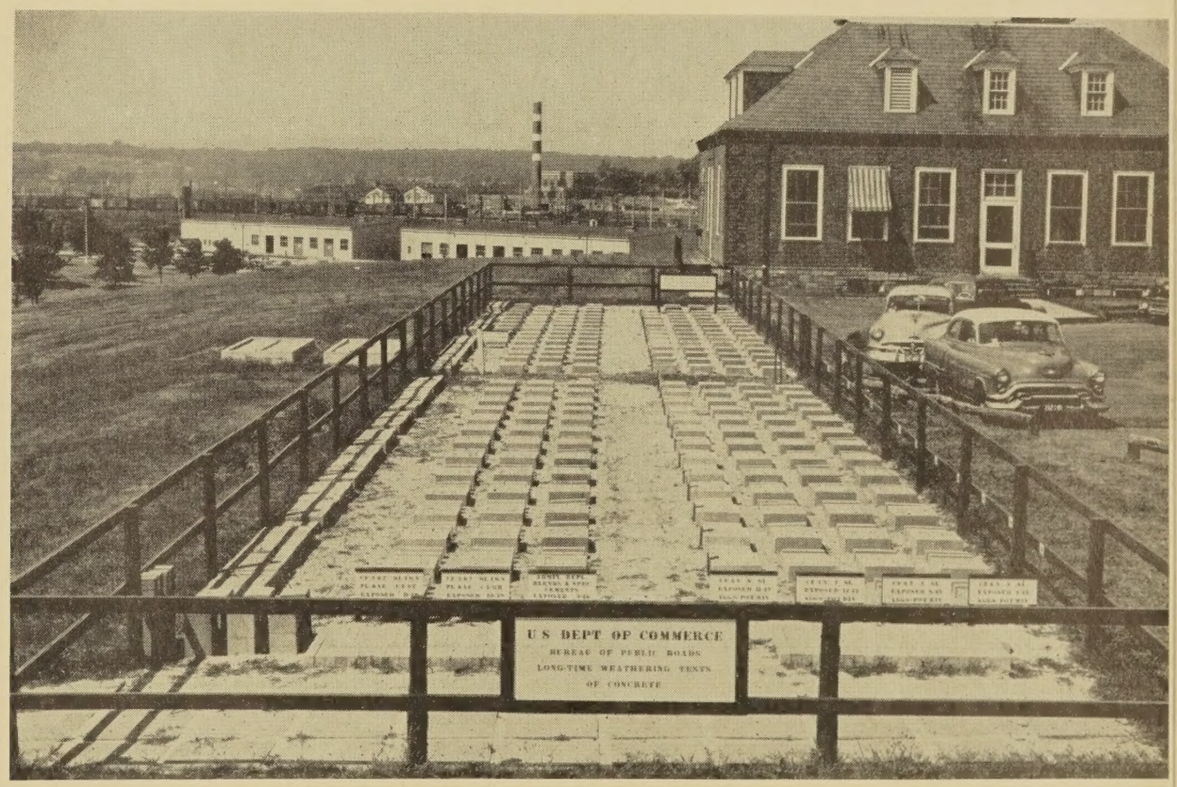
VOL. 33, NO. 4

OCTOBER 1964

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

PUBLISHED
BIMONTHLY
BY THE BUREAU
OF PUBLIC ROADS,
U.S. DEPARTMENT
OF COMMERCE,
WASHINGTON



Exposure plot used to test durability of concrete specimens at the Bureau of Public Roads Laboratory

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Public Roads

A JOURNAL OF HIGHWAY RESEARCH

Vol. 33, No. 4 *October 1964*

Published Bimonthly

Muriel P. Worth, *Editor*
Jessie W. Dean, *Assistant Editor*

THE BUREAU OF PUBLIC ROADS

WASHINGTON OFFICE
1717 H St. NW., Washington, D.C., 20235

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PUBLIC ROADS is sold by the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402, at $1 per year (50 cents additional for foreign mailing) or 20 cents per single copy. Subscriptions are available for 1-, 2-, or 3-year periods. Free distribution is limited to public officials actually engaged in planning or constructing highways and to instructors of highway engineering. There are no vacancies in the free list at present.

Use of funds for printing this publication has been approved by the Director of the Bureau of the Budget, March 6, 1961.

U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

BUREAU OF PUBLIC ROADS
REX M. WHITTON, Administrator

Natural Weathering of Concrete Specimens Prepared With Cements Used in the Long-Time Study

eported by WILLIAM E. GRIEB
nd GEORGE WERNER,[1]
ighway Research Engineers

BY THE MATERIALS RESEARCH DIVISION
BUREAU OF PUBLIC ROADS

In 1940 the Portland Cement Association, in cooperation with several consumer agencies, sponsored an investigation known as the Long-Time Study of Cement Performance in Concrete. Twenty-seven cements were selected for this study. They represented the principal cement producing areas of the United States and covered the range of chemical composition commonly encountered. This included all five ASTM types and air-entraining cements.

The major objective of the study was to provide a comparison of the performance, particularly with respect to durability, of concrete made with these cements. Comparisons were to be made to determine whether durability was related to certain properties of the cements, such as chemical composition or fineness.

Cements used in this investigation were used in an independent study by the Bureau of Public Roads. Boxtype concrete specimens made with these cements were exposed to outdoor weathering for more than 15 years. Some of the results of these tests were as follows: Concrete made with the Types II, IV, and V, and air-entraining cements were, in general, more durable than concrete prepared with Types I and III cements. Concrete prepared with cements having tricalcium aluminate (C_3A) content of more than 10 percent had poorer durability than concrete made with cements having C_3A contents of less than 10 percent.

Introduction

N 1940 the Portland Cement Association sponsored a cooperative investigation known *The Long Time Study of Cement Performance Concrete.* The investigation was designed develop information on the performance of different cements in concrete subjected to different conditions of natural exposure at several locations. The five ASTM types of portland cement were included in the study. Information on the cements is quoted from the 10-year report (*1*):[2]

"The cements were made at representative cement plants under good operating conditions. Free lime in the clinker was uniformly low and the finished cements had autoclave expansions well below the limits permitted in ASTM and other specifications. A crew of trained observers was present to record data and take samples at various stages of the manufacturing process. Twenty-one clinkers were made and ground with gypsum to make 21 cements. In addition, 6 of the 21 clinkers were ground with gypsum and an air-entraining agent, making 27 test cements in all. There were eight cements of Type I composition (identified as Nos. 11 to 18, inclusive), five of Type II (Nos. 21 to 25, inclusive), three of Type III (Nos. 31, 33, and 34), four of Type IV (Nos. 41, 42, 43, 43A), and one Type V (No. 51). The six air-entraining cements are identified by the letter "T" following the cement number. (The term "air-entraining cement" had not come into use in 1939–40 when these cements were manufactured, and the letter "T" was used to indicate a "treated" cement.)"

Two of the Type IV cements, Nos. 43 and 43A, had different alkali contents, although produced by the same plant.

The Portland Cement Association and other cooperating agencies studied the behavior of the 27 cements in concrete subjected to different exposure conditions: (1) Test roads constructed in areas having severe, moderate, and mild climatic conditions; (2) piling exposed to sea water or fresh water, in severe or mild climates; (3) thin to moderate-sized concrete sections exposed to severe natural weathering; (4) specimens of *near-job-size* placed in exposure plots, in severe and mild climates; and (5) specimens placed in sulfate soils in mild climate. Many reports of the condition of the concrete for these projects have been published (*2*).

Summary

The following is a summary of the observations made on specimens prepared with cements used in the *Long Time Study of Cement Performance in Concrete.* The summary is based principally on the conditions of the boxtype specimens at the time of the 1961 examination.

- Concretes containing 6½ bags of cement per cubic yard and having water contents of less than 6.0 gallons per bag had excellent durability. Only 8 of 54 specimens in this category had evidence of serious distress after 16 years of exposure.
- Concretes containing 5½ bags of cement per cubic yard and approximately 6¼ gallons of water per bag had evidence of serious distress in 11 of 27 specimens after 16 years of exposure.
- Concretes containing 4½ bags of cement per cubic yard and more than 8 gallons of water per bag for most of the mixes had evidence of serious distress in 19 of 27 specimens after 12 years of exposure; 13 of the specimens had evidence of serious distress after only 3 years of exposure.
- The C_3A content of the cements appeared to have an appreciable effect on the durability of the concrete. Omitting the leanest mix of about 4½ bags per cubic yard, 18 of the 33 specimens prepared with cements having C_3A contents of more than 10 percent had evidence of significant to severe distress. Conversely, only one of the 48 specimens made with cements having less than 10 percent C_3A had evidence of significant distress.
- The use of treated (air-entraining) cements generally increased the durability of the concretes as contrasted with that of similar concretes prepared with the corresponding non-air-entraining cements. Although a number of the specimens prepared with the treated cements were given a poor rating, almost all of the disintegration causing such a rating occured in the basin of the boxes. Specimens prepared with cement No. 11T had the highest air content, averaging more than 10 percent, but had the second poorest average of durability for the treated cements.

Mr. Werner retired from the Bureau of Public Roads in ly 1964.

[2] References indicated by italic numbers in parentheses are listed on page 67.

Table 1.—Chemical properties of cements

[In percentages]

Cement No.	Silicon dioxide [1]	Aluminum oxide	Ferric oxide	Calcium oxide	Magnesium oxide	Sulfur trioxide	Loss on ignition	Free lime [2]	Sodium oxide	Potassium oxide	Chloroform soluble	Computed compound composition [3,4]				
												C_3S	C_2S	C_3A	C_4AF	$CaSO_4$
11	20.70	6.03	2.27	63.50	3.20	1.58	2.07	0.43	0.17	0.50	0.010	51	21	12	7	2.7
12	21.15	6.78	2.27	63.25	2.93	1.58	1.22	0.11	0.26	0.42	0.008	43	28	14	7	2.7
13	22.25	4.88	2.07	66.00	1.03	1.75	1.60	1.61	0.09	0.15	0.008	52	24	9	6	3.0
14	22.30	5.14	2.91	63.25	2.32	1.78	1.12	0.19	0.12	1.06	0.008	43	31	9	9	3.0
15	20.50	6.54	2.36	66.70	0.67	1.90	0.90	0.44	0.06	0.28	0.010	61	13	13	7	3.2
16	21.30	5.22	3.38	64.75	1.87	1.61	1.39	0.73	0.22	0.46	0.010	54	20	8	10	2.7
17	21.40	6.20	3.00	65.50	0.85	1.72	0.68	0.42	0.23	0.30	0.008	51	23	11	9	2.9
18	21.45	6.83	2.12	64.55	1.96	1.68	1.27	0.33	0.16	0.15	0.022	45	28	14	6	2.9
21	23.90	5.06	3.04	63.70	1.00	1.30	1.30	0.65	0.18	0.46	0.030	33	44	8	9	2.2
22	22.55	5.23	3.52	62.90	2.97	1.44	0.91	0.05	0.19	0.29	0.008	40	34	8	11	2.4
23	21.70	5.16	5.34	64.40	0.71	1.56	0.60	0.43	0.50	0.16	0.005	49	26	5	16	2.7
24	21.00	5.09	4.76	61.55	2.72	1.73	2.22	0.88	0.11	1.07	0.010	41	29	5	14	2.9
25	22.65	5.10	4.70	62.35	2.04	1.85	0.80	0.21	0.19	0.52	0.015	35	39	6	14	3.1
31	20.55	5.61	2.09	64.40	3.02	2.15	1.70	1.45	0.22	0.32	0.010	53	19	11	6	3.7
33	20.25	5.89	2.36	65.55	1.32	2.25	1.70	1.83	0.20	0.37	0.012	56	16	12	7	3.8
34	20.50	4.59	3.11	65.60	2.19	1.81	1.69	2.27	0.28	0.30	T	62	12	7	10	3.1
41	22.80	4.98	4.77	59.85	2.81	1.90	1.91	0.44	0.08	1.01	0.018	23	48	5	14	3.2
42	26.40	3.15	2.55	63.35	1.63	1.52	0.88	0.21	0.24	0.28	T	27	55	4	8	2.6
43	23.30	5.52	4.33	61.85	1.34	2.02	0.58	0.12	0.99	0.14	0.022	25	48	7	13	3.4
43A	25.45	3.80	3.00	63.40	1.07	1.82	1.03	0.35	0.35	0.03	0.020	28	52	5	9	3.1
51	24.40	3.25	3.00	64.90	1.47	1.44	0.86	0.54	0.11	0.52	0.012	46	35	4	9	2.5
11T	20.70	6.08	2.22	63.65	3.22	1.61	1.69	0.47	0.19	0.53	0.020	51	21	12	7	2.7
12T	21.30	6.46	2.34	63.70	2.80	1.57	1.29	0.12	0.22	0.32	0.020	46	27	13	7	2.7
16T	21.65	4.98	3.42	64.60	1.83	1.56	1.39	0.75	0.21	0.46	0.035	53	23	9	10	2.7
18T	21.70	6.66	2.09	64.45	1.85	1.73	1.17	0.38	0.13	0.17	0.042	46	30	14	6	2.9
21T	23.85	4.71	3.24	64.25	1.10	1.34	0.96	0.60	0.19	0.42	0.038	38	40	7	10	2.1
33T	20.50	5.71	2.34	65.75	1.32	1.98	1.87	1.84	0.19	0.35	0.020	57	16	11	7	3.4

[1] Percentages are based on weight.
[2] Free lime percentages are those reported by Portland Cement Association.
[3] Corrected for free lime.
[4] C_3S: tricalcium silicate; C_2S: dicalcium silicate; C_3A: tricalcium aluminate; C_4A tetracalcium aluminoferrite; $CaSO_4$: calcium sulphate.

Table 2.—Physical properties of cements

Cement No.	Specific gravity	Specific surface	Autoclave expansion	Normal consistency	Merriman sugar test		Time of set		Mortar strength					Air in mortar (ASTM C-185)	
					Neutral	Clear	Initial	Final	Tensile (1:3) after—			Compressive (1:2.75) after—		Hand mix	Machine mix
									3 days	7 days	28 days	7 days	28 days		
		Sq. cm./g.	*Percent*	*Percent*	*Ml.*	*Ml.*	*Hr., Min.*	*Hr., Min.*	*P.s.i.*	*P.s.i.*	*P.s.i.*	*P.s.i.*	*P.s.i.*	*Percent*	*Percent*
11	3.12	1,870	0.11	24.5	5	6	3,45	5,00	310	375	485	2,765	4,460	4.6	4.3
12	3.17	1,840	0.13	25.0	3	3	3,45	5,15	300	405	440	2,750	4,800	4.8	5.2
13	3.09	1,780	0.00	25.0	48	56	3,00	5,15	260	320	415	1,965	3,900	3.7	2.7
14	3.13	1,860	0.11	23.0	4	5	3,15	5,15	320	385	460	2,865	5,185	6.0	5.4
15	3.12	1,920	0.16	28.0	46	66	4,45	7,15	370	435	510	3,815	5,150	4.5	3.0
16	3.19	1,850	0.06	25.0	6	7	3,30	6,00	360	400	505	2,935	4,800	4.8	4.0
17	3.18	1,790	0.08	25.0	6	7	3,30	5,30	335	435	505	2,835	4,465	5.6	3.8
18	3.14	1,920	0.06	25.0	20	29	3,30	6,00	300	375	460	2,850	4,850	2.3	2.1
21	3.17	1,760	0.01	25.0	9	13	5,30	8,+	210	310	405	1,950	3,800	4.6	4.6
22	3.21	1,860	0.08	24.0	2	2	4,00	6,00	250	355	470	1,900	4,435	4.2	3.7
23	3.14	1,800	0.01	25.5	3	3	4,20	8,15	250	340	420	2,175	4,460	2.2	---
24	3.17	1,960	0.12	23.0	5	5	2,30	5,00	275	350	425	2,215	4,185	5.9	5.2
25	3.24	1,930	0.07	24.0	2	2	4,30	6,30	230	305	425	1,315	3,135	5.6	4.4
31	3.12	2,730	0.09	28.0	50	73	1,30	3,30	420	545	550	5,185	6,700	3.0	2.3
33	3.11	2,500	0.17	27.0	52	73	1,30	3,45	450	515	530	5,000	5,665	1.9	1.0
34	3.17	2,440	0.09	27.0	50	64	3,00	5,00	485	460	490	3,865	5,500	3.2	2.8
41	3.22	2,000	0.10	23.0	3	3	3,20	6,30	220	255	390	1,110	2,685	5.3	---
42	3.24	1,920	0.00	25.0	2	2	6,35	7,40	185	250	400	840	2,250	1.8	2.1
43	3.22	2,010	0.02	25.0	3	3	3,30	5,30	170	265	400	1,035	3,065	6.2	5.7
43A	3.21	2,000	0.00	24.5	7	8	3,15	5,15	165	240	420	885	2,765	4.8	5.4
51	3.19	2,000	−0.01	25.5	5	7	5,30	7,00	255	305	425	1,750	3,935	3.6	3.0
11T	3.14	1,900	0.14	25.0	4	5	3,45	5,15	265	320	415	2,350	3,850	17.3	17.3
12T	3.16	1,750	0.15	25.0	3	3	4,00	6,25	245	390	470	2,315	4,300	9.4	9.3
16T	3.19	1,730	0.04	25.0	4	4	4,00	6,00	285	350	465	2,310	3,750	11.9	12.1
18T	3.14	2,040	0.08	26.0	30	46	2,00	3,45	260	325	400	2,600	4,665	11.2	10.6
21T	3.21	1,840	0.02	24.5	24	34	5,30	8,45+	210	285	390	1,800	3,465	11.2	11.9
33T	3.11	2,520	0.19	27.5	51	74	3,15	4,00	395	440	470	4,090	4,700	12.4	12.6

In the concretes prepared with the treated cements, poor durability was associated with high C_3A content. The use of treated cements appeared to be of most benefit in the lean-mix concretes. The average rating for the treated cements of the lean-mix concrete, 4.5 bags per cubic yard, was much better than the average ratings for the corresponding untreated cements.

- Most of the specimens prepared with the Types II, IV, V, and the treated cements had excellent durability.
- The specimens prepared with the Types I and III cements generally had poorer durability than those containing the other types of cement. Concretes prepared with two of the three Type III cements and three of the eight Type I cements had very poor durability. However certain of the Type I cements, Nos. 12, 14, 16, and 17, furnished concrete of very good durability.

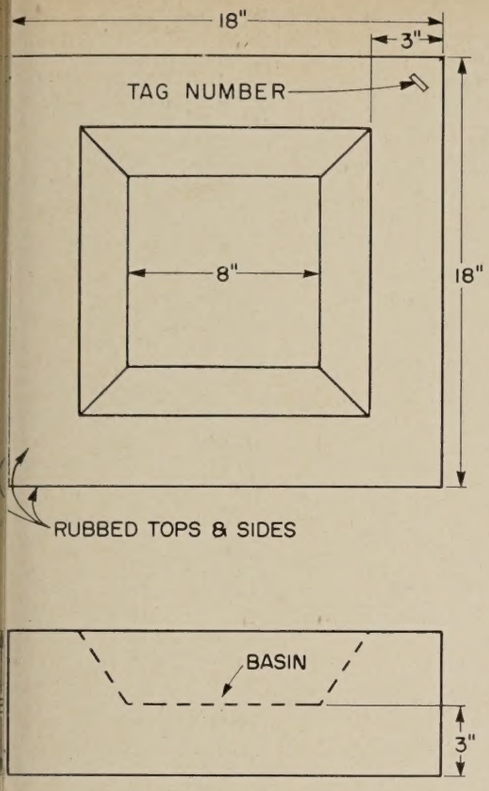


Figure 1.—Outdoor exposure box.

Participation by the Bureau of Public Roads

The Bureau of Public Roads cooperated with the Portland Cement Association in the regular inspection of several of the projects. In addition, samples of the 27 cements were sent to the Public Roads laboratory for special independent studies. The results of tests for the chemical and physical properties of these cements are shown in tables 1 and 2, respectively. The results of some tests differ slightly from those reported by other cooperating agencies (*2, 3*).

Test specimens

Outdoor exposure tests of concrete specimens made with the 27 cements were an important part of the Public Roads study. Both boxtype and beam specimens were included. These specimens were placed in an exposure plot in 1945 and 1949. The box specimens were 18 inches square, 6 inches deep, and had a 3-inch deep basin. The basin was 12 inches square at the top; its sides were so tapered that it was 8 inches square at the bottom. The dimensions and shape of the box are shown in figure 1.

In preparing the box specimens, an 18-inch square wooden form was partially filled with concrete to a depth of 3¼ inches and rodded, and the surface was smoothed. The wooden core, which formed the basin of the box, was then placed on the smoothed surface. It was held in place by supporting strips nailed to the upper surface of the vertical sides of the wooden form. The mold was filled with concrete. The side slopes of the basin, as well as the vertical sides of the box, were spaded. The 3-inch top surface of the box was finished by careful screeding with a steel straightedge. After molding, a metal identification tag was inserted in a corner of the top surface.

Four groups of box specimens were made for each of the 27 cements. A set of three 3- by 4- by 16-inch beams, in which stainless steel gage studs had been cast in their ends, was made from the same batch of concrete as the box. These beams were cured in the same manner as the box specimens, and they were stored together in the outdoor exposure area.

The box and beam specimens were cast in an air-conditioned laboratory and left in their molds, which were covered with wet burlap for 48 hours, then removed from the molds and stored in moist air at 73° F. for approximately 28 days. They were then stored on the ground in an outdoor exposure plot adjacent to the laboratory. A photograph of the exposure plot appears on the cover of this magazine.

Table 3.—Grading and physical properties of aggregates

Grading and physical properties	Potomac River aggregate [1] used in rows 1, 2, and 3		White Marsh aggregate [2] used in row 4	
	Sand	Gravel	Sand	Gravel
Grading, percentage passing sieves:				
1 inch	------	100	------	100
¾ inch	------	75	------	75
½ inch	------	40	------	40
⅜ inch	100	15	100	15
No. 4	98	0	98	0
No. 8	85	------	81	------
No. 16	71	------	68	------
No. 30	48	------	53	------
No. 50	18	------	25	------
No. 100	4	------	6	------
Fineness modulus	2.76	7.10	2.69	7.10
Physical properties:				
Bulk specific gravity:				
Dry	2.59	2.58	2.63	2.64
Saturated surface dry	2.63	2.60	2.64	2.65
Absorption, pct	1.6	0.8	0.4	0.4
Strength ratio (Ottawa sand):				
Compressive strength:				
At 7 da., pct	113	------	97	------
At 28 da., pct	116	------	96	------
Tensile strength:				
At 7 da., pct	117	------	117	------
At 28 da., pct	114	------	112	------
Los Angeles wear test loss, pct	------	30.3	------	41.6
Accelerated soundness, Na_2SO_4 loss, pct	------	3.4	------	2.3

[1] Rounded and subangular quartz, and quartzite containing some chert.
[2] Rounded and subangular quartz, quartzite, and sandstone.

