposed. However, any reinforcing bars extending from the footing into an exposed substructure element shall be epoxy coated.

Any element exposed to salt water splash shall generally have epoxy coated reinforcing bars throughout the element. However, if the element is tall, plain steel may be used beginning with the first splice at 15 feet or higher above the pavement or mean high water. In an area that has large waves frequently exceeding the mean high water level, the height shall be increased to 50 feet above mean high water.

4. Elements Immersed in Seawater
All substructure elements immersed in seawater shall utilize epoxy coated reinforcing bars. This includes reinforcing bars in footings. The limits of seawater shall be the same as those stated in 3. above.

The design guidelines described above are for general conditions and they will cover most bridges. Special cases will occur, such as intersecting roadways with multiple levels, where the designer will have to analyze the conditions and protect the substructure elements accordingly.

When epoxy coated reinforcing bars are used in substructure elements, those reinforcing bars to be coated shall be identified on appropriate plan sheets and in the bar list for the bridge.

Any questions regarding this policy may be referred to the Special Design Unit of the Structures Division.