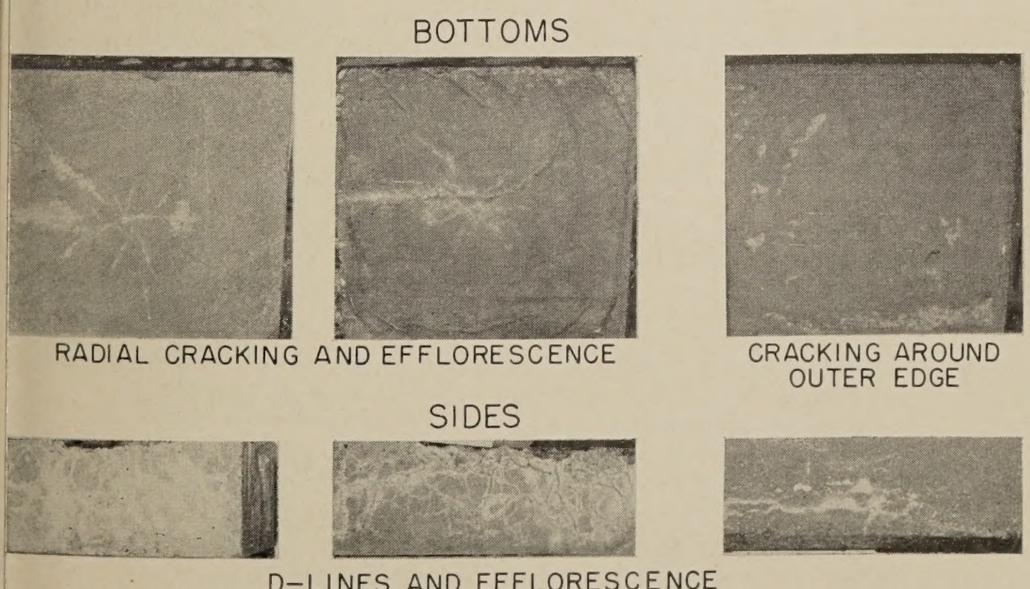


Figure 2.—Examples of distress in bottoms and sides of box specimens.

Each of the four groups of box and beam specimens was arranged in a separate row in the exposure plot. In the first three groups made, two adjacent side surfaces and the corresponding top faces of the boxes (fig. 1) were rubbed with a carborundum stone and water immediately after being removed from the molds, after 48 hours. The concrete was rubbed enough to break only the mortar surface and not deep enough to abrade the coarse aggregate. The rubbing developed a finish that was similar to that often used on handrails and other exposed surfaces of bridges. The other surfaces of the boxes were not rubbed. After about 4 years, all of the surfaces had weathered to a uniform sandy texture, and no difference between the rubbed and the unrubbed surfaces was apparent. The surfaces of the boxes in the last row were not rubbed.

The basin of each box was filled with pea-sized gravel and covered with water. The

only purpose of the gravel was to hold the water in the basins during windy weather. The temperature at the site of the exposure plot was considered moderate, averaging approximately 40 cycles of freezing and thawing per year. It is emphasized that deicing agents were not used in this study.

Concrete mixes

The aggregates used in making the concretes in the first three rows of specimens were a river sand and a gravel consisting mainly of rounded and subangular quartz and quartzite containing minor amounts of chert, micaceous schist, weathered granite, and gneiss. A bank sand and a gravel of rounded and subangular quartz, quartzite, and sandstone was used in making the concretes in the fourth row. Grading and other physical properties of the aggregates are listed in table 3.

The mix data for all four rows of specimens are listed in table 4. Nearly identical mixes were used in making the concrete specimens prepared with the same cements in the first and second rows. In these two rows, the cement content ranged from 6.3 to 6.6 bags per cubic yard of concrete, and the slump was from 4.7 to 6.6 inches. The sand content (percent of sand in total aggregate by solid volume) was 41 percent for the mixes prepared with the plain (non-air-entrained) cements. For those prepared with the treated (air-entraining) cements, the sand content ranged from 35 to 40 percent to obtain a uniform cement content. The weight of coarse aggregate per bag of cement was the same for all mixes in the first two rows. The water content ranged from 5.4 to 6.1 gallons per bag of cement for the concretes prepared with the plain cements and from 5.0 to 5.5 gallons for those made with the treated cements.

The air content ranged from 1.1 to 2.3 percent for the mixes prepared with the plain cements and from 4.0 to 11.2 for those made with the treated cements. The air content was determined by the use of a displacement pycnometer with an extension chimney. The method is identical in principle to the rolling procedure of ASTM Method C 173. The displacement method was used because no pressure air meter was available in the laboratory at the time these specimens were made.

The concrete in the third row was similar to that in the first two rows, except that the cement contents ranged from 5.4 to 5.7 bags per cubic yard of concrete, and the slump ranged from 4.5 to 6.1 inches. The water content ranged from 6.3 to 7.1 gallons per bag for concretes prepared with the plain cements and from 5.4 to 6.3 gallons for the treated cements.

The cement content of the concretes in the fourth row ranged from 4.4 to 4.8 bags of cement per cubic yard, and the slumps were from 7.0 to 8.5 inches. This mix was leaner than would be recommended for highway construction but was included so that failures might occur in a reasonable length of time. The water content ranged from 8.7 to 9.3 gallons per bag for concretes prepared with the plain cements and from 6.9 to 8.6 for those prepared with the treated cements. As previously stated, the fine and coarse aggregates used in this row were from a different source than those used in rows 1, 2, and 3.

Table 4.—Concrete mix data for four rows of specimens

Cement		Water	Slump, concrete	Weight of plastic concrete	Air, measured	Cement	Water	Slump, concrete	Weight of plastic concrete	Air, measured
	ROW 1 [1]					ROW 2 [1]				
Identification	*Bags/cu. yd.*	*Gal./bag of cement*	*Inches*	*Lb./cu. ft.*	*Percent*	*Bags/cu. yd.*	*Gal./bag of cement*	*Inches*	*Lb./cu. ft.*	*Percent*
11	6.5	5.6	5.1	147.6	1.3	6.5	5.6	4.8	147.2	1.8
12	6.5	5.6	5.8	147.5	1.4	6.5	5.6	5.2	147.3	1.6
13	6.5	5.7	5.7	147.3	1.2	6.4	5.7	4.8	146.8	1.3
14	6.5	5.7	6.6	147.3	1.4	6.4	5.7	5.5	146.7	1.9
15	6.4	5.8	5.5	147.0	1.5	6.4	5.7	5.0	146.6	1.4
16	6.5	5.7	6.4	147.4	1.5	6.5	5.6	5.4	147.2	1.5
17	6.5	5.8	6.0	147.8	1.1	6.5	5.7	5.5	147.3	1.4
18	6.5	5.6	4.9	147.4	1.3	6.5	5.6	4.7	147.8	1.3
21	6.5	5.5	5.2	147.7	1.5	6.5	5.5	4.9	147.6	1.5
22	6.5	5.5	4.9	147.8	1.6	6.5	5.5	5.0	147.6	1.5
23	6.5	5.6	5.3	148.6	1.2	6.5	5.6	5.9	148.1	1.1
24	6.5	5.5	6.0	147.6	1.9	6.5	5.4	5.7	147.2	1.9
25	6.5	5.5	5.3	147.9	1.7	6.5	5.5	5.5	147.5	1.6
31	6.4	6.1	5.0	146.7	1.3	6.4	6.1	5.2	146.6	1.4
33	6.4	5.9	5.6	147.5	1.1	6.4	5.9	5.3	146.5	1.3
34	6.4	5.8	5.2	147.1	1.5	6.4	5.8	5.5	147.0	1.4
41	6.5	5.4	5.7	147.9	1.9	6.5	5.4	5.6	147.3	2.0
42	6.5	5.5	5.4	148.4	1.2	6.5	5.5	5.0	147.8	1.3
43	6.4	5.6	5.0	146.5	2.2	6.4	5.6	5.7	146.6	2.3
43 A	6.5	5.5	5.2	147.4	2.1	6.5	5.5	5.8	147.0	2.1
51	6.5	5.5	5.7	148.1	1.3	6.5	5.5	5.1	147.8	1.3
11 T	6.4	5.0	5.4	134.6	11.2	6.4	5.0	5.5	134.7	10.9
12 T	6.6	5.3	5.9	144.2	4.0	6.6	5.3	5.4	144.2	4.0
16 T	6.4	5.2	6.2	139.1	7.9	6.4	5.1	5.7	139.0	7.9
18 T	6.4	5.5	5.1	142.9	4.6	6.3	5.5	5.0	142.4	4.6
21 T	6.5	5.1	5.5	141.6	------	6.4	5.1	6.0	140.6	6.6
33 T	6.3	5.4	5.8	137.7	8.4	6.3	5.3	5.4	138.1	8.0
	ROW 3 [2]					ROW 4 [3]				
11	5.5	6.6	5.7	146.8	1.2	4.4	8.7	8.0	146.1	1.0
12	5.5	6.6	5.9	146.6	1.5	4.4	8.7	7.0	145.7	1.2
13	5.5	6.7	6.0	146.3	1.3	4.5	8.8	8.0	146.3	------
14	5.5	6.5	4.9	146.4	1.7	4.5	8.8	7.5	146.8	------
15	5.5	6.7	4.5	146.5	1.3	4.5	9.0	7.5	146.5	------
16	5.5	6.6	5.1	146.7	1.6	4.4	8.8	8.0	145.7	1.0
17	5.5	6.7	5.5	146.7	1.6	4.4	9.0	7.0	145.9	------
18	5.5	6.5	4.7	147.1	1.3	4.4	9.2	7.5	146.5	0.7
21	5.5	6.6	4.9	147.0	1.2	4.4	9.1	7.5	145.9	0.8
22	5.5	6.8	6.0	146.7	1.3	4.5	8.8	8.0	146.9	------
23	5.5	6.5	4.7	147.4	1.3	4.5	9.0	8.5	147.1	------
24	5.5	6.5	4.9	146.8	1.9	4.5	8.8	8.5	146.3	------
25	5.5	6.5	5.0	146.8	1.7	4.4	8.8	7.0	145.6	1.3
31	5.4	7.1	4.7	145.4	1.5	4.4	9.2	7.0	145.4	0.7
33	5.5	6.9	5.4	146.4	1.2	4.4	9.3	8.0	145.3	0.8
34	5.5	7.0	6.1	146.3	1.3	4.4	9.3	8.5	145.9	------
41	5.5	6.5	5.9	146.7	1.9	4.4	9.0	8.5	146.0	------
42	5.5	6.5	5.9	147.4	1.3	4.5	8.9	8.0	146.8	------
43	5.4	6.6	5.5	145.2	2.3	4.4	8.9	8.0	144.5	------
43 A	5.5	6.3	5.1	146.3	2.2	4.4	8.9	7.5	145.1	------
51	5.5	6.6	5.8	147.2	1.3	4.5	8.9	8.0	146.9	------
11 T	5.5	5.4	5.3	134.3	10.7	4.8	6.9	8.5	137.2	7.6
12 T	5.7	5.9	4.8	144.8	3.1	4.5	8.1	7.5	143.7	3.3
16 T	5.5	6.0	5.9	139.5	6.9	4.6	7.5	8.5	138.2	7.5
18 T	5.4	6.3	5.3	142.3	4.6	4.4	8.6	7.5	141.2	4.2
21 T	5.5	5.9	5.8	140.4	6.2	4.6	8.0	8.5	141.5	4.6
33 T	5.4	6.0	5.8	138.0	7.8	4.6	7.9	8.0	140.5	5.2

[1] Aggregates used: Potomac River sand and Potomac River gravel.
Proportions (dry weight):
Plain cement, 94-192-276.
Air-entraining cement (11T), 94-150-276.
(12T, 16T, 33T, 21T), 94-171-276.
(18T), 94-184-276.

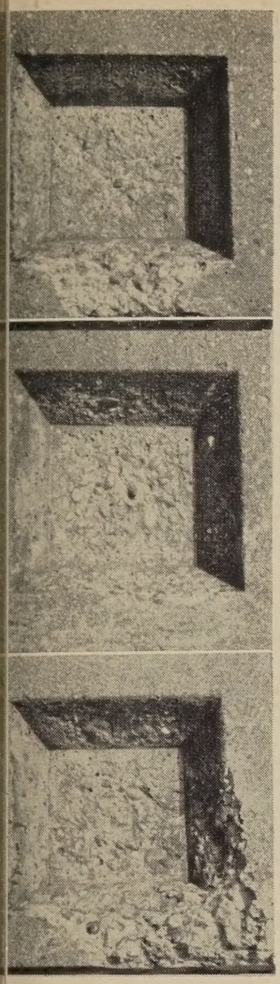
[2] Aggregates used: Potomac River sand and Potomac River gravel.
Proportions (dry weight):
Plain cement, 94-234-330.
Air-entraining cement (11T), 94-183-330.
(12T, 16T, 21T, 33T), 94-209-330.
(18T), 94-224-330.

[3] Aggregates used: White Marsh sand and White Ma gravel.
Proportions (dry weight):
Plain cement, 94-320-400.
Air-entraining cement (11T), 94-220-400.
(12T, 18T), 94-290-400.
(16T, 21T, 33T), 94-270-400.

Examination and Rating of Box Specimens

All box specimens were examined each year, generally during the summer months. Prior to an examination, the pea gravel and all loose particles of concrete were removed. The basin and all surfaces of the box specime were thoroughly washed.

The basins were examined, and the exte and depth of scaling on their slopes and fl were recorded. The boxes were then set o side, and their bottoms were inspected evidence of cracks through the floor of t basin. Such cracks were generally outlir by efflorescence, and they appeared in rad form on the bottom of the boxes. A typi



C 15—R6

C 18—R6

C 33—R7

ure 3.—Distressed concrete boxes in row ; cement (C), rating (R); made Jan. 1945, photographed Aug. 1961.

Table 5.—Ratings of outdoor exposure boxes, 1955–61 inclusive

Cement, type and number	Row 1				Row 2				Row 3				Row 4			
	1955	1958	1960	1961	1955	1958	1960	1961	1955	1958	1960	1961	1955	1958	1960	1961
I:																
11	1	1	1	1	2	3	3	3	4	5	[1]6	7	[2]6	8	8	8
12	1	1	1	1	2	3	3	3	3	3	[1]4	4	1	2	2	2
13	1	1	1	1	1	1	2	2	2	2	2	2	[1]7	8	8	9
14	1	1	1	1	1	1	1	1	1	1	1	2	3	[1]4	4	4
15	2	[1]3	5	6	3	4	[1]4	5	[1]6	8	8	8	[2]8	9	9	10
16	1	1	1	1	1	1	1	1	2	2	2	2	[2]3	4	4	5
17	2	2	3	3	1	1	1	1	2	3	3	[1]4	2	3	3	3
18	3	3	[1]6	6	4	4	[1]6	7	[1]6	9	9	9	[2]9	10	10	10
II:																
21	1	1	1	1	1	1	1	1	2	2	2	3	[2]3	5	5	5
22	1	1	1	1	1	1	2	2	1	2	2	2	[2]6	7	6	6
23	1	1	1	1	2	2	2	2	2	2	3	3	[2]3	4	5	5
24	1	1	1	1	1	1	1	1	2	2	2	3	1	1	2	2
25	1	1	1	1	1	1	1	1	2	2	2	2	[2]3	4	4	4
III:																
31	4	4	3	3	4	4	3	4	[1]6	7	7	7	[2]9	10	10	10
33	4	[1]5	7	7	4	4	[1]6	7	[1]6	7	9	9	[2]9	9	9	10
34	2	2	2	2	2	2	2	2	2	2	2	2	[2]8	8	9	9
IV:																
41	1	1	1	1	1	1	1	1	1	1	1	1	[1]4	5	4	4
42	1	1	1	1	1	1	1	1	5	4	4	4	[2]2	5	5	5
43	1	1	1	1	1	1	1	1	1	1	1	1	[2]2	[1]5	4	4
43A	1	1	1	1	1	1	1	1	1	1	1	1	[2]2	[1]3	3	3
V:																
51	2	2	2	2	1	1	1	1	2	2	2	3	[2]2	5	5	5
Treated:																
11T	1	1	1	1	1	4	[1]5	4	4	[1]5	5	5	1	1	1	2
12T	1	1	1	1	1	1	1	1	1	1	1	1	1	[1]3	4	4
16T	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1
18T	3	3	3	3	2	3	3	3	3	[1]4	4	4	2	[1]5	5	5
21T	1	1	1	1	1	1	2	2	2	2	3	2	1	1	1	1
33T	1	1	1	1	1	1	1	1	[1]5	5	5	5	1	1	2	2

[1] First evidence of leaking through concrete. [2] Leaking through concrete prior to 1955.

Rating *Condition of specimen*

1 Less than 10 percent light scaling in basin, no other defects.
2 5 to 50 percent light to moderate scaling in basin.
3 20 to 70 percent moderate scaling in basin.
4 40 to 90 percent moderate scaling in basin, plus slight radial cracks in bottom.
5 30 to 60 percent moderate to deep scaling in basin, plus radial cracks in bottom.
6 50 to 90 percent moderate to deep scaling in basin, plus radial cracks in bottom, plus few cracks in top and side surfaces.
7 50 to 90 percent moderate to deep scaling in basin, plus radial cracks in bottom, plus cracks or D-lines in top and side surfaces.
8 70 to 100 percent deep scaling in basin, plus radial cracks in bottom, plus numerous cracks or D-lines in top and side surfaces.
9 100 percent deep scaling in basin, plus radial cracks in bottom, plus top and side surfaces partly disintegrated.
10 100 percent deep scaling in basin, plus radial cracks in bottom, plus disintegration of top and side surfaces.

These descriptive examples are presented only for the purpose of illustration. Slightly different sets of distress conditions can result in the same rating. In terms of distress, a rating of 3 or less was considered to indicate superficial failure of the concrete; a rating of 4 or 5, significant failure; and a rating of more than 5, severe failure.

Each box was so placed in the exposure area that the metal identification tag was at the northeast corner. Examinations revealed that the eastern and southern surfaces showed, in general, more scaling than the other surfaces. The prevailing air currents were from the east and south.

Progressive Changes in Box Specimens

Prior to1951, no significant signs of incipient disintegration were noted in any of the box specimens. In 1951, an examination showed more than 10 square inches of scaling in the basins of the following listed boxes:

Row 1 (6½ bags, 5-inch slump)—Cements Nos. 33, 34.

Row 2 (6½ bags, 5-inch slump)—Cement No. 11T.

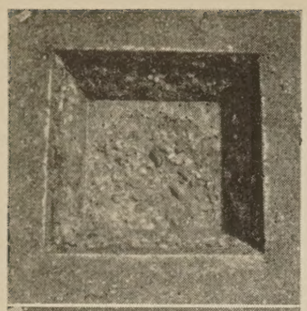
Row 3 (5½ bags, 5-inch slump)—Cements Nos. 15, 25, 51, 11T, 21T, 33T.

Row 4 (4½ bags, 8-inch slump)—Cements Nos. 11, 13, 18, 31, 33, 34, 41.

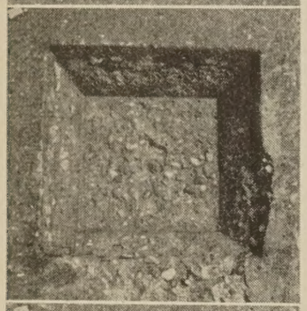
*mple of this condition is shown in figure 2. Le boxes were then placed in the normal rizontal position, and their top and side rfaces were examined for D-lines,[3] crazing, cking, scaling, or other sign of disintegra-in.

After an examination, the gravel was washed d again placed in the basins of the boxes. Le gravel at the time of examination was most free from mold or algae. Prior to 1955, te examination of the boxes consisted of ting scaling and signs of disintegration. om 1955 on, each box was given a numerical ting that, in the opinion of two examiners, presented its overall condition. The rating le was from 1 through 10, inclusive. A ting of 1 indicated less than 10 percent light aling in the basin and no other defects; whereas a rating of 10 indicated 100 percent ep scaling in the basin, radial cracks on the ttom, and disintegration of the top and sides the box. A typical case for each value of te rating scale is described as follows:

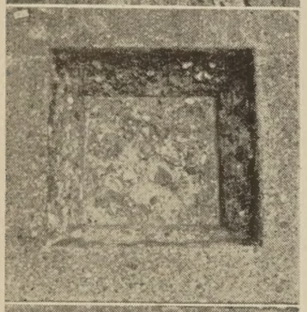
[3] D-lines, as defined by the Highway Research Board in its *Special Report 30, Pavement Condition Surveys*, are "A form of disintegration characterized by the successive formation of a series of fine cracks at rather close intervals paralleling joints, joints, and cracks, and usually curving across slab corners, the initial cracks forming very close to the slab edge and additional cracks progressively developing, each a little farther from the edge than the preceding one. Ordinarily the cracks are filled with a calcareous deposit."



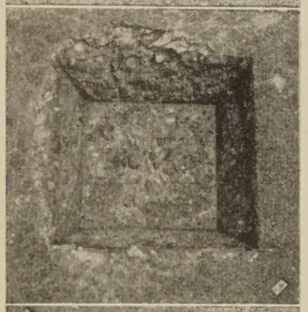
C 15—R5



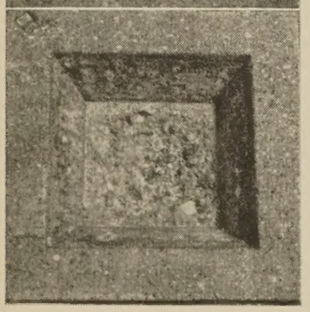
C 18—R7



C 31—R4

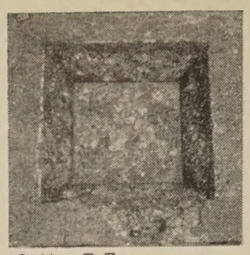


C 33—R7

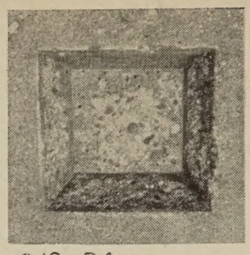


C 11T—R4

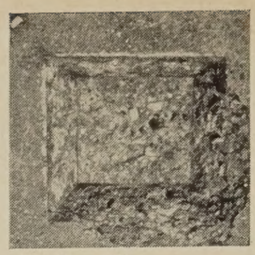
Figure 4.—Distressed concrete boxes in row 2; cement (C) rating (R); made June 1945; photographed Aug. 1961.



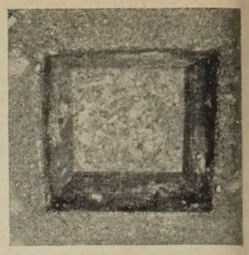
C 11—R 7



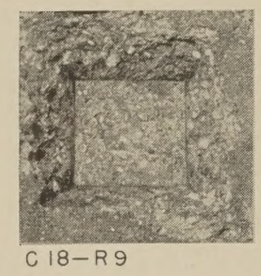
C 12—R4



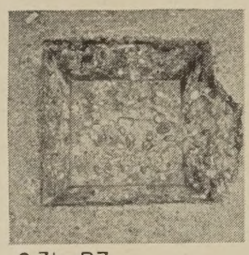
C 15—R8



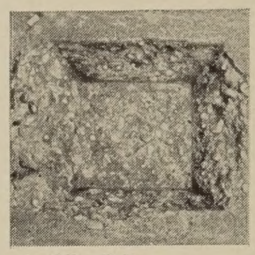
C 17—R4



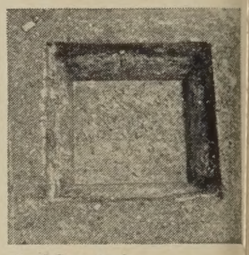
C 18—R9



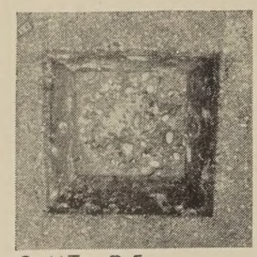
C 31—R7



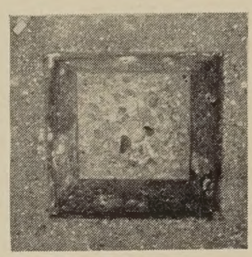
C 33—R9



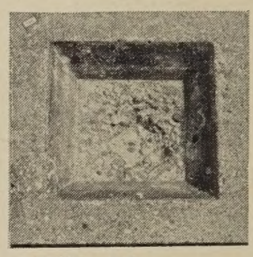
C 42—R4



C 11T—R 5



C 18T—R4



C 33T—R5

Figure 5.—Distressed concrete boxes in row 3; cement (C), rating (R); made Oct. 194 photographed Aug. 1961.

The 1951 examination of the bottoms of the boxes showed no evidence of leakage through the concrete.

In 1952, more than 10 square inches of scaling was noted in the basins of the following listed additional boxes:

Row 1—None.
Row 2—Cements Nos. 18, 31.
Row 3—Cements Nos. 12, 31, 33, 42, 51, 18T.
Row 4—Cements Nos. 15, 16, 21, 22, 23, 25, 43.

In addition, 13 boxes from row 4 showed evidence of leakage through the concrete. These boxes were made with cements Nos. 11, 15, 16, 18, 21, 22, 23, 25, 31, 33, 34, 42, and 51. None of the specimens from the other three rows showed evidence of leakage. The first time that significant signs of disintegration were observed in any of the specimens was during this 1952 examination.

The boxes in row 1 were made in January 1945, and 5 days after being placed in the exposure plot they were subjected to freezing. They had received approximately 290 cycles of freezing and thawing at the time of the 1952 examination. The cement content of the concrete ranged from 6.3 to 6.6 bags per cubic yard, and the slump was from 4.9 to 6.6 inches.

The boxes in row 2 were made in June 1945, and were first subjected to freezing after about 5 months. At the time of the 1952 examination, they had been exposed to approximately 280 cycles of freezing and thawing. As stated previously, the mixes and slumps of the concretes in this row were nearly identical to those of the companion concretes in row 1.

The boxes in row 3 were made in October 1945 and were approximately 40 days old when first subjected to freezing. They had received about 280 cycles of freezing and thawing at the time of the 1952 examination. The cement content in row 3 was one bag less than that in rows 1 and 2, and the slumps of the concretes averaged about the same a those in rows 1 and 2.

The boxes in row 4 were made in Septemb 1949 and were subjected to freezing aft about 2 months. They had been exposed 120 cycles of freezing and thawing at t time of the 1952 examination, when significa signs of incipient disintegration were note The concrete in this row contained 4.4 to 4 bags of cement per cubic yard, and the slun ranged from 7.0 to 8.5 inches.

Examinations in 1953 and 1954 reveal little progress in the disintegration of the b specimens. The ratings of the boxes from t 1955, 1958, 1960, and 1961 examinations a listed in table 5. This table also shows wh cracks forming on the bottom of the box were first noticed.

Results of the Latest Examinatio of Box Specimens

The results of the latest examination of t box specimens, made in May 1961, compr the principal part of this report. A summa of this examination is presented in table The table shows the percentages and dep of scaling on the slopes and floors of t basins, together with any major defects signs of disintegration on the bottom, si and top surfaces of the box specimens.

Row 1. Table 6 lists the condition of concrete boxes in row 1 according to the 19 examination. The boxes had been expo

o approximately 650 cycles of freezing and hawing. In general, they were still in excel-ent condition after more than 16 years of xposure. Only 3 of the 27 box specimens vere given a rating of more than 3. These hree boxes were prepared with cements Nos. 5, 18, and 33. Their condition is shown in igure 3. All had deep scaling in their basins, particularly on the basin floors. The bottoms f the boxes had radial cracks and the charac-eristic efflorescence. Areas of D-lines and fflorescence were also on their top and side urfaces, indicative of incipient disintegration. Each of these three cements contained more han 10 percent of tricalcium aluminate (C_3A).

Nineteen of the concrete boxes in row 1 howed no appreciable scaling or other defects nd were given a rating of 1. All of the oxes prepared with the Type II and IV ements were in this group. The box made vith treated cement No. 18T had deep scal-ng over 90 percent of the basin floor, but, ecause its other surfaces were free of defects, t was given a rating of 3. The air content f the concrete in this box specimen was 4.6 ercent, and the C_3A content of the cement vas 14 percent.

The average of the ratings for row 1 was .5 for the concrete boxes prepared with Type cements, 1.0 for those made with Type II, .0 for those made with Type III, 1.0 for hose made with Type IV, 2.0 for the one nade with Type V, and 1.3 for those made vith treated cements.

Row 2. The condition of the concrete boxes n row 2 are listed in table 6. The boxes had eceived 640 cycles of freezing and thawing at he time of the 1961 examination. Although f greater age before being subjected to freez-ng, the box specimens in row 2 were, on the vhole, scaled slightly more than those in row 1. The reason for this difference is not known. Fourteen of the box specimens in row 2 were given a rating of 1, as compared with 19 in ow 1. Five of the specimens were rated more han 3. These contained cements Nos. 15, 18, 31, 33, and 11T. The C_3A content of each of hese five cements was more than 10 percent. Box specimens in row 1 that were prepared vith cements Nos. 15, 18, and 33 were also ated more than 3.

The five specimens rated more than 3 howed deep scaling in their basins and evi-dence of incipient disintegration on their side nd top surfaces. Four of the five specimens howed radial cracks and efflorescence on heir bottoms. The condition of these box pecimens is shown in figure 4. The box prepared with the treated cement 11T, which ntrained 10.9 percent air in the concrete, was given a rating of 4. However, no tests were made to determine the size and spacing of the air voids in the hardened concrete. The 12 percent C_3A content for cement 11T might be a factor in causing the poor dura-bility of the concrete.

The average of the ratings for row 2 was 2.8 for the box specimens made with the Type I cements, 1.5 for those made with Type II, 4.3 for those made with Type III,

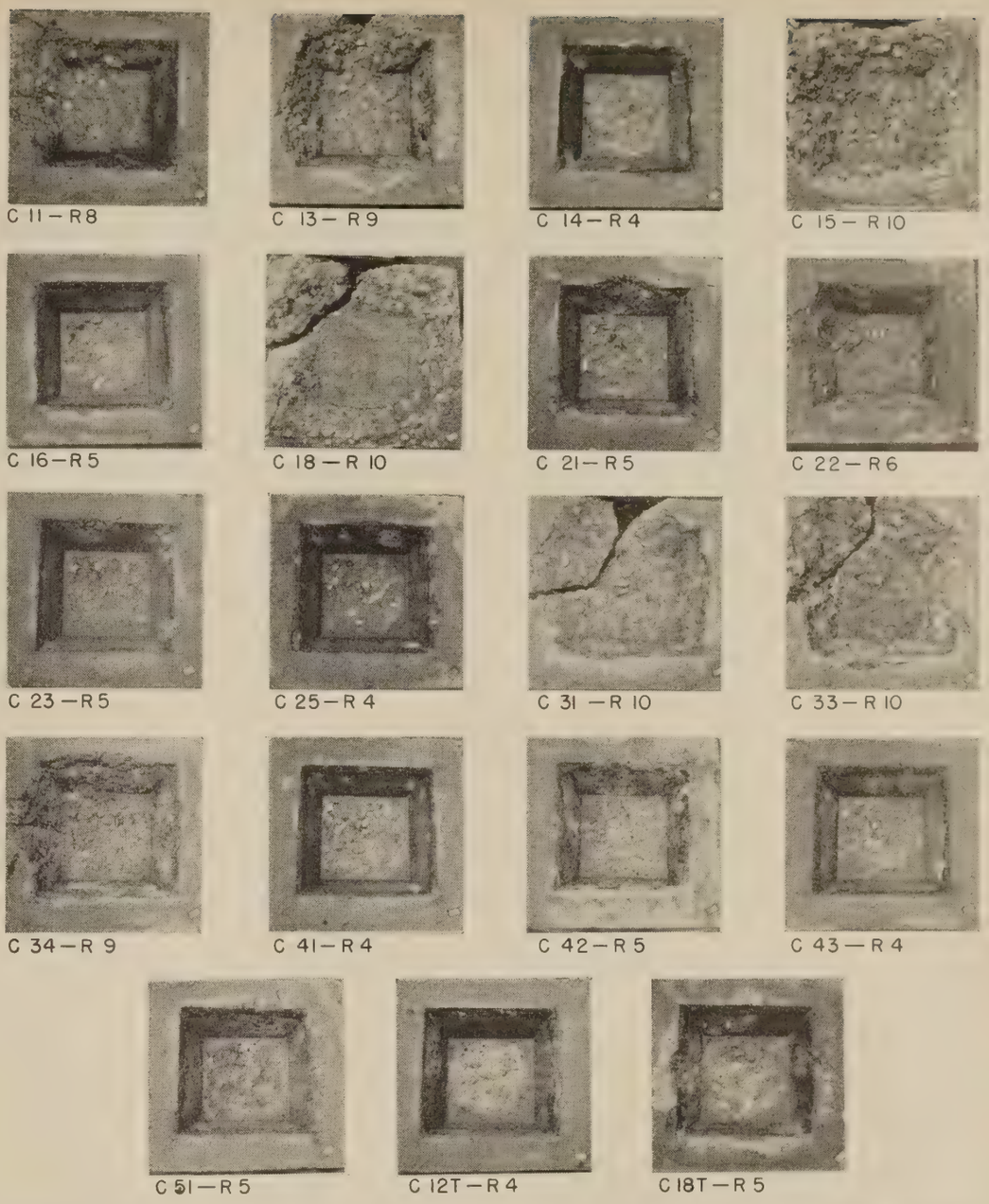


Figure 6.—Distressed concrete boxes in row 4; cement (C), rating (R); made Sept. 1949; photographed Aug. 1961.

1.0 for those made with Type IV, 1.0 for the one made with Type V, and 2.0 for those made with the treated cements.

Row 3. Table 6 summarizes the condition of the concrete boxes in row 3. Like those in row 2, they had received 640 cycles of freezing and thawing at the time of the 1961 examination. The specimens in row 3 were scaled considerably more than those in the first two rows. Only four of them were given a rating of 1. This group included three of the four Type IV cements and one of the six treated cements. Eleven of the 27 concrete boxes were rated more than 3. The condition of each is shown in figure 5.

The box specimens rated more than 3 were made with cements Nos. 11, 12, 15, 17, 18, 31, 33, 42, 11T, 18T, and 33T. All of these cements, except No. 42, had a C_3A content of more than 10 percent. All of the box specimens, except the one prepared with cement No. 42, had deep scaling over more than 40 percent of the surface area of the basin and had radial cracking and efflorescence on the bottoms of the boxes. The failure of the specimen made with cement No. 42 appeared to be structural. This concrete box had only moderate scaling over about 30 percent of its basin area. The bottom of the boxes had no sign of efflorescence, but it had D-lines around the outer edge of its bottom surface, as shown in figure 2.

Concrete prepared with three of the six treated cements had ratings of more than 3. These three cements, Nos. 11T, 18T, and 33T, had C_3A contents or more than 10 percent. The air contents of the concretes made with the above cements were 10.7, 4.6, and 7.8 percent, respectively, which indicates that air content alone did not ensure good durability for the conditions of exposure of the concrete boxes. In row 3, cement No. 12T was the only cement with C_3A content of more than 10 percent that produced concrete having good durability. The box specimen prepared with this cement had a rating of 1. The air content of the concrete was 3.1 percent.

Table 6.—Conditions and ratings of outdoor exposure boxes

Cement, type and number	Scaling in basin [1]		Box specimen [2]		
	Sides	Floor	Bottom	Sides	Top
ROW 1 [3]					
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
I:					
11	5 L	None	No action	No action	No action
12	10 L	do	do	do	do
13	2 L	do	do	do	do
14	None	do	do	do	do
15	50 D	70 M	8-in. dia., R.C., EFF.	50 D-lines, EFF.	50 D-lines, EFF.
16	5 L	None	No action	No action	No action
17	60 M	60 M	do	do	do
18	80 M	90 D	4-in. dia., R.C., EFF.	75 D-lines, EFF.	75 D-lines, EFF.
II:					
21	None	None	No action	No action	No action
22	do	do	do	do	do
23	1 L	do	do	do	do
24	None	do	do	do	do
25	do	do	do	do	do
III:					
31	75 M	90 M	No action	do	do
33	80 D	80 D	15-in. dia., R.C., EFF.	70 D-lines, EFF.	70 D-lines, EFF.
34	20 M	80 M	No action	No action	No action
IV:					
41	None	None	do	do	do
42	do	do	do	do	do
43	do	do	do	do	do
43A	do	do	do	do	do
V:					
51	do	100 L	do	do	do
Treated:					
11T	do	None	do	do	do
12T	do	do	do	do	do
16T	do	do	5L	do	do
18T	do	90 D	No action	do	do
21T	do	None	do	do	do
33T	5 M	do	do	do	do

Scaling in basin [1]		Box specimens [2]		
Sides	Floor	Bottom	Sides	Top
ROW 2 [4]				
Percent	*Percent*	*Percent*	*Percent*	*Percent*
50 M	70 M	No action	Several cracks	Several cracks.
60 M	50 M	do	No action	No action.
15 L	10 L	do	do	Do.
None	None	do	do	Do.
80 M	90 M	6-in. dia., R.C., EFF.	do	10 D-lines, EFF.
5 M	None	No action	do	No action.
None	do	do	do	Do.
90 D	100 D	9-in. dia., R.C., EFF.	40 D-lines, EFF.	50 D-lines, EFF.
3 L	None	No action	No action	No action.
10 L	40 L	do	do	Do.
20 L	60 L	do	do	Do.
10 L	None	do	do	Do.
None	do	do	do	Do.
90 M	90 M	do	5 D-lines, EFF.	15 D-lines, EFF.
90 D	80 M	12-in. dia., R.C.	70 D-lines, EFF.	90 D-lines, EFF.
25 L	80 M	No action	No action	No action.
None	None	do	do	Do.
do	do	do	do	Do.
do	do	do	do	Do.
do	do	do	do	Do.
do	90 D	8-in. dia., R.C., EFF.	Several cracks	Do.
do	None	No action	No action	Do.
do	do	do	do	Do.
5 L	90 D	do	do	Do.
10 L	40 L	do	do	Do.
2 M	None	do	do	Do.

ROW 3 [5]					
I:					
11	90 D	90 D	9-in. dia., R.C., EFF.	80 D-lines, EFF.	70 --lines, EFF.
12	70 M	70 D	4-in. dia., R.C.	No action	No action
13	40 L	40 L	No action	do	do
14	25 L	None	do	do	do
15	100 D	90 D	15-in. dia., R.C., EEF.	80 D-lines, EFF.	80 D-lines, EFF.
16	2 L	80 M	No action	No action	No action
17	15 M	80 D	12-in. dia., R.C., EFF.	do	do
18	100 D	100 D	15-in. dia., R.C., EFF.	100 D-lines, EFF.	80 Disintegrated.
II:					
21	15 M	80 M	No action	No action	No action
22	45 L	None	do	do	do
23	20 L	70 M	do	do	do
24	30 M	70 M	do	do	do
25	10 L	70 M	do	do	do
III:					
31	90 D	90 D	12-in. dia., R.C., EFF.	30 D-lines, EFF.	50 Disintegrated.
33	100 D	75 D	15-in. dia., R.C.	100 D-lines, EFF.	80 Disintegrated.
34	70 M	None	No action	No action	No action
IV:					
41	None	None	No action	No action	No action
42	25 M	40 M	20-percent D-lines.	30 D-lines	30 D-lines, EFF.
43	None	None	No action	No action	No action
43A	do	do	do	do	do
V:					
51	25 L	100 M	do	do	do
Treated:					
11T	10 M	90 D	8-in. dia., R.C., EFF.	do	do
12T	2 L	None	No action	do	do
16T	None	80 M	do	do	do
18T	5 L	80 D	4-in. dia., R.C.	do	do
21T	None	80 D	No action	do	do
33T	do	90 D	12-in. dia., R.C, EFF.	do	do

ROW 4 [6]					
70 D	90 D	15-in. dia., R.C., EFF.	30 D-lines, EFF.	20 Disintegrated. 70 D-lines, EFF.
40 M	None	No action	No action	Light D-lines.
90 D	100 D	16-in. dia., R.C., EFF.	100 D-lines, EFF.	40 Disintegrated. 100 D-lines, EFF.
5 M	80 M	10-in. dia., R.C	No action	Light D-lines.
		Disintegrated		
None	80 D	16-in. dia., R.C., EFF.	1 crack thru	1 crack thru.
50 D	None	No action	No action	30 D-lines, EFF.
		Disintegrated		
30 M	80 D	16-in. dia., R.C., EFF.	1 crack thru	20 D-lines, EFF.
60 D	90 D	16-in. dia., R.C., EFF.	15D-lines, EFF.	10 Disintegrated. 40 D-lines, EFF.
15 M	75 D	16-in. dia., R.C., EFF.	30 D-lines, EFF.	35 D-lines, EFF.
15 M	None	No action	No action	No action.
10 L	75 D	12-in. dia., R.C., EFF.	do	Do.
		Disintegrated		
		Disintegrated		
100 D	100 D	16-in. dia., R.C., EFF.	60 D-lines, EFF.	85 D-lines, EFF.
3 L	90 D	12-in. dia., R.C., EFF.	1 crack thru	Light D-lines.
60 M	75 M	12-in. dia., R.C., EFF.	1 crack thru	10 D-lines, EFF.
10 L	75 D	10-in. dia., R.C., EFF.	No action	Light D-lines.
40 L	75 M	2-in. dia., R.C	do	Do.
40 M	90 M	12-in. dia., R.C., EFF.	1 crack thru	15 D-lines, EFF.
10 L	None	No action	No action	Light D-lines.
5 M	75 D	12-in. dia., R.C., EFF.	do	Do.
None	None	No action	do	No action.
50 M	90 D	10-in. dia., R.C., EFF.	1 crack thru	1 crack thru.
None	None	No action	No action	Light D-lines.
15 M	do	do	do	Do.

[1] D, deep; M, moderate; and L, light.
[2] R.C., radial cracking; and EFF, efflorescence.
[3] Boxes made January 1945; rated May 1961. Mix: Cement factor 6.3—6.6 bags, slump 4.9—6.6 inches, water 5.0—6.1 gallons.
[4] Boxes made June 1945, rated May 1961. Mix: Cement factor 6.3—6.6 bags, slump 4.7—6.0 inches, water 5.0—6.1 gallons.
[5] Boxes made October 1945, rated May 1961. Mix: Cement factor 5.4—5.7 bags, slump 4.5—6.1 inches, water 5.4—7.1 gallons.
[6] Boxes made September 1949, rated May 1961. Mix: Cement factor 4.4—4.8 bags, slump 7.0—8.5 inches, water 6.9—9.3 gallons.

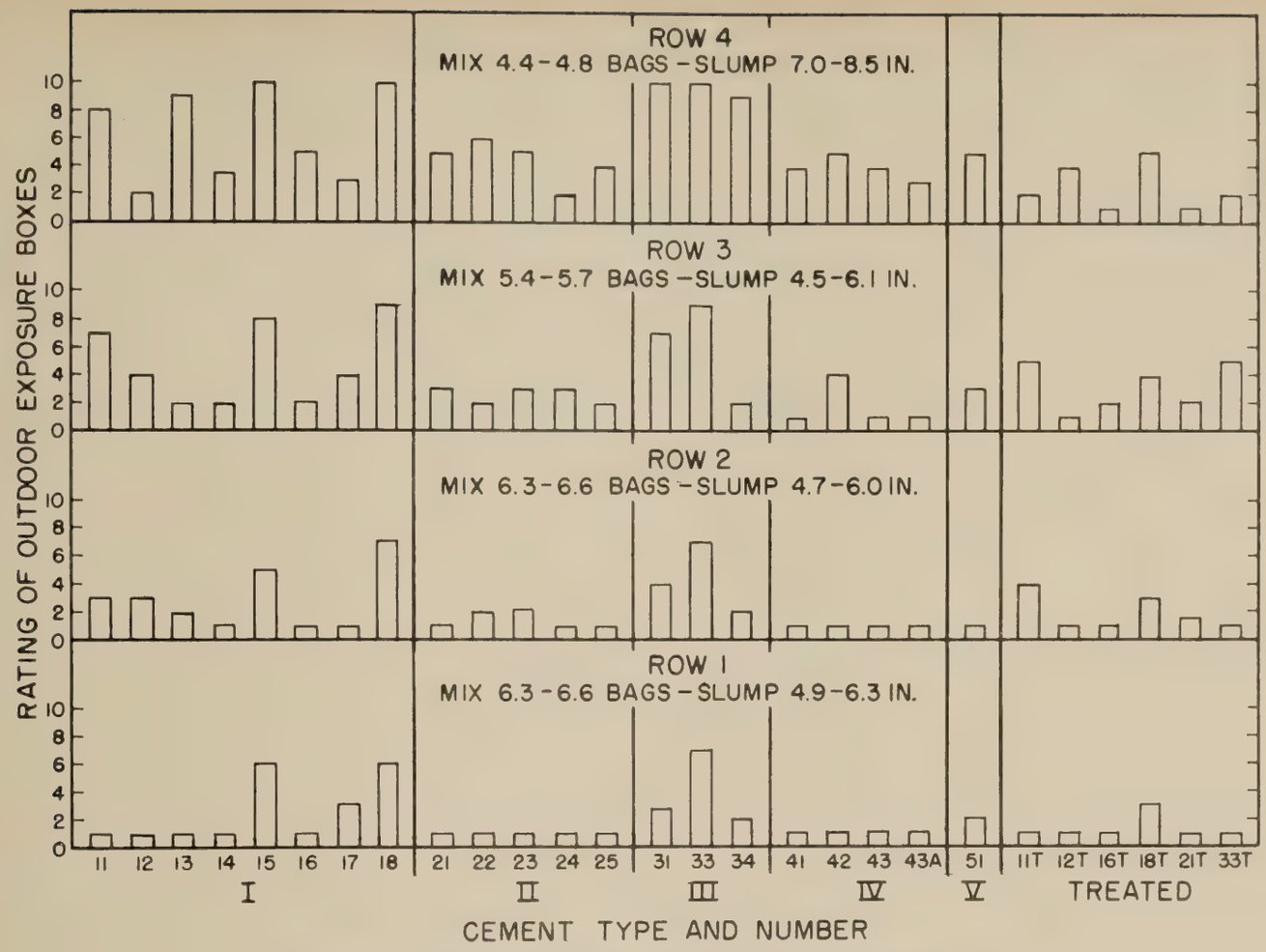


Figure 7.—Visual ratings of outdoor exposure boxes, May 1961.

Average ratings for the box specimens in ow 3 were 4.8 for those made with Type I ements, 2.6 for those made with Type II, .0 for those made with Type III, 1.8 for hose made with Type IV, 3.0 for that made ith Type V, and 3.2 for those made with the reated cements.

Row 4. The condition of the concrete oxes in row 4 are presented in table 6. s mentioned previously, the concrete in ow 4 was prepared with aggregates from a ifferent source than the concretes in the ther three rows. The box specimens in ow 4 had been exposed to 480 cycles of reezing and thawing at the time of the 1961 xamination.

As might be expected, the somewhat low ement content, high slump concrete in row 4 eveloped considerably more distress than the oncretes in the other three rows. Only two f the box specimens in this row, the ones repared with treated cements, Nos. 16T nd 21T, were given a rating of 1. The four ox specimens prepared with cements Nos. 12, 4, 11T, and 33T were rated at 2. Oddly, he specimen prepared with cement No. 11T, hich was rated 4 and 5 in rows 2 and 3, was ne of those rated as 2. Nineteen of the 27 ox specimens in this row were given ratings of more than 3. No consistent relation existed between the ratings of these specimens and the C_3A content of the cements. The four concrete boxes that were given a rating of 10—Nos. 15, 18, 31, and 33—contained cements with C_3A contents of more than 10 percent. However, of the six concrete boxes that had a rating of 2 or less, three were prepared with cements having a C_3A content of more than 10 percent. Figure 6 shows the condition of the concrete boxes having a rating of more than 3.

For this row, the water content of the concrete appeared to have more effect on the durability than the chemical composition of the cement.

The average of the ratings for concrete in row 4 was 6.4 for the box specimens made with Type I cements, 4.2 for those made with Type II, 9.7 for those made with Type III, 4.0 for those made with Type IV, 5.0 for that made with Type V, and 2.5 for those made with the treated cements. The box specimens in row 4 prepared with the treated cements showed, in general, much better durability than those prepared with the corresponding untreated cements. This condition was not so pronounced for the other three rows. The beneficial effects of entrained air were more apparent for the lean concrete.

Table 7.—Summary of ratings of outdoor exposure boxes, rated May 1961

Cement, type and number	Rating for rows—			
	1	2	3	4
I:				
11	1	3	7	8
12	1	3	4	2
13	1	2	2	9
14	1	1	2	4
15	6	5	8	10
16	1	1	2	5
17	3	1	4	3
18	6	7	9	10
II:				
21	1	1	3	5
22	1	2	2	6
23	1	2	3	5
24	1	1	3	2
25	1	1	2	4
III:				
31	3	4	7	10
33	7	7	9	10
34	2	2	2	9
IV:				
41	1	1	1	4
42	1	1	4	5
43	1	1	1	4
43A	1	1	1	3
V:				
51	2	1	3	5
Treated:				
11T	1	4	5	2
12T	1	1	1	4
16T	1	1	2	1
18T	3	3	4	5
21T	1	2	2	1
33T	1	1	5	2

Table 8.—Change in N^2 in beams after 12 to 16 years of exposure[1]

Cement, type and number	Percent increase or decrease in N^2, in rows—			
	1	2	3	4
I:				
11	−11.0	−6.1	−14.5	−20.3
12	−7.2	−6.7	−6.7	−12.9
13	8.4	7.6	7.5	3.8
14	−10.5	3.3	−1.6	0.9
15	−7.2	3.5	2.2	[2] −46.1
16	1.7	3.8	3.3	6.9
17	−5.1	−1.8	−2.5	−8.2
18	1.3	2.9	0.3	[2] −51.8
Average	−3.7	0.8	−1.5	−16.0
II:				
21	10.5	−5.0	13.0	23.4
22	10.4	2.4	5.0	−10.4
23	10.4	5.2	7.2	−1.0
24	6.2	1.4	2.7	2.1
25	14.7	10.9	19.6	10.5
Average	10.4	3.0	9.5	4.9
III:				
31	−8.7	−5.1	−9.2	[2] −58.4
33	−6.6	0.5	−18.4	[2] −34.3
34	−1.0	1.8	4.9	[2] −45.3
Average	−5.4	−0.9	−7.6	−46.0
IV:				
41	8.3	8.7	23.6	20.5
42	17.3	18.9	37.4	34.4
43	9.8	5.5	12.5	18.4
43A	18.0	19.2	22.2	27.1
Average	13.4	13.1	23.9	25.1
V:				
51	13.4	13.9	19.3	0.6
Treated:				
11T	−15.7	−13.8	−6.5	8.1
12T	−5.8	−7.9	−8.4	−9.1
16T	1.9	2.5	2.5	10.5
18T	−2.0	−3.1	0.6	3.4
21T	7.5	6.0	12.6	21.5
33T	−0.6	4.1	1.6	7.0
Average	−2.4	−2.0	0.5	6.9

[1] Each percent is the average of tests on three 3- x 4- x 16-inch beams.
[2] Beams showed numerous cracks.

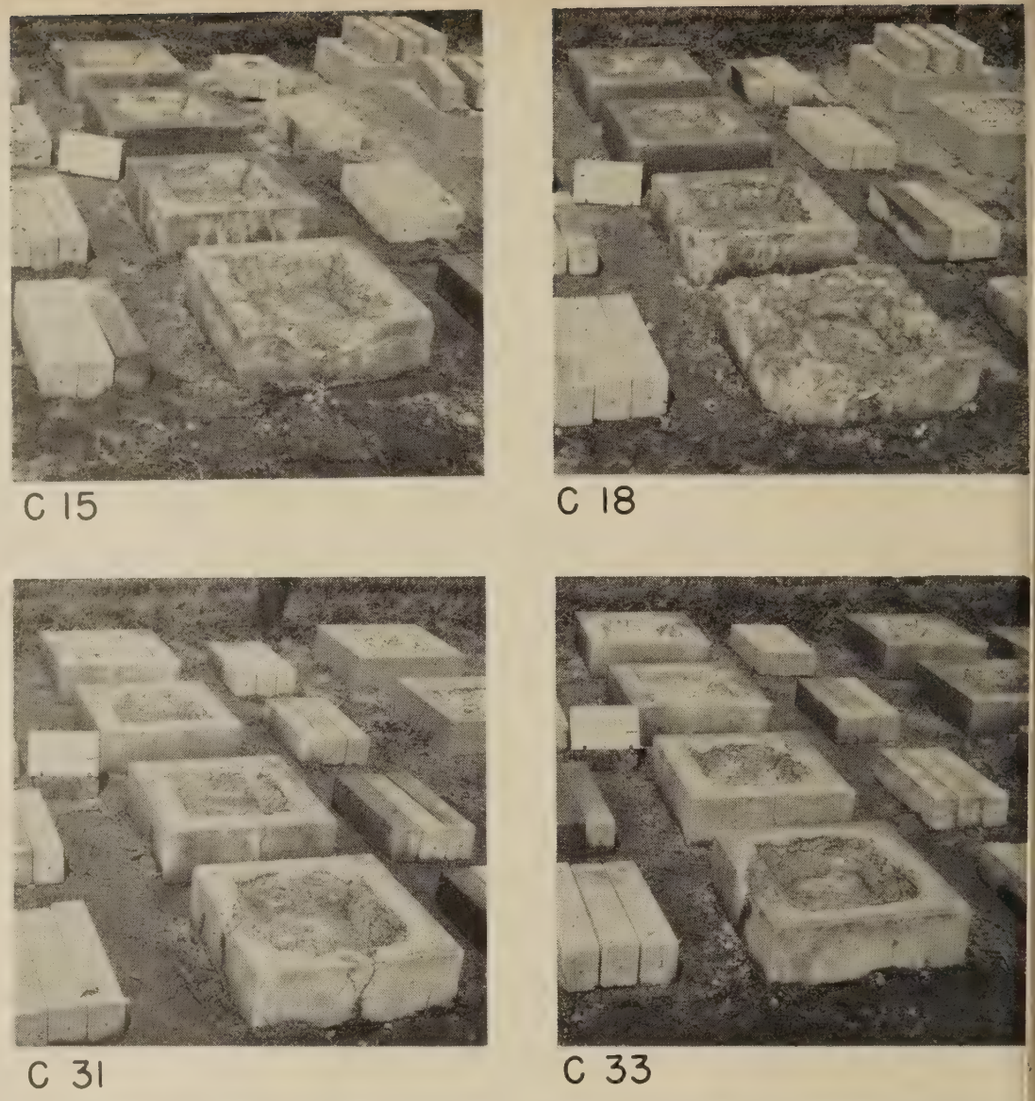


Figure 8.—Concrete boxes made with cements (C) having the poorest durability

Summary of All Four Rows

The ratings of the individual concrete boxes at the time of the last inspection are listed in table 7 and are shown in figure 7. Overall, the concretes prepared with Type III cements showed the poorest resistance to natural weathering. However, the concrete boxes prepared with cement No. 34, Type III, had good durability in all but the fourth row. The concrete containing the Type I cements had the next poorest resistance to natural weathering. No appreciable difference in overall durability was noted between the concretes made with cement Types II, IV, V, and the treated cements.

The concrete boxes prepared with cements Nos. 15, 18, 31, and 33 had the poorest durability. The condition for all four rows of the box specimens prepared with these cements is shown in figure 8. These four cements had C_3A contents of more than 10 percent. Conversely, the best overall ratings were given the concrete boxes prepared with cements Nos. 24, 43, 43A, 12T, 16T, and 21T. With the exception of No. 12T, all of these cements had a low C_3A content. In general, the concrete boxes made with the cements having a high C_3A content had the poorest durability. The exceptions were the concrete boxes prepared with cements Nos. 12, 17, and 12T. The durability of the concrete boxes prepared with cements Nos. 12 and 17 was poor only for row 3.

Fifteen of the 24 box specimens made with treated cement had better (lower) ratings than those prepared with the corresponding untreated cement from the same plant, 6 had equal ratings, and only 3 had poorer ratings. The treated cements showed to best advantage in row 4 specimens, which contained low-cement, high-slump concrete. The poorest durability for the concrete containing the treated cements was for the box specimens containing cements Nos. 11T, 18T, and 33T, each of which had a high C_3A content. The concrete made with cement No. 12T, which also had a high C_3A content, had good durability.

The air content for the concretes prepared with the treated cements Nos. 11T, 16T, and 33T were high; for the concretes prepared with treated cement No. 21T, it was moderate; and for cements Nos. 12T and 18T, it was low. For the conditions of exposure, the durability of the concretes made with the treated cements appeared to have been influenced by the chemical composition of the cement as well as the air content of the concrete.

Results of Tests on Beam Specimen

The three beams for each mix, made fro the same batches of concrete as the box were placed in the exposure plot and mo cured for 28 days, and were examined at t same time as the boxes. Determinatio of length and sonic modulus were ma The results of these determinations w compared with results of similar det minations made just before the specim were placed in the exposure plot. To mi mize the effects of moisture and temperatu the beams were brought into the laborat and stored in water, at a temperature of ° F., for 5 to 7 days prior to the perio determinations.

Table 8 data show the changes in the sc moduli (N^2) that developed in the be from the time of the initial readings until time of the 1961 examination. The d indicate only a very general correlation e tween the loss of N^2 for the beams and condition rating that was given compar boxes. Decreases and increases in N^2 w about evenly divided among the beams m from the same batch of concrete as the boxes that were assigned a rating of n than 3 in the 1961 examination. Howeve decrease in N^2 in the beams was noted i

Table 9.—Change in length of beams after 12 to 16 years of exposure[1]

Cement, type and number	Percent increase or decrease in length, in rows—			
	1	2	3	4
I:				
11	0.140	0.068	0.099	0.089
12	.074	.028	.026	.032
13	−.001	−.006	−.021	−.001
14	.054	.009	−.002	−.006
15	.065	.008	.008	[2].208
16	.011	−.004	−.014	−.004
17	.011	.007	−.021	.008
18	.049	.021	.032	[2].369
Average	.050	.016	.013	.087
II:				
21	−0.009	−0.005	−0.024	−0.002
22	.004	.006	−.012	.022
23	−.009	−.012	−.086	−.006
24	.020	−.005	−.018	.004
25	.013	−.001	−.025	.006
Average	.004	−.003	−.033	.005
III:				
31	0.133	0.081	0.032	[2]0.259
33	.101	.063	.062	[2].163
34	.036	.019	−.023	[2].187
Average	.090	.054	.024	.203
IV:				
41	0.001	−0.002	−0.022	0.007
42	−.011	−.014	−.033	.009
43	−.003	−.013	−.029	.004
43A	.001	−.017	−.029	−.004
Average	−.003	−.012	−.028	.004
V:				
51	−0.008	−0.015	−0.029	0.026
Treated:				
11T	0.069	0.039	0.010	0.024
12T	.029	.011	.066	.030
16T	−.008	−.009	−.027	−.017
18T	.034	.001	−.002	.022
21T	−.008	−.010	−.069	−.002
33T	.029	.002	−.007	.010
Average	.024	.006	−.015	.011

[1] Each percent is the average of tests on three 3- x 4- x 6-inch beams.
[2] Beams showed numerous cracks.

percent of all of the specimens made with Types I and III cements. The boxes prepared with these two types of cement had the poorest overall ratings. An increase in N^2 was noted in more than 95 percent of the beams prepared with Types II, IV, and V and in 60 percent of those prepared with the treated cements.

The groups of beams prepared with the lean mix (4½ bags per cubic yard) and cement Types I and III showed the greatest loss in N^2. The five sets of beams prepared with cements Nos. 15, 18, 31, 33, and 34, had an average loss in N^2 of more than 30 percent at the time of the 1961 examination. All of the cements, except No. 34, had high C_3A contents. Numerous cracks had occurred in these beams. Their corresponding boxes were rated either 9 or 10 and were considered to be disintegrated. However, five sets of the lean-mix beams showed an average increase in N^2 of more than 20 percent. These beams were made with cements Nos. 21, 41, 42, 43A, and 21T. The corresponding boxes were rated 5, 4, 5, 3, and 1, respectively.

The lack of correlation between the two methods of determining resistance to weathering is believed to be due, in part, to (1) differences in the strength-gaining characteristics of concretes made with the different cements and (2) differences in moisture conditions caused by the basins of the boxes being kept full of water. Because of the latter conditions, large percentages of the concrete in the box specimens were sound, except for scaling of the floors and the slopes of the basins and radial cracks in the bottoms.

Table 9 lists the changes in length of the beams between initial readings and the 1961 examination. An analysis of this data indicates only a very general relation between the changes in length of the beams and the condition rating of comparable boxes. The results are similar to those obtained from tests for changes in sonic moduli. The beams prepared with the Types I and III cements had the greatest increases in length. The beams prepared with the Types II, IV, V, and the treated cements had little or no increase in length. The five sets of beams that had a loss in N^2 of more than 30 percent also had expansion of more than 0.15 percent. The same reasons for lack of correlation between the loss in N^2 of the beams and the condition rating of the boxes apply to length change.

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139 Million Drivers in 1980

Reported by E. M. COPE, Chief, Highway Statistics Division, and ARLENE R. MUNDY, Economist Office of Planning

BY THE HIGHWAY STATISTICS DIVISION BUREAU OF PUBLIC ROADS

Knowledge of the numbers, ages, and sex of licensed drivers is useful to public agencies in planning, research, making administrative decisions, and in formulating and carrying out safety programs. It is also useful to both Government and industry in forecasting, and to the latter in market research. Although requirements for obtaining driver licenses vary among the States, and the statistics concerning the numbers of drivers' licenses vary in completeness and significance, the information now available can be expanded to useful totals. Some of the States know how many drivers they have licensed; a few have made summaries by sex or age groups. Selected data from the States are presented, and on the basis of these and other information, the numbers of male and female drivers licensed are estimated separately for each State. Estimates of the sex and age grouping of licensed drivers are also given for the United States as a whole. It is forecast that the number of drivers' licenses will reach 125 million by 1975, and 139 million by 1980.

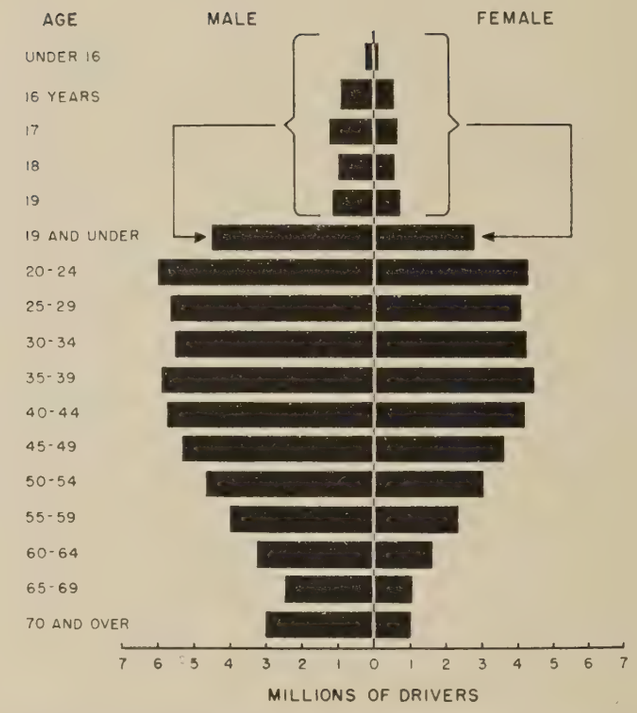

Figure 1.—Estimated number of licensed drivers, by age and sex, 1963.

139 Million Drivers in 1980

JUST 16 YEARS from now, in 1980, there will be 139 million licensed drivers of vehicles in the United States. There are already, in 1964, about 95 million licenses held by the persons who drive the approximately 85 million automobiles, trucks, and buses now registered. These drivers are the object of an almost endless barrage of advice, suggestions, admonitions, and beckonings, but surprisingly little is known about them.

Although all States require vital information, such as age and sex, to be stated on the application for a driver's license, only a few States have recognized and extracted these data as valuable aids in analyses of accident exposure and rates, the formulation and direction of highway safety programs, or the many other uses to which such data could be applied. Where it is available, data on the sex and age distribution of vehicle drivers is also a useful source of information for social and economic

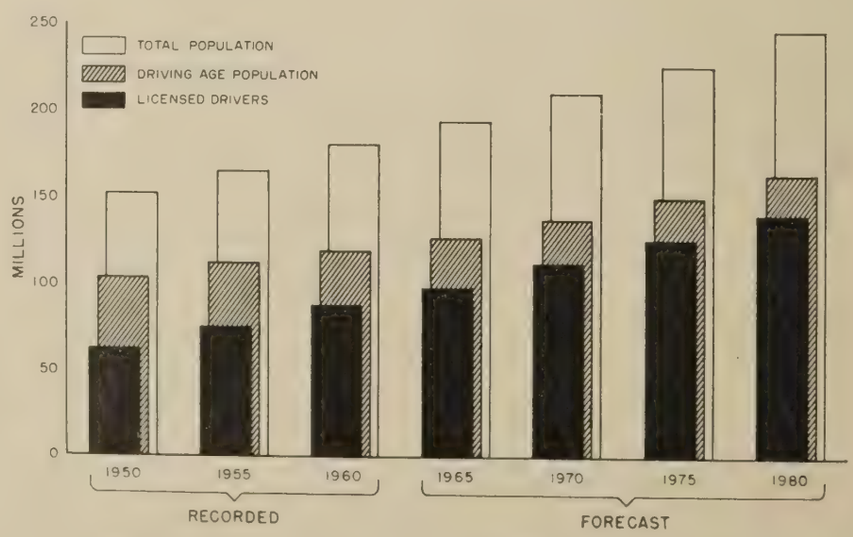

Figure 2.—Comparison of numbers of licensed drivers with total population and driving age population, 1950–80.

Table 1.—Administration and terms of state operators' and chauffeurs' licenses, Jan. 1, 1964

State	Office of issue	Learner's permit		Operator's license					Chauffeur's license		
						Minimum age					
						Unlimited operation except		Restricted operation for minors	Motor scooter or motorcycle		
		Length of term [1]	Minimum age [2]	Length of term (years)	Renewal date	[3]	[4]			Length of term (years)	Renewal date	Minimum age [2]
Alabama	Driver License Division, Dept. of Public Safety.	1 month	15	2	Birthday	16	-----	-----	14	-----	-----	-----
Alaska	Dept. of Public Safety	60 days	14	3	Birthday	18	*16	-----	[5] 13	[8] 1	Sept. 2	18
Arizona	Motor Vehicle Div., Highway Dept.	5 months*	15 yr., 7 mo.	3	Birthday	18	*16	-----	----	2	Birthday	18–21
Arkansas	Motor Vehicle Div., Revenue Dept.	60 days	14	1	Jan. 1	18	*14	-----	13	1	Jan. 1	18–21
California	Div. of Drivers Licenses, Dept. of Motor Vehicles.	6 months	15½	3 and 5	Birthday	16	-----	14	----	(6)	-----	-----
Colorado	Motor Vehicle Div., Dept. of Revenue.	5 months	15½–16	3	Birthday	17	16	-----	[5] 14	3	Birthday	17
Connecticut	Div. of Registry, Dept. of Motor Vehicles.	-----	-----	2	Birth month	21	16	-----	----	1	May 1	21
Delaware	Motor Vehicle Dept., Highway Commission.	60 days	16	[7] 2	Birthday	16	-----	-----	----	[7] 2	Birthday	18
Florida	Drivers License Div., Dept. of Public Safety.	2 years	14	2	Birth month	18	*16	*14	----	2	Birth month	18
Georgia	Drivers License Div., Dept. of Public Safety.	1 year	15	1 or 5	Birthday	16	-----	-----	----	1 or 5	Birthday	18
Hawaii	County Police Dept	60 days*	15	Indefinite	-----	20	*15	-----	15	1	Issuance	18–21
Idaho	Motor Vehicle Div., Dept. of Law Enforcement.	120 days	16	2	Birthday	16	-----	14	----	1	Birthday	18
Illinois	Driver License and Safety Responsibility Div., Motor Vehicle Dept.	6 months	15–16	3	Birthday	18	*16	*15	----	1	Issuance	18–21
Indiana	Drivers Licensing, Bur. of Motor Vehicles.	1 year*	15–16	2	Birth month	18	*16	*15	----	1	Birth month	18–21
Iowa	Safety Responsibility Div., Dept. of Public Safety.	2 years	14	2	Birthday	16	-----	14	----	1	Birthday	18
Kansas	Driver License Div., Motor Vehicle Dept.	2 months	14	2	Birthday	16	-----	14	14	2	Birthday	16–18
Kentucky	Div. of Driver Licensing, Dept. of Public Safety.	2 months	16	2	Birth month	18	*16	-----	----	1	Jan. 1	18–21
Louisiana	Driver License Div., Dept. of Public Safety.	2 years	15	2	Birthday	15	-----	-----	14	1	Issuance	18
Maine	Motor Vehicle Dept., Dept. of State.	1 year	15–17	2	Birthday	18	*17	*15	17	-----	-----	-----
Maryland	Dept. of Motor Vehicles	60 days*	16	2	Birth month	21	*16	-----	16	2	Issuance	16
Massachusetts	Registry of Motor Vehicles	6 months	16–18	2	Birthday	18	-----	*16	----	[5] 1	Issuance	21
Michigan	Div. of Driver and Vehicle Services, Dept. of State.	60 days	16	3	Birthday	18	*16	*14	15	1	Issuance	18
Minnesota	Drivers License Div., Dept. of Highways.	6 months	15	4	Birthday	21	*16	-----	[5] 15	1	Birthday	18
Mississippi	Drivers License Div., Dept. of Public Safety.	60 days	15	1 or 2	Issuance	15	-----	-----	----	1 or 2	Issuance	17
Missouri	Driver's License Unit, Dept. of Revenue.	60 days	15–16	3	Issuance	16	-----	-----	----	1	Issuance	18–21
Montana	Highway Patrol	6 months*	13–15	2	Birthday	21	*15	*13	----	2	Birthday	18–21
Nebraska	Driver's License and Safety Equipment, Dept. of Motor Vehicles.	1 year	15	2	Sept. 1 odd year.	20	16	-----	----	-----	-----	-----
Nevada	Drivers License Div., Dept. of Motor Vehicles.	6 months	15½	[9] 5	Birthday	18	*16	14	[5] 14	5	Birthday	18
New Hampshire	Div. of Motor Vehicles, Dept of Safety.	School term.	15–16	2	Birthday	16	-----	15	16	[10] 2	Birthday	18
New Jersey	Licensing Service, Motor Vehicle Div., Dept. of Law and Public Safety.	2 months*	17	1 or 3	Issuance	17	-----	16	17	(11)	Indefinite	21
New Mexico	Drivers Service Div., Dept. of Motor Vehicles.	2 months	14–16	2	Birth month	18	16	15	13	1	Birth month	18
New York	Dept. of Motor Vehicles	6 months	16	3	Issuance	18	-----	16	----	3	Issuance	18
North Carolina	Driver License Div., Dept. of Motor Vehicles.	1 month	16	4	Birthday	18	*16	-----	----	2	Birthday	18–21
North Dakota	Safety Responsibility Div., Highway Dept.	3 months	13	2	Birth month	16	-----	*13	----	-----	-----	-----
Ohio	Driver License Sect., Ohio State Highway Patrol.	6 months*	16	3	Birthday	21	16	14	16	3	Birthday	18
Oklahoma	Driver License Div., Dept. of Public Safety.	6 months	15½–16	2	Birth month	16	-----	-----	14	2	Birth month	18–21
Oregon	Drivers License Div., Dept. of Motor Vehicles.	1 year	15	2	Birthday	16	-----	14	----	2	Birthday	18
Pennsylvania	Bur. of Motor Vehicles, Dept. of Revenue.	3 or 4 months.*	16	2	Feb. 1	18	-----	*16	----	-----	-----	-----
Rhode Island	License Div., Registry of Motor Vehicles.	90 days	16	2	Oct. 1	16	-----	-----	----	2	Oct. 1	18–21
South Carolina	Motor Vehicle Div., Highway Dept.	6 months	14	4	July 1	16	-----	14	----	1	Jan. 1	18
South Dakota	Dept. of Motor Vehicles	60 days	14	4	Birthday	16	-----	14	----	-----	-----	-----
Tennessee	Driver License Div., Dept. of Safety.	10 days	16	2	Birthday	16	-----	-----	14	2	Birthday	18–21
Texas	Dept. of Public Safety	2 years	14–16	2	Issuance	18	*16	14	14	1	Issuance	16–17–21
Utah	Drivers' License Div., Dept. of Public Safety.	4 months	15½–16	3 and 5	Birthday	16	15½	-----	----	3 and 5	Birthday	18–21
Vermont	Motor Vehicle Dept	1 year	15	1	Birthday	18	16	-----	----	-----	-----	-----
Virginia	Div. of Motor Vehicles	90 days	15	3	Birth month	18	*15	-----	----	1	Issuance	18–21
Washington	Operator's License Div., Dep. of Licenses.	6 months	15	2	Birthday	21	*16	-----	----	-----	-----	-----
West Virginia	Opertrs. & Chauff. Div. and Driver Imprvmt. Div., Dept. of Motor Vehicles.	2 months	16–21	4	Issuance	16	-----	-----	16	1	Issuance	18–21
Wisconsin	Motor Vehicle Dept	6 months	16	2	Birthday	16	14	-----	----	1	Birthday	18
Wyoming	Motor Vehicle Div., Dept. of Revenue of the Board of Equalization.	90 days	15	3	Birthday	21	*15	-----	14	1	Issuance	18–21
Dist. of Col	Dept. of Motor Vehicles	60 days*	16	3	Issuance	18	*16	-----	----	-----	-----	-----

[1] An asterisk (*) is shown if the learner's permit is mandatory before obtaining an operator's license.

[2] Where more than one age is shown for a State, the lower age (or ages) is qualified by certain restrictions, such as completion of driver training courses, times of operation, type of operation, proof of necessity in hardship cases, and parent or guardian approval.

[3] No special provisions for minors. [4] Special provisions for minors and an asterisk indicates that signature of parent or guardian is mandatory before issuance of license.

[5] Motor scooter license only.

[6] Drivers' licenses are not designated operators' or chauffeurs' licenses. The applicant is required to take an examination appropriate to the type of motor vehicle he will operate, class 1, 2, or 3.

[7] Indefinite issue for drivers meeting specified requirements. Taxicab drivers' licenses are issued only to persons 21 or over, are issued annually, and expire May 31.

[8] Required only for school bus operators.

[9] Two years for those over 65 years old.

[10] Commercial license is required for any person operating a vehicle having more than 1-ton capacity and not owned by the operator.

[11] For-hire bus operator's license is issued for an indefinite period, but evidence of physical fitness, good character, and experience must be furnished each 12 months.

Table 2.—Number of States issuing drivers' licenses at specified minimum ages, 1964

Minimum age of issuance	Number of States issuing—		
	Learner permits	Junior or special licenses (restricted operation)	Regular driver licenses (unlimited operation)
13	2	2	--
14	9	12	2
15	23	5	7
16	15	4	37
17	1	--	2
18	--	--	3
TOTAL	50	23	51

Table 3.—Specified periods for which States issue learners' permits and regular drivers' licenses, 1964

Period for which issued	Number of States issuing—	
	Learner's permits	Regular driver's licenses
Less than 3 months	18	--
3–6 months	21	--
School term	1	--
1 year	6	2
2 years	4	27
3 years	--	12
4 years	--	5
5 years	--	4
Indefinite	--	1
TOTAL	50	51

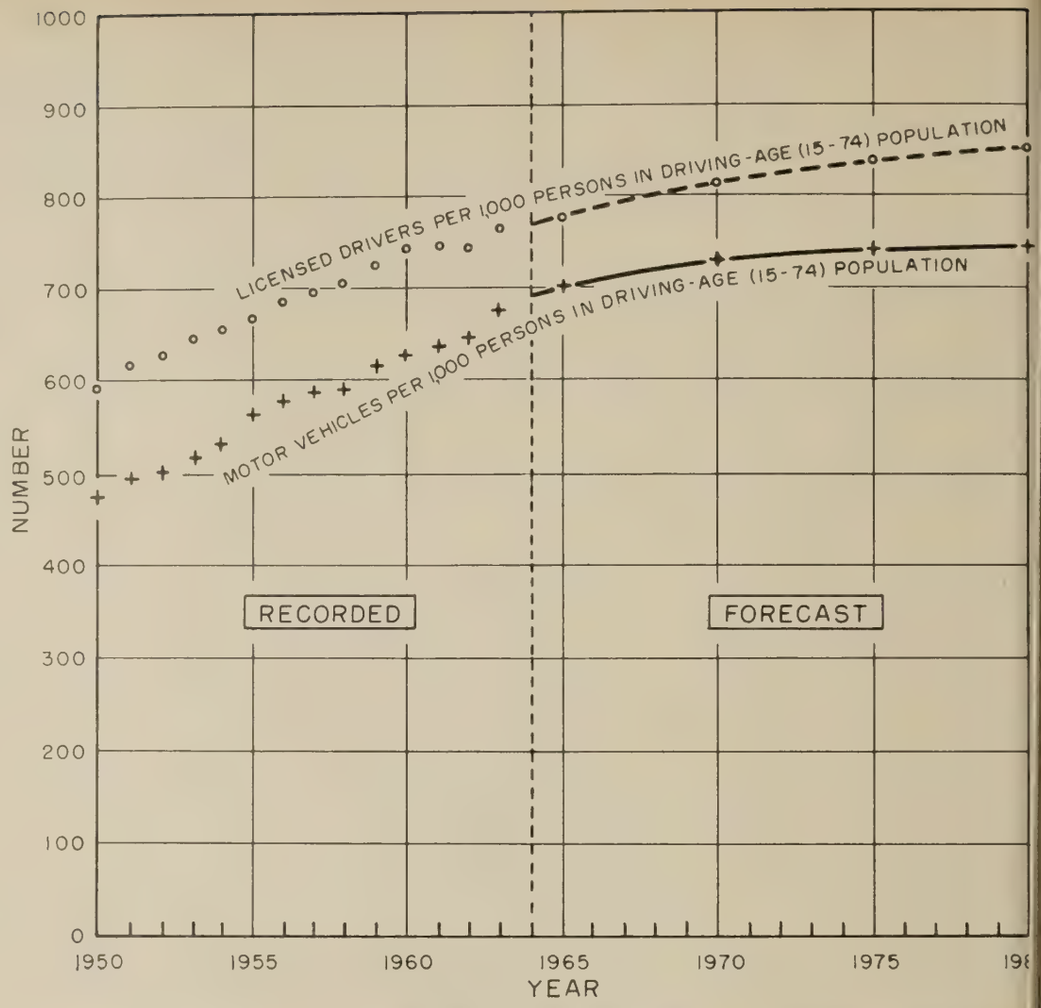

Figure 3.—Relationship of the numbers of licensed drivers and vehicle registrations population in the vehicle-operating age groups.

analysts, and for business in the analysis of wants and needs, forecasting of markets, and efficiency in distribution and advertising. Fortunately, there is an increasing recognition of the potential value of the information that the licenses can produce, in addition to their primary function of certifying the ability of the holder to operate a vehicle, and maintaining a record of his traffic law violations.

From a highway safety standpoint, alone, the nearly universal ownership and operation of vehicles require more attention to the qualifications and practices of individual drivers. This has been evidenced by several major developments in recent years. The list is impressive. Without attempting to put them in their order of importance, it includes highly organized high school driver education programs, the point system for control of hazardous drivers, revamping and tightening of driver licensing by the States, more adequate staffing and record systems, and the establishment, by the Federal Government, of the Federal Driver Register, in which all of the States cooperate in exchanging information on individual drivers having records of offenses leading to suspension or revocation of their licenses. The District of Columbia is treated as a State for the purposes of this study. It should be remembered, when making comparisons, that it is a compact central city having a highly developed public transportation system, and that its statistics exclude the suburban and rural areas that tend to balance or average the statistics of the 50 States. The statistics on driver licenses, vehicle ownership, and related factors for other major cities, if obtained separately and not submerged in the totals of their States, would undoubtedly be similar to those of the District of Columbia.

Driver license administration, requirements, and fees

Generally, use of the information from a driver's license is aided by knowledge of the minimum qualifications required to obtain the license, the ease with which it can be obtained, the length of time it is valid, and its cost. Any of these factors, and perhaps others as well, can affect the significance of the data.

These factors, and other significant information, are shown for each State in tables 1, 4, 5, and 6. Table 1 lists the agency in each State that administers the issuance and recording of licenses. It also lists the minimum ages at which licenses may be obtained, the lengths of the terms for which they are issued, and the factors governing the dates of expiration and renewal. All States except Connecticut issue learners' permits. Forty-one States issue junior or other restricted licenses. The restrictions differ among the States and are too numerous to be listed. Such licenses, generally, are issued to persons too young qualify for regular licenses and are to perm operation of a vehicle to and from school, shopping or marketing, or for making oth trips under prescribed conditions (see table The restrictions may also cover the type vehicle to be operated, operation betwe sunrise and sunset, and other factors, such insurance coverage requirements or requi ments for written approval of parents.

The terms of both learner permits a regular driver licenses, as may be seen table 1, differ considerably among the Stat In some, learner permits are issued for period as short as 1 month, but four Sta issue them for periods as long as 2 yea The great majority are for 6 months or l

The driver licenses of more than half the States are issued for 2-year terms. even dozen issue them for 3 years, and o two for 1-year terms. Although issuance licenses for indefinite terms was at one ti fairly common among the States, Hawai now the only one in which an indefi term regular driver's license may be obtain For certain drivers with safe driving reco Delaware issues an indefinite term lice for which the fee is $10. Relatively few these are issued, and for purposes of t study, they are considered to be spe licenses. A summary of the terms of St drivers' licenses is shown in table 3.

Table 4.—Driver license examination, renewal, and reciprocity, Jan. 1, 1964

State	Kind of examination required for original or renewal of drivers' license [1]					Age requirement for reexamination for renewals	Renewal notices mailed [2]		Expiration date extended for military personnel during service and after discharge	Reciprocity				Point system in use [3]
										New residents			Nonresidents	
	Written	Oral	Driving	Vision	Other		Operators	Chauffeurs		Time limit to obtain driver license after establishing residence	Must surrender license from former State	Examination for persons having legal license from former State	May obtain license	
Ala.	F		F	F			Yes* [4]		No	1 month	Yes	Driving	No	Yes.
Alaska	F		F	F & R	Sign recognition.	70	No	No	No	90 days	No	None	No	No.
Ariz.	F		F	F & R		65	Yes	Yes	No	Immediately	No	Entire	No	No.
Ark.	F	F	F	F	As necessary.		No	No	No	Immediately	Yes	No	No	No.
Calif.	F & R	F & R	F	F & R	Hearing, signs, simple English.		No	No	Duration of service.	10 days	Yes	Entire	Have Calif. address.	Yes.
Colo.	[4] F & R	If illiterate.	[4] F & R	F & R	Physical, aptitude.		No	No	[5]	30 days	Yes	Driving waived.	No	Yes.
Conn.	F	If illiterate.	F	F	Sign recognition.		Yes [6]	Yes [6]	No	60 days	Ill. and S.D. only.	Driving waived.	Valid in Conn. only.	Yes.
Del.	F		F	F		63	Yes [6]	Yes [6]	90 days	90 days	Yes	Written and vision.	No	No.
Fla.	F	F	F	F	Signs, veh. insp.		No	No	Duration of service.	Immediately	Yes	Entire	Pass entire exam.	Yes.
Ga.	F	F	F	F	Sign recognition.		No	No	No	30 days	Yes	Written and vision.	No	No.
Hawaii	F		F	F						90 days	No	None		Yes.
Idaho	F	F	F	F & R			No	No	No	Immediately	Yes	Entire	No	Yes.
Ill.	F	F	F	F	Signs and laws.	69	No	No	No	90 days	Yes	Entire	Chauf. employed in Ill.	Yes.
Ind.	[7] F & R	If illiterate.	F	[8] F		75	No	No	Duration of service.	Indefinite	Yes	Written and vision.	No	Yes.
Iowa	F	If illiterate.	F	F & R			No	No	6 months	Immediately	No	Entire	No	No.*
Kans.	F		F	F			Yes*	Yes	30 days	90 days	Yes	Entire	Servicemen only.	Yes.
Ky.	F	If illiterate.	F	F			No	No	No	Immediately	Yes	Entire	No	Yes.
La.	F	F	F	F & R			No	No	60 days	90 days	Yes	Entire	No	Yes.
Maine	F		F	F		[9] 75	Yes		30 days	Immediately	Yes	Driving waived.	Pass entire exam.	Yes.
Md.	F		F	F	Sign recognition.	60	Yes	No	No	30 days	Yes	Driving waived.	Chauf. employed in Md.	Yes.
Mass.	F		F	F			Yes [6]		60 days	Immediately	No	Driving waived.	Upon application.	No.
Mich.	F	F	F	F & R	Physical		No	No	No	Immediately	No	Driving waived.	No	Yes.
Minn.	F		F	F	Doctors, report.		No	Yes	90 days	60 days	Yes	Entire	No	Yes.
Miss.	F	If illiterate.	F	F	Sign recognition.		No	No	No	60 days	Yes	Entire	No	No.
Mo.	F	If illiterate.	F	F			Yes*	Yes	No	Immediately	Yes	Entire	Chauf. employed in Mo.	Yes.
Mont.	F	If illiterate.	F	[8] F			Yes*	Yes	30 days	90 days	Yes	Entire	No	Yes.
Nebr.	F		F	F			No	No	No	30 days	No	Entire	No	Yes.
Nev.	F		F	F & R			No	No	Duration of service.		Yes	None	No	No.*
N.H.	F	If illiterate or non-English.	F	F		75	Yes [6]	Yes [6]	No	[10]	Yes	Driving waived.	Valid in N.H. only.	No.
N.J.	F		F	F			Yes*		90 days	60 days	No	Driving waived.	Valid in N.J. only.	Yes.
N.Mex.	F		F	F			No	No	No		Yes	Entire	90-day permits	No.
N.Y.	F	F	F	F	Medical	[11] 66	Yes	Yes	[12]	30 days	No	Not if reciprocity agreement exists.	Valid in N.Y. only.	Yes.
N.C.	F & R	F & R	F & R	F& R			Yes	Yes	No	Immediately	Yes	Driving waived.	No	Yes.
N.Dak.	F	F	F	F			Yes*		No	60 days	Yes	Entire	No	No.
Ohio	F	F	F	F			No	No	No	Immediately	Yes	Entire	No	Yes.
Okla.	F	F	F	F			Yes	Yes	No	Immediately	Yes	Entire	By surrendering home State license.	Yes.
Oreg.	F	F	F	F	Sign recognition.		Yes*	Yes	No	Immediately	Yes	Entire	No	No.
Pa.		F	F	F	Physical		Yes		Duration of service.	30 days	No	Driving waived.	No restriction.	No.
R.I.	F		F	F		70	Yes*	Yes	30 days	Immediately	Yes	Entire	If employed in R.I.	No.
S.C.	F	F	F	F			No	Yes	90 days	90 days	Yes	Entire	Chauf. only.	Yes.
S.Dak.	F		F	F & R			No		Duration of service.	90 days	Yes	Entire	Operators only.	No.
Tenn.	F		F	F			Yes*	Yes	Duration of service.	Immediately	Yes	Entire	No	No.
Tex.	F	If illiterate.	F	F	Sign recognition.		Yes*	Yes*		Immediately	No	Entire	If needed	No.
Utah	F		F	F & R			No	No	90 days	60 days	No	Entire	Upon application.	Yes.
Vt.	F	F	F	F			Yes*	No	[13]	6 months	No	Driving waived.	Valid in Vt. only.	No.
Va.	F	F	F	F			Yes	No	6 months	Immediately	No	Driving waived.	Pass entire exam.	No.
Wash.	F		F	F & R			Yes*		No	30 days	Yes	Entire	No	Yes.
W.Va.	F		F	F			Yes*	Yes	6 months	30 days	Yes	None	No	Yes.
Wis.	F		F	F	Sign recognition.		Yes*	Yes	No	Immediately	Yes	Entire	No	Yes.
Wyo.	F		F	F			No	No	No	90 days	No	Dept. may waive exam.	No	No.
D.C.	F	If illiterate.	F	F	Reaction	65	Yes*		Up to 6 years.	[10]	No	Driving waived.	Valid in D.C. only unless a diplomat.	Yes.

[1] F=original license; R=renewal. Other examinations apply to the original issue, or in special cases, or as needed for renewals.

[2] Asterisk indicates renewal notice can be forwarded if addressee has moved.

[3] Asterisk indicates law provides for point system but is not yet in use.

[4] Renewal applicants are required to take written and driving tests if they have had a traffic violation during the term of license, or at the discretion of the examiner.

[5] For civilians, expiration date may be extended up to 2 years, depending upon need and circumstances; for military and dependents, up to 3 years, or 90 days after return to Colorado, whichever is sooner.

[6] Operators and chauffeurs renewal notices are mailed, except those under suspension or revocation.

[7] Written test required every 4 years.

[8] Vision test required for renewals every 4 years in Indiana, and for every third renewal in Montana.

[9] If the applicant has been examined within the past year, or has received a license effective on his 74th birthday, he is required to be examined at 76 years and every renewal thereafter.

[10] Ranges from immediately to 6 months depending on reciprocity with each State.

[11] Reexamination for those over 65 if involved in an accident or if requested by insurance company.

[12] For operators, expiration date may be extended to the Sept. 30 next succeeding 60 days after separation; for chauffeurs, to the next May 31 next succeeding 60 days after separation.

[13] Maximum of 4 years beyond original expiration date or 30 days after discharge from the Armed Forces, whichever occurs first.

Table 4 shows the general State provisions for driver license examinations, renewals, and reciprocity. All States require driving and vision tests for applicants who have not previously been licensed to drive, but many waive the driving test for persons holding valid licenses issued by other States. It is interesting to note, in table 4, that several States issue licenses to persons who cannot read. While some road signs have distinctive shape or color, others do not, and one cannot help wondering what mysteries road signs and warnings must hold for such drivers.

The requirement of a vision test at each driver's license renewal is a somewhat new development that is now in effect in 13 States. In addition, Indiana requires a vision test on every second renewal of a license, and Montana requires one on every third renewal. The 15 States requiring retesting of vision are pleased with the results, and it is probable that the requirement will be adopted by others. A ripple of surprise followed one State's discovery, recently, that some persons receiving aid for the blind were also holders of valid drivers' licenses—a situtation since corrected in that State.

Although the driver license laws of many States are sufficiently broad to permit the administrative requirement of reexamination of licensed drivers for cause, or under specific circumstances, at present only 11 have instituted programs of mandatory reexamination of applicants who have reached a specified age. The States requiring reexaminations and the ages at which they are required are shown. Some States mail notices of approaching license expiration and need for renewal. These account for a significant part of the administration cost of the States (table 4) that do send renewal notices.

Some States make special provisions for the extension of the terms of drivers' licenses of persons in the armed services (table 4). Where a specified time is indicated, it is the period for which the license remains valid after the termination of active service. Such extensions do not apply to service in the reserves or to temporary service in the National Guard.

Nearly all States require that a person residing in the State and employed therein must obtain a driver's license to qualify for the operation of vehicles within the State. Most, however, allow a period of grace. These are shown in table 4, but the definitions of residence and employment differ somewhat among the States, and should be checked locally if any question of individual compliance is involved.

Table 4 also reflects, in its last column, the fact that 30 of the States have adopted a point system of dealing with traffic law violators. In addition, the legislatures of two more States have authorized such systems, but have not yet put them into operation.

As may be seen in table 5, the information on driver licenses differs among States. The only items included in all are name, address, signature, and birth date.

The driver licenses of all States show date of expiration, except in Hawaii, where they are issued for an indefinite term. Surprisingly, the licenses of four States do not show weight, and those of four do not show sex. Included in these, Connecticut, Massachusetts, and Pennsylvania licenses show neither. The Pennsylvania license is the only one that does not show height. Never included on the driver licenses of all States, race remains an item shown on those of 29 States.

Although still appearing on the licenses of all but seven States, color of hair probably remains as a vestige of days when more confidence could be placed in it as an item of identification. Artificial hair coloring and even artificial hair have become so commonplace that color of hair has lost much of its value as an item of personal description. Some States have already dropped it from the license description, and others are considering dropping it. All States except Connecticut, Maryland, and Pennsylvania show color of eyes on their licenses.

A new development is the inclusion of a photograph as part of the driver's license, now a requirement in seven States. Colorado, the District of Columbia, Louisiana, and New Mexico use color photographs.

Although the items of information shown on the drivers licenses (table 5) may be dropped or added to from time to time, there is a remarkable degree of uniformity in the inclusion of major items required for identification, administration, and law enforcement. This uniformity, and the tendency to increase, of both the uniformity and the care with which it is administered, give added value and significance to the data available from the State records of licenses.

As may be seen in table 6, the fees for drivers' licenses are scarcely more than nominal. In many States they hardly cover the cost of administering the licenses. The fees have never been regarded by the States as a source of revenue beyond the amounts needed to support the function, and have remained low. One result of this is that licenses are readily obtainable by persons in all economic levels. Since car ownership is not required, and possession of a driver's license appears to be almost a social requirement of the modern American scene, the effort to qualify seems to be almost universal among young people. Thus, there is created a broad-based source of data, in driver license records, that is useful for many purposes. These data should contain little bias of an economic nature; and since a license, once obtained, is relinquished only with great reluctance, the data source is almost certain to improve with the passage of time.

The fee for a driver's license, divided by the term for which the license is issued, yields the annual cost. The highest annual cost, $4, is in Rhode Island, which collects $8 for a 2-year license and puts the revenue from this source in its general fund without earmarking it for highway purposes, as most States do. South Carolina's driver license, at 50 cents, is the lowest in original cost; and since it is for a 4-year term, its 12½-cent annual cost is also the lowest, with the possible exception of Hawaii's, which is issued for an indefinite term. The costs of driver licenses, shown in table 6, are summarized in table 7.

Availability of data from drivers licens records

There are several reasons why the State do not extract more driver license infor mation from their files, but the principa underlying cause probably is the tendency t look on the records as places where one ca ascertain that an individual has met th requirements for a license, and as a record information on individual drivers. Th largely explains, too, the fact that many the States cannot supply a count of tot drivers licenses in force. But another in portant factor is the need for modern dat processing equipment capable of handlin the sheer magnitude of the job of extractin the data from the records. As the equip ment and staff become available, the State are beginning to put driver license data punch cards or tapes and to summarize the contents.

Age and sex distribution of licensed drive

As of the summer of 1964, 19 States we able to supply counts of drivers' licens outstanding at the end of 1963, segregated b age groups and by sex. These, listed table 8, are undoubtedly indicative of th age and sex groupings of other States. the 19 States for which 1963 data we available, 60.2 percent of the licensed drive were male, and 39.8 percent were femal and in none of the 19 States did the rat change as much as 3 percentage points fro this average.

Perhaps the most noticeable characterist of the drivers license distribution of th 19 States given in table 8 is the fact th males substantially outnumber females all States and all age groups. Althoug differences between the age and sex groupin of licensed drivers among the States a significant, there is also a surprising degree overall consistency. The highest percenta of male drivers, Kentucky's 62.8 was on 5.1 percentage points higher than Delaware low of 57.7. Since the populations of Ke tucky and Delaware are 49.6 percent an 49.5 percent male, respectively, differenc in the elements of motivation and vehic usage, rather than in the male-female rati of the total population, must account for th difference between the two States in th percentages of male versus female drive

Despite the stability of the overall mal female ratios of the States, the State-to-Sta age group compositions of licensed drive differ considerably. Probing for the reaso for these differences is beyond the scope this study, but they undoubtedly could found, and their significance measure Some of the differences may be attributab to the economic characteristics of the Stat or to the age and sex distributions of t populations. Wage levels, per capita incom urban-rural relationships, topography, clima and other factors might be expected to i fluence the makeup of the driving populatio

As expected, it was found that the ratios f male-to-female drivers increase substantia and progressively in the age groups 55 a above. This statistical fact takes on addi

Table 5.—Items included on operator's license, Jan. 1, 1964

State	Name	Address	License number	Color of eyes	Color of hair	Photograph	Finger or thumb print	Restrictions (eye glasses, automatic transmission, etc.)	Expiration date	Race	Weight	Height	Signature of operator	Sex	Birth date	Violations resulting in convictions	Other items
Alabama	X	X	X	X	X			X	X	X	X	X	X	X	X		
Alaska	X	X	X	X	X			X	X		X	X	X	X	X		(1).
Arizona	X	X	X	X	X	X			X	X	X	X	X	X	X		
Arkansas	X	X	X	X	X				X	X	X	X	X	X	X		Date of issue.
California	X	X	X	X	X	X	Optional	X	X		X	X	X	X	X		
Colorado	X	X	X	X	X	X	Right index	X	X		X	X	X	X	X		
Connecticut	X	X	X				Pub. svc. opr. only.	X	X			X	X		X	X	
Delaware	X	X	X	X	X	Chauf. only		X	X	X	X	X	X	X	X		
Florida	X	X	X	X	X			X	X	X	X	X	X	X	X		
Georgia	X	X	X	X	X			X	X	X	X	X	X	X	X	X	
Hawaii	X	X	X	X	X	Optional	Right thumb	X	None	X	X	X	X	X	X	X	(2).
Idaho	X	X	X	X	X			X	X	X	X	X	X	X	X		
Illinois	X	X	X	X	X			X	X	X	X	X	X	X	X		
Indiana	X	X	X	X	X			X	X	X	X	X	X	X	X		
Iowa	X	X	X	X				X	X	X	X	X	X	X	X	X	Soc. Sec. No.
Kansas	X	X	X	X	X			X	X	X	X	X	X	X	X		
Kentucky	X	X	X	X	X			X	X	X	X	X	X	X	X		
Louisiana	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	
Maine	X	X		X	Optional			X	X		X	X	X	X	X	X	
Maryland	X	X	X					X	X	X	X	X	X	X	X		
Massachusetts	X	X	X	X	X			X	X			X	X		X		
Michigan	X	X	X	X	X		Chauf. only	X	X		X	X	X	X	X	X	Point system.
Minnesota	X	X	X	X	X			X	X		X	X	X		X		
Mississippi	X	X	X	X	X			X	X	X	X	X	X	X	X		
Missouri	X	X	X	X	X			X	X		X	X	X	X	X	X	
Montana	X	X	[3] X	X	X	X		X	X		X	X	X	X	X		
Nebraska	X	X	X	X	X			X	X	X	X	X	X	X	X		
Nevada	X	X	X	X	X		X	X	X		X	X	X	X	X		
New Hampshire	X	X	X	X	X			X	X		X	X	X	X	X	X	Blood type.
New Jersey	X	X	X	X	X			X	X		X	X	X	X	X		
New Mexico	X	X	X	X	X	X		X	X		X	X	X	X	X		(4).
New York	X	X	X	X		Chauf. only		X	X			X	X	X	X	X	
North Carolina	X	X	X	X	X			X	X	X	X	X	X	X	X		
North Dakota	X	X	X	X	X			X	X	X	X	X	X	X	X	X	(5).
Ohio	X	X	X	X	X	Chauf. only		X	X		X	X	X	X	X	X	Point system.
Oklahoma	X	X	X	X	X			X	X	X	X	X	X	X	X		
Oregon	X	X	X	X	X			X	X		X	X	X	X	X		
Pennsylvania	X	X	X					X	X				X		X		
Rhode Island	X	X	X	X	X			X	X		X	X	X	X	X		
South Carolina	X	X	X	X	X			X	X	X	X	X	X	X	X		
South Dakota	X	X	X	X	X			X	X	X	X	X	X	X	X		
Tennessee	X	X	X	X	X			X	X	X	X	X	X	X	X	X	
Texas	X	X	X	X	X			X	X	X	X	X	X	X	X		
Utah	X	X	X	X	X	Chauf. only		X	X	X	X	X	X	X	X		
Vermont	X	X	X	X	X			X	X		X	X	X	X	X		
Virginia	X	X	X	X	X			X	X	X	X	X	X	X	X		
Washington	X	X	X	X	X			X	X		X	X	X	X	X		
West Virginia	X	X	X	X	X			X	X	X	X	X	X	X	X		Blood type.
Wisconsin	X	X	X	X	X			X	X	X	X	X	X	X	X		
Wyoming	X	X	X	X	X			X	X	X	X	X	X	X	X		
Dist. of Col.	X	X	X	X	X	X		X	X		X	X	X	X	X		

[1] Issuance date includes code number for place of issuance.
[2] Date of issue and signature of examiner are also shown on the license. Violations resulting in convictions and points under the point system are entered by the court.
[3] Applicant's birth date is included in the license number; first letter of last name and year, day of birth, and month.
[4] Blood type, and physical and mental condition.
[5] Written warning of traffic violation, explanation of change of address notice, mailing of notice of renewal application, and basis for suspension and revocation.

Table 6.—Driver license fees and service charges, Jan. 1, 1964

State	Payment at time license is issued										
	Learner's permit fee		Operator's license fee			Chauffeur's license fee			Service charge [1]		
	Amount	Amount applied to operator's license	Original	Renewal	Duplicate	Original	Renewal	Duplicate	Learners	Operators	Chauffeurs
Alabama	[2] $0.35		$4.25	$4.25	$0.25				$0.10	$0.10	$0.10
Alaska	1.00		5.00	5.00	1.00	$2.00					
Arizona	2.00		2.50	2.50	1.00	2.50	$2.50	$1.00			
Arkansas	No fee		2.00	2.00	2.00	5.00	5.00	1.00			
California	3.00	$3.00	3.00	3.00	1.00						
Colorado	2.25	2.25	2.25	2.25	1.25	5.25	5.25	1.25			
Connecticut			[3]	6.00	1.00	3.00	3.00	1.00			
Delaware	4.00	4.00	4.00	4.00	1.00	[4] 4.00	4.00	1.00			
Florida	3.00		3.00	3.00	.25	5.00	5.00	.25	[5] .50	[5] .50	[5] .50
Georgia	1.00		1.00 or 5.00	1.00 or 5.00	1.00	2.00 or 10.00	2.00 or 10.00	1.00			
Hawaii	1.00		3.00		.50	3.00	1.00	.50			
Idaho	3.00		4.00	4.00	.75	3.00	3.00	.75			
Illinois	3.00	3.00	3.00	3.00	1.00	5.00	3.00	1.00			
Indiana	1.00		1.50	1.50	1.50	1.50	1.50	1.50			
Iowa	3.00		3.00	3.00	.25	4.00	4.00	.50			
Kansas	.50		[6]	2.00	.50	[6]	4.00	.50			
Kentucky	1.00		2.00	2.00	1.00	2.00	2.00	2.00	1.00	.75	.25
Louisiana	2.50	2.50	2.50	2.50	1.50	[7] 3.50	[7] 3.50	1.50			
Maine	3.00		5.00	5.00	.50						
Maryland	5.00	5.00	7.00	2.00	.50	8.00	3.00	.50		.25	
Massachusetts	2.00		[8] 8.00	5.00	1.50	[9] 5.50	2.50	1.50			
Michigan	No fee		4.00	2.50	1.00	4.00	2.75	1.00		[10]	[10]
Minnesota	1.00		3.00	3.00	.50	3.00	2.00	1.00			
Mississippi	.50		2.50	2.50	1.00	4.50	4.50	1.00		[11] .25	[11] .25
Missouri	.25		1.00	1.00	.25	3.00	3.00	.25			
Montana	4.00	4.00	4.00	4.00	.50	4.00	4.00	.50			
Nebraska	1.00		3.00	3.00	.50						
Nevada	3.00	3.00	3.00	3.00	1.00	5.00	5.00	1.00			
New Hampshire			5.00	4.00	1.00	7.00	4.00	1.00			
New Jersey	2.00		3.00 or 8.00	3.00 or 8.00	2.00	No fee					
New Mexico	.50		3.25	3.25	1.00	2.75	2.75	1.00			
New York	.50		[8] 5.00	3.00	3.00	[8] 8.00	6.00	3.00	.50	.20	.20
North Carolina	No fee		2.50	2.50	.50	4.00	4.00	.50			
North Dakota	[12] 3.00	[12] 3.00	[12] 3.00	3.00	1.00						
Ohio	.75		1.00	1.00	.50	1.50	1.50	1.00	.25	.25	.25
Oklahoma	No fee		4.00	4.00	1.00	[13] 8.00	[13] 8.00	1.00	.20	.20	.20
Oregon	.50		2.75	2.75	.25	2.00	2.00	.25			
Pennsylvania	4.00	4.00	4.00	4.00	.50						
Rhode Island	No fee		[8] 13.00	8.00	1.00	[8] 13.00	8.00	1.00			
South Carolina	No fee		.50	.50	.50	2.00	2.00	No fee			
South Dakota	2.00		2.00	2.00	2.00						
Tennessee	4.00	4.00	4.00	4.00	2.00	6.00	6.00	2.00			
Texas	[14] 3.00	Total fee	3.00	3.00	.25	[15] 6.00	6.00	.25			
Utah	3.00	3.00	3.00	2.00	1.00	3.00	2.00	1.00			
Vermont	1.00		[8] 4.50	2.50	.50						
Virginia	No fee		2.00	2.00	.25	3.00	3.00	.25			
Washington	1.50	.50	[8] 6.00	4.00	.50						
West Virginia	4.00		5.00	5.00	1.00	3.00	3.00	1.00			
Wisconsin	1.50		[8] 4.50	2.00	1.00	[8] 5.00	2.00	1.00			
Wyoming	No fee		2.00	2.00	1.00	2.00	2.00	1.00			
District of Columbia	2.00		3.00	3.00	.50						

[1] All service charges are a part of the regular fees as listed, except Maryland and Mississippi which are in addition to the given fee.

[2] Learner's permit fee for 15-year-olds is $0.50.

[3] $5 examination fee plus $0.25 per month from date of issue to last day of month of next birthday and $3 or $6, depending upon year of birth.

[4] $0.50 on exchange from a valid operator's license.

[5] The county judge receives $0.50 of the stated fee for each of the first 10,000 licenses issued, and $0.35 each thereafter. $1 of each fee goes to the Driver Education Fund, and the balance to General Revenue.

[6] Operators, $1 to $3; chauffeurs, $2 to $6, depending upon year of birth, even or odd year. $3, additional if examination is needed.

[7] New Orleans Parish, $5.50.

[8] The difference between new and renewal license fee is the charge for examination when one is required, except in Wisconsin where the examination fee is $2.

[9] Required only for schoolbus operators.

[10] $2 for each original license and $0.50 for each renewal.

[11] The additional $0.25 is charged only when renewed by sheriff's office or renewal agents.

[12] $1.50 for 17 years and under. No charge is made for the learner's permit, but the license fee is collected at the time the permit is issued.

[13] Commercial chauffeur, $10 original, $10 renewal.

[14] Same as original license for which application is being made; $3 for operator, $4.50 for private chauffeur, $6 for commercial chauffeur.

[15] Commercial operators to transport property, $4.50.

gnificance when it is remembered that the e expectancy of women is now 73½ years, ½ years longer than that of men in the nited States. In the age groups in which ıe ratio of males to females is decreasing, ıe ratio of male-to-female licensed drivers creases substantially and progressively. his undoubtedly indicates a more rapid ıpering off of driving by women in the upper ge groups. This may change, however, as ore women who have been familiar with ıtomobiles all of their lives progress into der age groups.

There are no conclusive statistics on the mount of driving by young males as compared to that by young females. However, linois, which has shown an active interest in river license records as a source of informaon, some time ago added to the license pplication the question, "Approximately ow many miles did you drive a motor ehicle during the past 12 months?" In ıe analysis of a large sample of the responses, was found that the males in each age group aid they had driven approximately twice as ıany miles as was reported by female drivers. f this is indicative of driving in the United tates as a whole, males do approximately 0 percent of all driving, and females about 0 percent.

The considerable increase in automobile ısurance premiums that is invoked in most reas for vehicles driven by male drivers nder 25 years of age may have some de- erring effect on their applying for licenses, ut it is doubtful that this factor could be ıeasured.

The data in table 8 were the primary ource of male-female driver license distriıution by age groups (figure 1) and were also ısed in obtaining the estimate of male-female ıreakdowns for all States that are shown in able 9. The total numbers of drivers' icenses (table 10) were taken from Public Roads table MV–12 for 1963. The distriıution of licensed drivers in effect in 1963, by ıge grouping and by sex, is shown in figure 1; he percentage distribution is shown in able 11.

It may reasonably be expected that the hanges in the age distribution of the popula- ion, plus the increasing dependency on motor ehicles, will tend to increase the relative ıroportions of licensed drivers in the older ıge groups of both sexes. Although somewhat speculative, it also seems probable that the ıumber of licensed female drivers will increase nore rapidly than the number of male drivers, ıntil the preponderance of male licensed lrivers is substantially less than the 60–40 ratio of 1963.

The total number of driver licenses listed n table 9 are taken from Public Roads table MV–12 (table 10 in this article), which in turn were based on data supplied by the States. In that table, for the States that cannot supply totals of licenses in force, Public Roads estimated the number on the ıasis of the number issued over a series of years. The male-female segregations in table 9 are those reported by the 19 States that are included in table 8, plus estimates by Public Roads for the remainder. In making the segregations, the most important single factor was the male-female ratio of driver licenses in adjacent States, or in States deemed most similar in characteristics.

Outlook and Forecast

The total population of the United States, the persons of driving age (15 through 74), and the number of licensed drivers are compared in figure 2. The bars for the years through 1960 are from records and estimates, and those for 1965 through 1980 are projections. Worth noting, however, is the fact that the center bar, population in the 15–74 potential driving ages, is close to a statistical certainty. The birth rate after 1965 will not affect the 15–74 age group until 1980; and the effect of even a substantial lengthening of life expectancy could scarcely have an important impact on the totals within this age bracket.

The number of persons licensed to drive, per 1,000 persons in the 15–74 driving age group. are shown in figure 3. Figure 3 also shows the number of motor vehicles registered per 1,000 persons in the 15–74 group. The population data and forecasts used in making these computations are basically those of the Bureau of the Census, interpolated by the Bureau of Public Roads where necessary for purposes of this report.

950, in the United States as a whole, there were 593 drivers' licenses per 1,000 people in the 15–74 age group. By 1960, the number had increased to 741, and in 1963, to 764. In the freehand extension of this curve in figure 3, the authors were mindful of the fact that the States have been tending to increase the minimum ages at which drivers licenses may be obtained. Consideration was also given to the fact that the reexamination of drivers reaching specified ages may be expected to have a restraining effect on the number of drivers who might otherwise continue to renew driver licenses despite sight or other physical deficiency. Eleven States now require reexamination of applicants for driver license renewal when the applicant has reached a specified age, and 15 States require vision tests of applicants for renewal. It seems probable that both the mandatory reexamination of older drivers and the retesting of vision at the time of license renewals will be adopted by additional States.

The freehand extrapolation of the drivers license curve indicates about 850 licenses per 1,000 persons in the 15–74 age group by 1980, with the number of licenses per 1,000 persons still increasing, although at a reduced rate.

In 1950, 103 million people were in the 15–74 age group; and there were 62 million drivers' licenses, or approximately 60 percent of the number of people in the group. In the following 13 years, the number of people in the driving age group increased 20 million, and the number of driver licenses increased 32 million. Thus, the number of licenses increased from 60 to 76 percent of the number of people in the 15–74 age group in the short 13-year span.

Table 7.—Grouping of driver license renewal fees, and the average cost[1] per year of drivers' licenses, 1964

Fee group	Number of States in each fee group for license renewal	Number of States having annual driver license cost within the fee groups shown
50 cents or less	1	6
$0.51–$1.00	3	18
$1.01–$1.50	1	8
$1.51–$2.00	9	11
$2.01–$2.50	7	5
$2.51–$3.00	13	2
$3.01–$3.50	1	-------
$3.51–$4.00	8	1
$4.01–$4.50	1	-------
$5.00	4	-------
$6.00	1	-------
$8.00	1	-------
TOTAL	50	51

[1] The renewal fees, divided by the number of years for which the license is issued.

The fact that the years 1960–61–62 constitute a flat spot of the drivers license curve of figure 3 is puzzling at first glance. But the greatly increased birth rate that started during World War II is the explanation. It resulted in a wave of teenagers entering the bottom of the 15–74 age group. They were not eligible for driver licenses in some States, and not necessarily licensed at the earliest possible time in the States where they were eligible. The 1963 increase of more than 3 million licenses is at least a preliminary indication that the ratio of drivers' licenses to the number of persons in the 15–74 age group has resumed its upward climb.

If the number of driver licenses do follow the forecast curve in figure 3, there will be more than 110 million by 1970, 125 million by 1975, and 139 million by 1980. Motor-vehicle registrations, 82.7 million in 1963, are projected to reach 110 million by 1975, and exceed 121 million by 1980.

Comparisons among States

Table 12 lists 1963 data about each State, which should be particularly useful. The first and second columns show total population, and population in the 15–74 driving age group. The motor-vehicle registrations listed in the third column include buses and trucks, as well as automobiles. About 70 percent of all trucks are light pickups that often serve as automobiles for personal transportation, as well as for the transportation of goods, and an arbitrary statistical assignment of a portion of the vehicles to personal transportation (versus transportation of goods) would imply a degree of precision that the basic data do not justify. The number of drivers licenses in the fourth column of table 12 are, as mentioned in the discussion of table 8 of this study, taken from Public Roads table MV–12 (table 10), which in turn were derived from the reports of the States.

The number of driver licenses per 1,000 persons in the total population, in the fifth

Table 8.—Drivers' licenses, by sex and age groups, for selected States, 1963

Age	Male	Female	Total	Percent male	Male	Female	Total	Percent male	Male	Female	Total	Percent male	Male	Female	Total	Percent male	Male	Female	Total	Percent male
	Alaska				Colorado				Connecticut				Delaware				Illinois			
Under 16																	6,211	5,369	11,580	53.6
16	785	334	1,119	70.2	45,506	33,519	79,025	57.6	13,167	9,776	22,943	57.4	1,813	1,424	3,237	56.0	61,614	48,772	110,386	55.8
17	960	470	1,430	67.1	27,422	16,758	44,180	62.1	18,600	10,867	29,467	63.1	2,561	1,582	4,143	61.8	70,688	54,271	124,959	56.6
18	1,100	635	1,735	63.4	21,941	13,991	35,932	61.1	14,938	11,775	26,713	55.9	2,056	1,714	3,770	54.5	59,192	43,205	102,397	57.8
19	1,211	831	2,042	59.3	24,812	16,456	41,268	60.1	16,995	14,382	31,377	54.2	2,340	2,094	4,434	52.8	60,151	44,230	104,381	57.6
20–24	7,843	5,300	13,143	59.7	111,295	80,474	191,769	58.0	91,600	73,800	165,400	55.4	18,346	15,328	33,674	54.5	335,669	252,472	588,141	57.1
25–29	8,349	7,040	15,389	54.3	69,476	48,951	118,427	58.7	87,200	68,900	156,100	55.9	18,856	15,598	34,454	54.7	314,727	229,386	544,113	57.8
30–34	8,236	6,923	15,159	54.3	64,260	45,842	110,102	58.4	88,800	71,200	160,000	55.5	18,591	15,330	33,921	54.8	307,746	226,277	534,023	57.6
35–39	8,111	6,339	14,450	56.1	63,964	48,007	111,971	57.1	94,400	77,100	171,500	55.0	17,769	14,777	32,546	54.6	326,703	242,231	568,934	57.4
40–44	7,280	5,523	12,803	56.9	63,379	44,067	107,446	59.0	96,000	75,900	171,900	55.8	16,106	13,536	29,642	54.3	318,341	233,187	551,528	57.7
45–49	6,128	3,921	10,049	61.0	44,016	27,163	71,179	61.8	89,000	65,300	154,300	57.7	13,118	9,627	22,745	57.7	297,973	208,872	506,845	58.8
50–54	4,617	2,573	7,190	64.2	39,096	23,866	62,962	62.1	72,700	49,000	121,700	59.7	10,468	7,097	17,565	59.6	267,918	174,325	442,243	60.6
55–59	3,324	1,585	4,909	67.7	31,333	19,664	50,997	61.4	60,100	36,600	96,700	62.2	8,265	4,710	12,975	63.7	233,360	135,298	368,658	63.3
60–64	1,975	655	2,630	75.1	26,466	15,475	41,941	63.1	45,000	24,000	69,000	65.2	5,993	2,860	8,853	67.7	184,236	92,260	276,496	66.6
65–69	932	222	1,154	80.8	26,172	12,383	38,555	67.9	35,400	16,000	51,400	68.9	6,861	3,255	10,116	67.8	142,255	58,685	200,940	70.8
70 and more	562	105	667	84.3	38,738	11,675	50,413	76.8	40,000	14,100	54,100	73.9	9,887	3,439	13,326	74.2	151,576	41,432	193,008	78.5
TOTAL	61,413	42,456	103,869	59.1	697,876	458,291	1,156,167	60.1	863,900	618,700	1,482,600	58.3	153,030	112,371	265,401	57.7	3,138,360	2,090,272	5,228,632	60.0
	Iowa				Kansas				Kentucky				Minnesota				Montana			
Under 16	505	126	631	80.0	9,886	6,687	16,573	59.7					1,698	709	2,407	70.5	19	8	27	70.4
16	17,811	11,831	29,642	60.1	16,981	13,224	30,205	56.2	18,355	10,484	28,839	63.6	19,675	13,034	32,709	60.2	4,312	2,626	6,938	62.2
17	22,603	16,522	39,125	57.8	17,439	14,108	31,547	55.3	25,930	11,654	37,584	69.0	22,353	16,237	38,590	57.9	4,526	3,010	7,536	60.1
18	18,079	13,768	31,847	56.8	15,872	12,410	28,282	56.1	20,824	12,628	33,452	62.3	23,751	16,407	40,158	59.1	4,463	2,964	7,427	60.1
19	20,456	16,218	36,674	55.8	17,204	13,174	30,378	56.6	23,692	15,423	39,115	60.6	21,168	16,886	38,054	55.6	4,391	3,283	7,674	57.2
20–24	82,895	69,752	152,647	54.3	90,798	64,659	155,457	58.4	107,125	71,900	179,025	59.8	143,542	114,814	258,356	55.6	25,391	22,318	47,709	53.2
25–29	77,119	64,443	141,562	54.5	84,611	57,448	142,059	59.6	97,258	63,441	160,699	60.5	119,491	88,933	208,424	57.3	23,108	20,885	43,993	52.5
30–34	85,300	73,424	158,724	53.7	83,461	58,470	141,931	58.8	89,082	66,261	155,343	57.3	104,610	82,619	187,229	55.9	21,417	18,696	40,113	53.4
35–39	86,407	72,120	158,527	54.5	88,244	61,814	150,058	58.8	90,210	64,851	155,061	58.2	95,982	80,990	176,972	54.2	25,716	21,064	46,780	55.0
40–44	83,511	69,019	152,530	54.8	84,018	60,431	144,449	58.2	88,941	57,943	146,884	60.6	100,451	75,468	175,919	57.1	21,800	17,220	39,020	55.9
45–49	77,783	61,162	138,945	56.0	73,138	53,668	126,806	57.7	77,524	47,369	124,893	62.1	99,356	66,667	166,023	59.8	20,268	16,948	37,216	54.5
50–54	70,568	50,975	121,543	58.1	67,724	48,775	116,499	58.1	70,477	39,193	109,670	64.3	86,041	60,580	146,621	58.7	17,287	13,480	30,767	56.2
55–59	59,790	40,411	100,201	59.7	58,909	42,136	101,045	58.3	59,764	25,236	85,000	70.3	72,445	47,098	119,543	60.6	15,957	10,220	26,177	61.0
60–64	52,783	30,810	83,593	63.1	47,986	32,484	80,470	59.6	47,219	17,481	64,700	73.0	63,351	37,505	100,856	62.8	12,962	7,914	20,876	62.1
65–69	43,548	19,007	62,555	69.6	39,496	23,803	63,299	62.4	30,024	9,587	39,611	76.0	53,220	26,257	79,477	67.0	10,177	5,070	15,247	66.8
70 and more	53,351	12,883	66,234	80.5	58,715	23,204	81,919	71.7	34,252	7,331	41,583	82.4	78,937	25,798	104,735	75.4	19,939	3,911	23,850	83.6
TOTAL	852,509	622,471	1,474,980	57.8	854,482	586,495	1,440,977	59.3	880,677	520,782	1,401,459	62.8	1,106,071	770,002	1,876,073	59.0	231,733	169,617	401,350	57.7
	New York				North Dakota				Ohio				Oklahoma				Oregon			
Under 16					7,904	3,068	10,972	72.0												
16	17,146	8,981	26,127	65.6	5,082	3,196	8,278	61.4	42,210	21,419	63,629	66.3	11,323	7,677	19,000	59.6	6,200	3,000	9,200	67.4
17	46,390	27,214	73,604	63.0	6,051	4,158	10,209	59.3	75,969	23,770	99,739	76.2	17,322	11,678	29,000	82.9	11,800	7,900	19,700	59.9
18	64,616	38,678	103,294	62.6	5,973	4,691	10,664	56.0	58,581	36,589	95,170	61.6	20,671	13,329	34,000	60.8	10,700	8,200	18,900	56.6
19	77,899	47,393	125,292	62.3	5,832	5,158	10,990	53.1	73,776	50,635	124,411	59.3	22,128	13,872	36,000	61.5	10,900	7,500	18,400	59.2
20–24	450,098	297,234	747,332	60.2	23,928	19,344	43,272	55.3	338,330	235,723	574,053	58.9	99,101	70,899	170,000	58.3	57,000	41,500	98,500	57.9
25–29	453,844	299,086	752,930	60.3	19,990	16,037	36,027	55.5	326,102	240,030	566,132	57.6	89,233	65,767	155,000	57.6	55,800	40,200	96,000	58.1
30–34	488,979	326,571	815,550	60.0	19,216	15,781	34,997	54.9	315,212	224,516	539,728	58.4	77,333	59,667	137,000	56.4	55,200	47,200	102,400	53.9
35–39	528,018	365,493	893,511	59.1	19,317	15,034	34,351	56.2	343,176	256,560	599,736	57.2	70,626	55,374	126,000	56.1	62,600	49,100	111,700	56.0
40–44	516,986	352,618	869,604	59.5	18,578	14,382	32,960	56.4	319,327	229,387	548,714	58.2	70,050	53,950	124,000	56.5	61,200	53,200	114,400	53.5
45–49	478,074	311,073	789,147	60.6	19,192	13,243	32,435	59.2	291,870	207,294	499,164	58.5	64,294	48,706	113,000	56.9	58,000	44,200	102,200	56.8
50–54	440,715	257,991	698,706	63.1	16,844	12,271	29,115	57.9	244,481	159,183	403,664	60.6	60,230	44,770	105,000	57.4	53,500	35,800	89,300	59.9
55–59	395,231	206,744	601,975	65.7	15,197	9,231	24,428	62.2	220,820	132,657	353,477	62.5	54,930	37,070	92,000	59.7	45,600	29,300	74,900	60.9
60–64	319,315	141,707	461,022	69.3	12,314	6,305	18,619	66.1	158,401	88,389	246,790	64.2	44,537	27,463	72,000	61.9	38,400	20,600	58,400	65.8
65–69	245,046	98,943	343,989	71.2	10,242	4,032	14,274	71.8	131,401	57,953	189,354	69.4	31,640	16,360	48,000	65.9	30,600	12,300	42,900	71.3
70 and more	272,257	90,051	362,308	75.1	14,362	2,930	17,292	83.1	149,735	46,465	196,200	76.3	40,007	14,993	55,000	72.7	40,600	11,500	52,100	77.9
TOTAL	4,794,614	2,869,777	7,664,391	62.6	220,022	148,861	368,883	59.6	3,089,391	2,010,570	5,099,961	60.6	773,425	541,575	1,315,000	58.8	598,100	410,900	1,009,000	59.3
	South Carolina				South Dakota				Texas				Wisconsin				Total, 19 States			
Under 16	5,204	2,705	7,909	65.8	8,195	3,409	11,604	70.6	50,289	36,726	87,015	57.8					153,447	95,002	248,449	61.8
16	12,184	6,518	18,702	65.2	5,407	3,292	8,699	62.2	45,021	30,522	75,543	59.6	17,408	10,042	27,450	63.4	351,299	233,819	585,118	60.0
17	16,594	7,502	24,096	68.9	6,437	4,282	10,719	60.1	66,700	44,965	111,665	59.7	25,864	16,684	42,548	60.8	466,939	287,134	754,073	61.9
18	14,670	6,956	21,626	67.8	5,953	3,954	9,907	60.1	69,156	44,595	113,751	60.8	12,687	10,242	22,929	55.3	430,364	286,727	717,091	60.0
19	15,217	7,941	23,158	65.7	5,813	4,347	10,160	57.2	72,654	45,546	118,200	61.6	22,584	15,105	37,689	59.9	480,517	326,633	807,150	59.5
20–24	80,453	49,469	129,922	61.9	24,050	21,140	45,190	53.2	329,971	236,070	566,041	58.3	116,398	88,460	204,858	56.8	2,533,833	1,830,656	4,364,489	58.1
25–29	76,809	52,781	129,590	59.3	21,906	19,798	41,704	52.5	321,401	236,881	558,282	57.6	105,458	85,765	191,223	55.2	2,370,738	1,721,370	4,092,108	57.9
30–34	73,218	53,462	126,680	57.8	21,405	18,686	40,091	53.4	320,248	247,090	567,338	56.5	92,324	79,676	172,000	53.7	2,334,638	1,737,691	4,072,329	57.3
35–39	75,246	54,469	129,715	58.0	20,666	16,928	37,594	55.0	320,272	251,111	571,383	56.1	112,684	91,096	203,780	55.3	2,450,111	1,844,458	4,294,569	57.1
40–44	74,312	50,212	124,524	59.7	19,384	15,312	34,696	55.9	292,246	225,075	517,321	56.5	117,931	84,885	202,816	58.2	2,369,841	1,731,315	4,101,156	57.8
45–49	64,506	39,515	104,021	62.0	18,157	15,182	33,339	54.5	262,470	198,837	461,307	56.9	116,646	74,985	191,631	60.9	2,171,513	1,513,732	3,685,245	58.9
50–54	55,365	31,897	87,262	63.5	16,540	12,897	29,437	56.2	236,692	175,939	412,631	57.4	101,014	68,139	169,153	59.7	1,932,277	1,268,751	3,201,028	60.4
55–59	41,977	22,639	64,616	65.0	14,994	9,603	24,597	61.0	197,708	133,423	331,131	59.7	93,054	59,655	152,709	60.9	1,682,758	1,003,280	2,686,038	62.7
60–64	30,171	13,938	44,109	68.4	12,232	7,468	19,700	62.1	151,076	93,156	244,232	61.9	81,373	47,505	128,878	63.1	1,335,790	707,375	2,043,165	65.4
65–69	21,569	9,235	30,804	70.0	10,684	5,322	16,006	66.8	117,487	60,747	178,234	65.9	56,440	23,480	79,920	70.6	1,043,194	462,641	1,505,835	69.3
70 and more	24,838	7,798	32,636	76.0	15,481	3,037	18,518	83.6	135,811	50,898	186,709	72.7	83,714	23,070	106,784	78.4	1,262,762	394,620	1,657,382	76.2
TOTAL	682,333	417,037	1,099,370	62.1	227,304	164,657	391,961	58.0	2,989,202	2,111,581	5,100,783	58.6	1,155,579	778,789	1,934,368	59.7	23,370,021	15,445,204	38,815,225	60.2

olumn, reflect the combined effects of the age mposition of the populations of the States, id the extent of driver license saturation in ich. Mississippi, in 1963, had only 353 ensed drivers per 1,000 persons in the total opulation. The next lowest was Louisiana, aving 397. At the other extreme, Wyoming id 672 licensed drivers per 1,000 persons, and ansas had 652.

Perhaps the most significant information in ble 12 is the number of licensed drivers per 000 persons in the 15–74 age group. The ansas total of 992 driver licenses per 1,000 rsons in the driving age group, is not much gher than the 971 in Wyoming and the 8 in Colorado, and many other States have ore than 900. The lowest number of driver enses per 1,000 persons in the 15–74 group as 629 in Mississippi; next were the 635 in the istrict of Columbia and 637 in Alaska. The mber of driver licenses per 1,000 persons driving age in the other States were broadly stributed between these highs and lows, ithout any obvious pattern.

The ratios of driver licenses to persons in the 5–74 groups raise some interesting questions. o begin with, some of the ratios would seem nprobable, if we were to assume that all enses were held by persons residing in the ate and included in the Census Bureau opulation counts. Granting that the ability nd desire to drive a motor vehicle is almost niversal, it is difficult to conceive of circumances that would result in a number of river licenses in any State that is equal to 92 out of each 1,000 persons in the 15–74 ge group. In Kansas, for which the statistics eld this rate, 16 is the minimum age at which license can be obtained. The need to amine the statistics is obvious.

Discussion of Limitations and Summary

There were two reasons for selecting the 5–74 age group for many of the essential atistical comparisons made in this study:) The State-by-State population data were adily available from the Bureau of the ensus, and (2) the age grouping is one in hich we should expect to count all but a ery few active motor vehicle operators. The 5-year terminal is reasonably close to the inimum driving ages permitted by the tates, and there is undoubtedly a statistical alancing of persons who do not obtain driver enses at age 15 by persons more than 74 ears old who retain their licenses.

Undoubtedly, many persons hold valid river licenses from more than one State. Even if this were not legal, there is no present procedure for eliminating the duplication caused by persons who move from one State to another, and who obtain another license, provided, of course, that the person has a good driving record. The requirements of the States for the obtaining of a driver's license by a new resident, coupled with the absence of any effective general ban on a driver continuing to renew licenses previously obtained in other States, tend to increase the totals of drivers' licenses. Although it seems probable that holding of multiple driver licenses is fairly common, examination of the ratios of licenses to motor-vehicle registrations, in the last column of table 12, makes it seem doubtful that the total resultant duplication could be very large. Indeed, another question is raised. Are there any substantial number of vehicles operated by unlicensed drivers, including persons who have allowed their licenses to expire? Possession of a driver's license is not a prerequisite to ownership or licensing of a vehicle in any State. No effort was made in this study to analyze the possible statistical effects of the holding of multiple licenses, nor to determine the extent of enforcement of the requirement of a license. However, it is not suggested that a study of these factors would be likely to yield conclusive findings.

The extent or diligence of enforcement of the license requirements for operators of motor vehicles, coupled with the severity of penalties for noncompliance, undoubtedly have some effect on the number of driver licenses issued. Probably of much greater importance, however, is the ease or difficulty of obtaining and retaining a license. Where the requirements are rigid, and strictly enforced, the process could be expected to reduce the number of licenses issued by screening out potentially incompetent or otherwise hazardous drivers. A ratio of licenses to persons in the 15-74 age group that is lower in one State than in another of similar characteristics might easily result from differences in the requirements of the States for obtaining licenses. This study does attempt to detect or measure the extent of any such effect, but the information in tables 1, 4, 5, and 6 may be useful for those who wish to do so. The tables, however, are of no assistance in determining the extent to which differences in the interpretations and strictness of enforcement among the States may affect either the number of licenses issued or the statistical structure of the driver-licensed population.

The fact that the mere grouping of number, sex, and age of licensed drivers does not furnish any information on driving exposure by the groups is so obvious that the authors are reluctant to state it. We do so only to suggest that it would be highly desirable for others to correlate the information in this report with available data on the miles driven by persons in corresponding age and sex groups. Such a study should prove to be extremely useful for many purposes.

The data and estimates presented in this report are admittedly less than might be desired, but they do produce some relationships between the number of driver licenses,

Table 9.—Estimated total drivers' licenses in force, by State and sex, 1963

State	Male drivers	Female drivers	Total drivers	Percentage male drivers of total
	Thous.	*Thous.*	*Thous.*	*Percent*
Alabama	891	587	1,478	60.3
Alaska	62	42	104	59.1
Arizona	534	361	895	59.7
Arkansas	531	350	881	60.3
California	5,367	3,686	9,053	59.3
Colorado	698	458	1,156	60.4
Connecticut	864	619	1,483	58.3
Delaware	153	112	265	57.7
Florida	1,906	1,167	3,073	62.0
Georgia	1,268	835	2,103	60.3
Hawaii	261	180	441	59.1
Idaho	240	162	402	59.8
Illinois	3,139	2,090	5,229	60.0
Indiana	1,507	993	2,500	60.3
Iowa	853	622	1,475	57.8
Kansas	855	586	1,441	59.3
Kentucky	880	521	1,401	62.8
Louisiana	819	539	1,358	60.3
Maine	286	177	463	61.9
Maryland	1,001	613	1,614	62.0
Massachusetts	1,515	934	2,449	61.9
Michigan	2,360	1,617	3,977	59.4
Minnesota	1,106	770	1,876	59.0
Mississippi	487	321	808	60.3
Missouri	1,368	900	2,268	60.3
Montana	232	169	401	57.7
Nebraska	514	363	877	58.6
Nevada	123	83	206	59.8
New Hampshire	224	138	362	61.9
New Jersey	1,960	1,209	3,169	61.9
New Mexico	317	213	530	59.8
New York	4,794	2,870	7,664	62.6
North Carolina	1,417	867	2,284	62.0
North Dakota	220	149	369	59.7
Ohio	3,089	2,011	5,100	60.6
Oklahoma	774	541	1,315	58.8
Oregon	598	411	1,009	59.3
Pennsylvania	3,620	2,232	5,852	61.9
Rhode Island	273	168	441	61.9
South Carolina	682	417	1,099	62.1
South Dakota	227	165	392	58.0
Tennessee	1,071	705	1,776	60.3
Texas	2,989	2,112	5,101	58.6
Utah	328	220	548	59.8
Vermont	120	74	194	61.9
Virginia	1,250	765	2,015	62.0
Washington	897	616	1,513	59.3
West Virginia	539	355	894	60.3
Wisconsin	1,155	779	1,934	59.7
Wyoming	135	91	226	59.8
Dist. of Col	211	136	347	60.5
TOTAL	56,710	37,101	93,811	60.5

Table 10.—Motor-vehicle operators' and chauffeurs' licenses, 1963 [1]

[Compiled for calendar year from reports of State authorities]

State	Learners' permits [2]		Operators' licenses						Chauffeurs' licenses [4]						Estimated total licenses in force during 1963 [5]	Private and commercial motor vehicles registered in 1963	Licensed operators per registered motor vehicle
	Issued during 1963	Amount of fee	Issued during 1963	Issued for, years	Renewal date	Amount of fee [3]			Issued during 1963	Issued for, years	Renewal date	Amount of fee [3]					
						New	Renewal	Duplicate				New	Renewal	Duplicate			
Alabama	79,197	$0.35	720,082	2	Birthday	$4.25	$4.25	$0.25		Not required.					1,478,420	1,435,359	1.03
Alaska	4,900	1.00	29,072	3	Birthday	5.00	5.00	1.00	[6] 175	1	Sept. 2	$2.00			103,869	89,412	1.16
Arizona	24,721	*2.00	271,903	3	Birthday	2.50	2.50	1.00	48,351	2	Birthday	2.50	$2.50	$1.00	895,299	733,505	1.22
Arkansas	N.A.	No fee	846,249	1	Jan. 1	2.00	2.00	2.00	34,277	1	Jan. 1	5.00	5.00	1.00	880,526	819,327	1.07
California	420,108	[7] 3.00	[8] 2,732,190	3 and 5	Birthday	3.00	3.00	1.00	[8] 40,641	3 and 5	Birthday	3.00	3.00	1.00	9,053,189	8,983,975	1.01
Colorado	33,294	[7] 2.25	358,872	3	Birthday	2.25	2.25	1.25	37,825	3	Birthday	5.25	5.25	1.25	1,156,167	1,052,104	1.10
Connecticut			809,250	2	Birth mo.	[9]	6.00	1.00	8,500	1	May 1	3.00	3.00	1.00	*1,482,600	1,261,770	1.18
Delaware	23,004	[7] 4.00	48,771	[10]	Birthday	4.00	4.00	1.00	5,097	[10]	Birthday	4.00	4.00	1.00	265,401	219,836	1.21
Florida	137,862	3.00	1,288,741	2	Birth mo.	3.00	3.00	.25	169,529	2	Birth mo.	5.00	5.00	.25	3,073,245	2,695,829	1.14
Georgia	83,887	1.00	966,333	1 or 5	Birthday	[11] 1.00	1.00	1.00	98,493	1 or 5	Birthday	[11] 2.00	2.00	1.00	2,102,442	1,752,035	1.20
Hawaii	33,885	*1.00	47,132	Indefinite		3.00		.50	3,803	1	Issuance	3.00	1.00	.50	*441,298	265,842	1.66
Idaho	11,295	[12] 3.00	206,300	2	Birthday	4.00	4.00	.75	18,660	1	Birthday	3.00	3.00	.75	402,143	398,161	1.01
Illinois	234,549	[7] 3.00	1,424,121	3	Birthday	3.00	3.00	1.00	307,116	1	Issuance	5.00	3.00	1.00	5,228,632	4,064,791	1.29
Indiana	77,920	*1.00	884,719	2	Birth mo.	1.50	1.50	1.50	[13] 234,179	1	Birth mo.	1.50	1.50	1.50	2,499,735	2,232,258	1.12
Iowa	51,377	3.00	671,595	2	Birthday	3.00	3.00	.25	153,634	1	Birthday	4.00	4.00	.50	1,474,980	1,414,312	1.04
Kansas	43,272	.50	626,011	2	Birthday	[14] 5.00	2.00	.50	59,727	2	Birthday	[14] 7.00	4.00	.50	1,440,977	1,261,771	1.14
Kentucky	139,975	1.00	650,177	2	Birth mo.	2.00	2.00	1.00	18,725	1	Jan. 1	2.00	2.00	2.00	*1,401,459	1,334,723	1.05
Louisiana	N.A.	[7] 2.50	665,678	2	Birthday	2.50	2.50	1.50	145,591	1	Issuance	3.50	3.50	1.50	1,358,046	1,281,479	1.06
Maine	45,991	3.00	463,465	1	Birthday	2.00	2.00	.50		Not required.					463,465	401,687	1.15
Maryland	164,959	* [7] 5.00	751,037	2	Birth mo.	*7.00	*2.00	.50	56,343	2	Issuance	*8.00	*3.00	.50	*1,613,746	1,301,408	1.24
Massachusetts			1,387,612	2	Birthday	[14] 8.00	5.00	1.50	[6] 2,693	1	Issuance	[14] 5.50	2.50	1.50	*2,448,517	1,955,851	1.25
Michigan	N.A.	No fee	1,431,761	3	Birthday	4.00	2.50	1.00	242,572	1	Issuance	4.00	2.75	1.00	*3,977,165	3,559,044	1.12
Minnesota	149,351	1.00	453,534	4	Birthday	3.00	3.00	.50	211,882	1	Feb. 1	3.00	[15] 2.00	1.00	*1,876,073	1,707,037	1.10
Mississippi	11,973	.50	525,911	1 or 2	Issuance	* [16] 2.50	* [16] 2.50	1.00	43,545	1 or 2	Issuance	*[16] 4.50	*[16] 4.50	1.00	808,199	807,238	1.00
Missouri	201,861	.25	465,445	3	Issuance	1.00	1.00	.25	192,663	1	Issuance	3.00	3.00	.25	2,268,392	1,880,346	1.21
Montana	5,733	*[7] 4.00	147,664	2	Birthday	4.00	4.00	.50	23,929	2	Birthday	4.00	4.00	.50	401,350	411,090	0.98
Nebraska	47,542	1.00	742,381	2	Sept. 1 odd year.	3.00	3.00	.50		Not required.					877,385	798,589	1.10
Nevada	5,435	[7] 3.00	118,202	5	Birthday	3.00	3.00	1.00	12,483	5	Birthday	5.00	5.00	1.00	205,885	235,162	0.88
N. Hampshire			101,461	2	Birthday	5.00	4.00	1.00	12,007	2	Birthday	7.00	4.00	1.00	361,547	280,030	1.29
New Jersey	381,820	*2.00	2,089,223	1 or 3	Issuance	[17] 3.00	[17] 3.00	2.00	[18] 14,790	Indefinite		No fee			*3,168,858	2,710,969	1.17
New Mexico	15,817	.50	223,699	2	Birth mo.	3.25	3.25	1.00	63,971	1	Birth mo.	2.75	2.75	1.00	529,791	473,028	1.12
New York	499,783	.50	1,879,550	3	Issuance	[14] 5.00	3.00	3.00	387,283	3	Issuance	[14] 8.00	6.00	3.00	7,664,391	5,455,455	1.40
North Carolina	123,913	No fee	569,982	4	Birthday	2.50	2.50	.50	73,187	2	Birthday	4.00	4.00	.50	2,283,576	1,891,847	1.21
North Dakota	N.A.	[7] 3.00	342,356	2	Birth mo.	*[19] 3.00	*3.00	1.00		Not required.					368,883	369,216	1.00
Ohio	391,744	*.50	2,528,605	3	Birthday	*.75	*.75	*.25	219,434	3	Birthday	*1.25	*1.25	*[20] .25	5,099,961	4,424,528	1.15
Oklahoma	15,780	No fee	599,731	2	Birth mo.	4.00	4.00	1.00	[13] 81,802	2	Birth mo.	8.00	8.00	1.00	1,315,000	1,313,615	1.00
Oregon	61,905	.50	539,592	2	Birthday	[21]	2.75	.25	26,381	2	Birthday	2.00	2.00	.25	1,009,000	994,804	1.01
Pennsylvania	349,489	*[7] 4.00	4,080,369	2	Feb. 1	4.00	4.00	.50		Not required.					5,851,840	4,571,750	1.28
Rhode Island	21,335	No fee	203,289	2	Oct. 1	[14] 13.00	8.00	1.00	12,534	2	Oct. 1	[14] 13.00	8.00	1.00	440,726	369,352	1.19
South Carolina	66,785	No fee	79,571	4	July 1	.50	.50	.50	[22] 6,811	1	Jan. 1	2.00	2.00	No fee	*1,099,370	956,151	1.15
South Dakota	N.A.	2.00	73,009	4	Birthday	2.00	2.00	2.00		Not required.					391,961	381,833	1.03
Tennessee	22,890	[7] 4.00	1,562,678	2	Birthday	4.00	4.00	2.00	95,452	2	Birthday	6.00	6.00	2.00	1,775,960	1,476,876	1.20
Texas	138,177	* [7] 3.00	[13] 2,658,095	2	Issuance	3.00	3.00	.25	150,466	1	Issuance	6.00	6.00	.25	5,100,783	5,009,008	1.02
Utah	24,823	[7] 3.00	124,287	5	Birthday	[17] 3.00	2.00	1.00	5,415	5	Birthday	[17] 3.00	2.00	1.00	547,952	476,642	1.15
Vermont	5,520	1.00	193,807	1	Birthday	[14] 4.50	2.50	.50		Not required.					193,807	160,675	1.21
Virginia	N.A.	No fee	815,492	3	Birth mo.	2.00	2.00	.25	88,601	1	Issuance	3.00	3.00	.25	2,014,448	1,619,474	1.24
Washington	184,492	[7] 1.50	801,867	2	Birthday	[14] 6.00	4.00	.50		Not required.					1,513,328	1,498,386	1.01
West Virginia	55,368	4.00	202,377	4	Issuance	5.00	5.00	1.00	43,251	1	Issuance	3.00	3.00	1.00	893,597	636,160	1.40
Wisconsin	148,435	1.50	991,225	2	Birthday	[14] 4.50	2.00	1.00	[6] 68,517	1	Birthday	[14] 5.00	2.00	1.00	1,934,368	1,711,987	1.13
Wyoming	6,523	No fee	54,358	3	Birthday	2.00	2.00	1.00	15,309	1	Issuance	2.00	2.00	1.00	226,438	212,879	1.06
Dist. of Col	46,034	*2.00	108,513	3	Issuance	3.00	3.00	.50		Not required.					347,193	211,954	1.64
TOTAL															93,811,383	81,560,560	1.15

[1] Complete data for all States were not available.

[2] In many States an instruction or learner's permit is provided but is not required except under certain circumstances. Only in the States indicated with an asterisk (*) is such a permit mandatory for applicants not possessing a valid operator's license. An instruction or learner's permit is not provided in the States for which leaders (...) appear. The number of permits issued is not available in the States for which N.A. appears.

[3] In the States marked with an asterisk (*) an additional nominal local service charge is collected at the time the license is issued.

[4] Includes public service and other special licenses that are issued to operators of vehicles for hire.

[5] Estimated by the Bureau of Public Roads from data reported by the States for current and previous years. No allowance was made for deaths, emigrations, or revocations. Chauffeurs' licenses have not been added to operators' licenses in the States that require an operator's license in addition to the chauffeur's license. Such States are indicated with an asterisk (*).

[6] Special licenses to operate school buses. In Wisconsin 5,261 are included at $2.50 each for a 2-year term.

[7] Permit fee is credited to operator license fee: in Pennsylvania $2 and in Washington $0.50 of permit fee is credited to operator license fee.

[8] Since September 15, 1961, drivers' licenses have not been designated as *Operator* or *Chauffeur* licenses by the State. The applicant is required to take an examination appropriate to the type of motor vehicle he will operate, class 1, 2, or 3. The class 3 license corresponds to the former *Operator* license.

[9] $5 examination fee, plus 25 cents per month from date of issuance to last day of month of next birthday, plus $3 or $6, depending upon year of birth.

[10] Licenses are issued for a 2-year period, but drivers meeting certain requirements and having a motor-vehicle operation record that shows no previous arrest or conviction can obtain licenses for an indefinite period—$10.

The number of licenses issued were:

	2-years	Indefinite	Tot
Operators	70,288	1,487	71,
Chauffeurs	4,912	185	5,

[11] Operator's fee is $5 for 5 years and chauffeur's fee is $10 for 5 years. Free licenses veterans.

[12] Every applicant for an instruction permit or operator's license who is required to t or who elects to take a driver training course in a public school is required to pay an ac tion fee of $3.

[13] Special commercial licenses are included as follows: 20,486 public passenger in India 43,821 commercial chauffeur in Oklahoma at $10 each, and 832,621 commercial operator Texas at $4.50 each, 1-year term.

[14] The difference between new and renewal license fees is the charge for examination w one is required, except in Wisconsin, where the examination fee is $2.

[15] Chauffeurs' licenses renewed during February are $2, thereafter $2.50. School operators' licenses (which are also valid chauffeurs' licenses) renewed during May are thereafter $2.50.

[16] Option of obtaining 1- or 2-year permits at $2.50 per year for operator's license and $ a year for chauffeur's license.

[17] 3-year license, $8 in New Jersey; original license issued for a 3-year term in Utah.

[18] Special bus drivers licenses. Issued for an indefinite period, but evidence of phy fitness, good character, and experience is required every 12 months.

[19] License fee for those under 18 is $1.50.

[20] An additional $0.50 is charged if the chauffeur's badge also needs to be replaced.

[21] Original license fees vary, $2.25, $2.75, or $3.25, depending upon length of time from of application to date of first renewal.

[22] A permit to operate "For hire" vehicles is required.

Table 11—Distribution of licensed drivers, by sex and by percentage in each age group 1963

Age	Male drivers	Female drivers	All drivers
Years	*Percent*	*Percent*	*Percent*
Under 16	0.3	0.3	0.3
16	1.6	1.6	1.6
17	2.2	1.8	2.0
18	1.8	1.8	1.8
19	2.0	2.1	2.0
(Under 20)	(7.9)	(7.6)	(7.7)
20–24	10.8	11.8	11.2
25–29	10.1	11.1	10.5
30–34	9.9	11.4	10.5
35–39	10.5	12.1	11.1
40–44	10.2	11.5	10.7
45–49	9.4	9.9	9.6
50–54	8.3	8.2	8.3
55–59	7.2	6.5	6.9
60–64	5.8	4.5	5.2
65–69	4.5	2.9	3.9
70 and over	5.4	2.5	4.4
TOTAL	100.0	100.0	100.0

population, and motor-vehicle registrations. Some data were obtained from records not well adapted to the extraction of statistics, or lacking the review and refinement that would have been desirable to assure complete accuracy and consistency. Many of the State offices that administer drivers' licenses suffer from a numbing lack of manpower and equipment to do such a job.

Yet even with these shortcomings, the report constitutes a sort of breakthrough. It attempts a summary of more information on the number, age, and sex of licensed drivers than has been found elsewhere; and it should be an encouragement to those who have use for such information. It is hoped that this, in turn, will bring about further steps toward providing the means to extract the data from driver license records, so that its tremendous potential value to government, business, and the general public may be fully realized.

Table 12.—Ratio of drivers' licenses in force to population and motor vehicles, 1963

State	Total population	Persons of driving age	Vehicle registration	Drivers' licenses			
				Number	Per 1,000 total population	Per 1,000 driving population	Per vehicle
	Thous.	*Thous.*	*Thous.*	*Thous.*	*Number*	*Number*	*Number*
Alabama	3,347	2,089	1,435	1,478	442	708	1.03
Alaska	248	163	90	104	419	637	1.16
Arizona	1,559	938	734	895	574	955	1.22
Arkansas	1,858	1,110	819	881	474	793	1.07
California	17,590	11,998	8,984	9,053	515	755	1.01
Colorado	1,961	1,195	1,052	1,156	590	968	1.10
Connecticut	2,666	1,788	1,262	1,483	556	829	1.18
Delaware	476	315	220	265	558	843	1.21
Florida	5,652	3,746	2,696	3,073	544	820	1.14
Georgia	4,140	2,607	1,752	2,103	508	807	1.20
Hawaii	694	467	266	441	636	945	1.66
Idaho	713	426	398	402	564	944	1.01
Illinois	10,182	6,966	4,065	5,229	514	751	1.29
Indiana	4,694	3,135	2,232	2,500	533	797	1.12
Iowa	2,780	1,782	1,414	1,475	531	828	1.04
Kansas	2,225	1,452	1,262	1,441	652	992	1.14
Kentucky	3,095	1,958	1,335	1,401	453	716	1.05
Louisiana	3,418	2,095	1,281	1,358	397	648	1.06
Maine	982	634	402	463	472	731	1.15
Maryland	3,289	2,158	1,301	1,614	491	748	1.24
Massachusetts	5,218	3,509	1,956	2,449	469	698	1.25
Michigan	8,116	5,245	3,559	3,977	490	758	1.12
Minnesota	3,500	2,215	1,707	1,876	536	847	1.10
Mississippi	2,290	1,284	807	808	353	629	1.00
Missouri	4,328	2,910	1,880	2,268	524	780	1.21
Montana	707	436	411	401	568	921	0.98
Nebraska	1,460	919	799	877	601	955	1.10
Nevada	368	218	235	206	560	944	0.88
New Hampshire	627	410	280	362	577	882	1.29
New Jersey	6,470	4,351	2,711	3,169	490	728	1.17
New Mexico	1,018	626	473	530	520	846	1.12
New York	17,708	11,863	5,455	7,664	433	646	1.40
North Carolina	4,760	2,998	1,892	2,284	480	762	1.21
North Dakota	634	390	369	369	582	946	1.00
Ohio	10,173	6,604	4,425	5,100	501	772	1.15
Oklahoma	2,487	1,545	1,314	1,315	529	851	1.00
Oregon	1,826	1,187	995	1,009	553	850	1.01
Pennsylvania	11,424	7,720	4,572	5,852	512	758	1.28
Rhode Island	885	590	369	441	498	747	1.19
South Carolina	2,483	1,516	956	1,099	443	725	1.15
South Dakota	737	424	382	392	532	924	1.03
Tennessee	3,694	2,358	1,477	1,776	480	753	1.20
Texas	10,323	6,489	5,009	5,101	494	786	1.02
Utah	983	574	477	548	557	955	1.15
Vermont	390	251	161	194	497	772	1.21
Virginia	4,331	2,705	1,619	2,015	465	745	1.24
Washington	3,050	1,931	1,498	1,513	496	784	1.01
West Virginia	1,778	1,158	636	894	503	772	1.40
Wisconsin	4,060	2,606	1,712	1,934	476	742	1.13
Wyoming	337	233	213	226	672	971	1.06
District of Columbia	797	547	212	347	436	635	1.64
TOTAL	188,531	122,834	81,561	93,811	498	764	1.15

New Publications

Three new publications have been issued recently by the Bureau of Public Roads, U.S. Department of Commerce. All are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. The price for each is as indicated and should be included with your order: *A Quarter Century of Financing Municipal Highways, 1937–61, $1.00; Traffic Assignment Manual,* $1.50; *Accidents on Main Rural Highways Related To Speed, Driver, and Vehicle, 35 cents.* A brief discussion of each of the new publications is presented in the following paragraphs.

A Quarter Century of Financing Municipal Highways, 1937–61

The first comprehensive survey of highway receipts, disbursements, and debt transactions of municipal governments during the past 25 years is presented in *A Quarter Century of Financing Municipal Highways, 1937–61.* Information is presented primarily on the highway revenues and expenditures of municipal governments. Data on the finances of State and county governments as they pertain to municipal areas have been included for comparative purposes. To broaden the area of coverage, estimates have been included for the 1921–36 period in the summary data.

This publication consists of two sections: The first contains summary tables and a discussion of municipal highway finance; the second (appendix) contains the detailed State-by-State tabulations upon which the summary tables were based. The tabulations of the highway finances of municipal governments that have been published in the Bureau of Public Roads annual *Highway Statistics* series since 1949, are superseded by the data in this publication. *A Quarter Century of Financing Municipal Highways, 1937–61* has been issued as a companion publication to the *Financing of Highways by Counties and Local Rural Governments, 1942–51.*

Traffic Assignment Manual

Issued as a companion publication to *Calibrating and Testing a Gravity Model for Any Size Urban Area,* which is also for sale by the Superintendent of Documents, the *Traffic Assignment Manual* documents the complete process of traffic assignment as currently defined and primarily is for use with the IBM 7090/94 computer. A brief history and general concepts of traffic assignment are presented, and the step-by-step procedures for each phase of the traffic assignment process are given. Also included is a discussion of the theory involved in the different phases of traffic assignment, a detailed glossary of terms, and a selected bibliography. The operation of the BELL and BELMN control monitors are described in detail, and the complete battery of Public Roads traffic assignment programs are included. This manual and the gravity model manual are expected to provide transportation planners with the necessary tools for comprehensive transportation planning studies.

Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle

Significant information on the relation of speed and characteristics of vehicles and drivers involved in accidents on main rural highways is presented in *Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle.* It is believed that the material presented in this publication is the first based on a nationwide study from which it has been possible to develop an understanding of these relationships. The study findings apply to 2- and 4-lane main rural highways of the nonfreeway type.

One of the important findings reported in this publication is that the greater the differential in speed of a driver and his vehicle from the average speed of all traffic, the greater the chance of that driver being involved in an accident. For example, a driver traveling at 40 or 80 miles per hour in relation to an average speed of 60 miles per hour for all traffic has a substantially greater chance of being involved in an accident than a driver traveling at the average speed.

Errata

In vol. 32, No. 9, August 1964, PUBLIC ROADS, *Effect of Moisture on Bituminous Pavements in Rocky Mountain Areas,* change last three sentences in first column of page 51 to read: Seal coats cost about 11 cents per square yard or, on a 3-inch thick mat, about an additional 70 cents per ton of mixture. This is more expensive than either the chemical additive, at 11 cents per ton of mixture, or hydrated lime, at 45 cents per ton of mixture. Furthermore, the seal coat may not always solve the problem, as there are so many uncertainties involved in seal coat construction as to make the results somewhat of a gamble.

U.S. GOVERNMENT PRINTING OFFICE:1964

PUBLICATIONS of the Bureau of Public Roads

A list of the more important articles in PUBLIC ROADS *and title sheets for volumes 24–32 are available upon request addressed to Bureau of Public Roads, Washington, D.C., 20235.*

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Annual Reports of the Bureau of Public Roads:

1951, 35 cents. 1955, 25 cents. 1958, 30 cents. 1959, 40 cents. 1960, 35 cents. 1962, 35 cents. 1963, 35 cents. (Other years are now out of print.)

REPORTS TO CONGRESS

Actual Discussion of Motortruck Operation, Regulation and Taxation (1951). 30 cents.

Federal Role in Highway Safety, House Document No. 93 (1959). 30 cents.

Highway Cost Allocation Study:

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