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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

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COVER

Four level interchange near Dayton, Ohio, where highways I-75 and U.S. 35 intersect. The use of four levels reduced the size of the construction area in the costly industrial vicinity.

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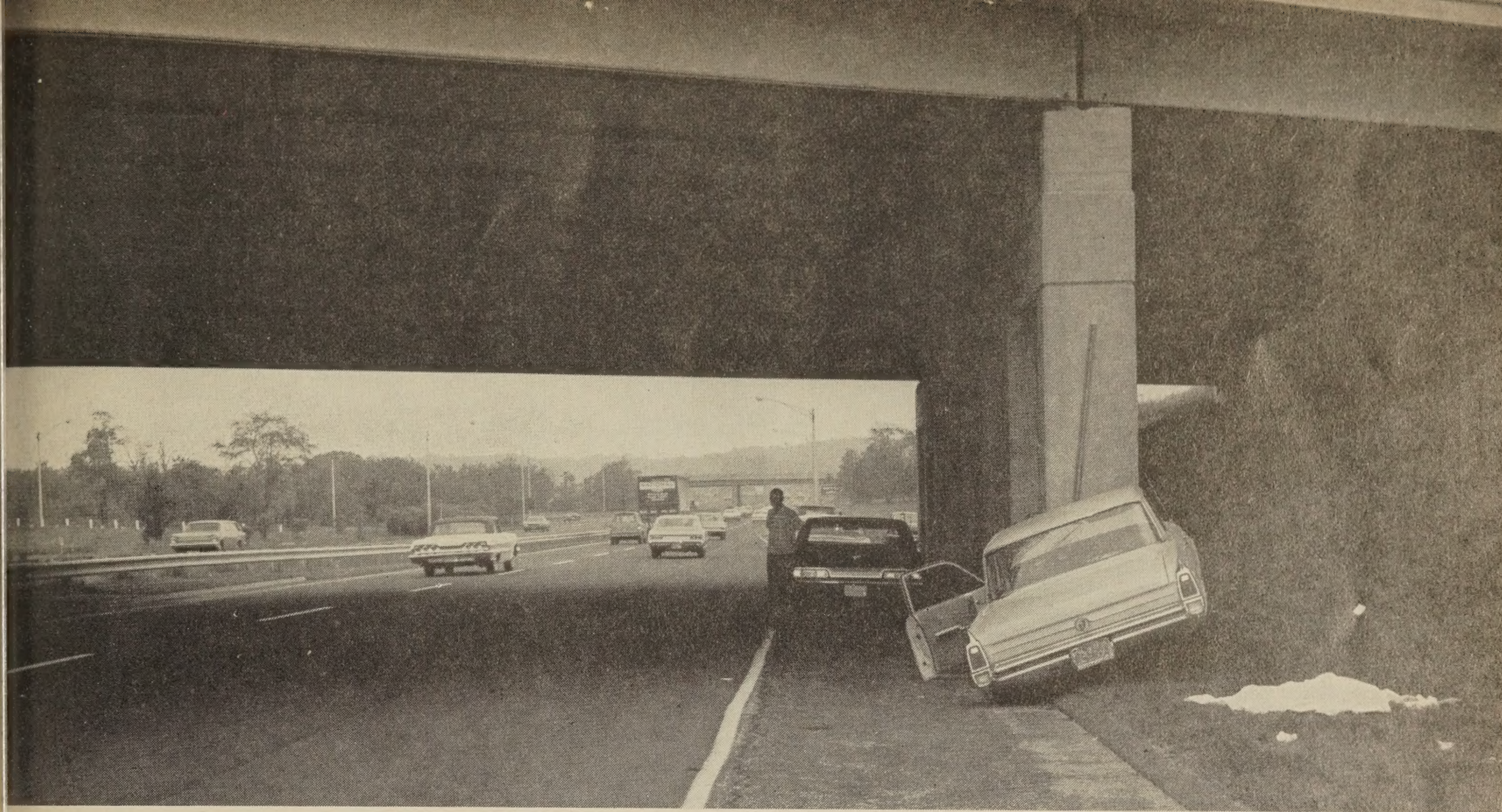

The most prevalent type of accident on the Interstate Highway System is the single-vehicle accident, in which the vehicle strikes a fixed roadside object or overturns.

Fatal Accidents on Completed Sections of the Interstate Highway System, 1968

BY THE OFFICE OF
TRAFFIC OPERATIONS
BUREAU OF PUBLIC ROADS

Reported by HAROLD R. HOSEA,
Accident Records Analyst,
Programs Division

Introduction

REPORTS of 2,754 fatal accidents that occurred in 1968 on sections of the Interstate Highway System complying fully to Interstate design standards have been analyzed from police investigation reports obtained from the States. These accidents, which constitute slightly less than 90 percent of the total allocated to the Interstate System under statistical reporting procedures developed by the Current Planning Division, Bureau of Public Roads, are discussed here. Accidents that occurred on certain frontage, service, and connector roads were omitted, as were a few for which reports were received too late to include in the discussion. Statistical data, compiled in accordance with the Planning Division's procedures, are summarized in an annual publication of the Bureau of Public Roads (*1*)[1].

The fatal accidents that occurred on the Interstate System in 1967 were also analyzed, but no formal report was issued for general distribution. Certain data for the two years, 1967 and 1968, were compared, and important differences in accident patterns are reported here, although not all the data are readily comparable because of recent refinements in statistical treatment.

Number and Characteristics of the Accidents

Types of accidents

The 2,754 accidents were divided into two broad categories for analysis: those involving a single vehicle, and those involving two or more vehicles. As indicated in table 1, the single-vehicle accidents accounted for two-thirds of the total. This ratio is virtually identical with that for the 1967 accidents, but there were minor differences in the proportions of specific types of accidents. The most significant difference was in the number of head-on collisions, which amounted to a smaller percentage of the total in 1968 than in 1967. This was true of both principal types of head-on collisions—those caused by wrong-way drivers and those caused by out-of-control vehicles that crossed medians.

Pedestrian accidents accounted for more than 7 percent of the accidents in both years, a proportion that seems high, as pedestrians are excluded by law or regulation from the Interstate System. In the 1967 study, it was

[1] Italic numbers in parentheses identify the references listed on page 224.

Table 1.—Fatal accidents on completed sections of the Interstate System, 1968—accident types, fatalities, injuries, and property damage

Type of accident	Accidents			Fatalities		Injuries		Property damage	
	Number	Percent		Total	Per accident	Total	Per accident	Total	Per accident
		Total	Subgroup						
								Thousands of dollars	*Dollars*
Total accidents, all types	2,754	100.0	----------	3,326	1.21	3,067	1.14	7,783.9	2,826
Single vehicle:									
Ran off road	1,462	53.1	79.4	1,685	1.16	1,223	0.84	3,281.3	2,244
Overturn on road	31	1.1	1.7	37	1.19	36	1.16	35.6	1,148
Collision with parked vehicle	96	3.5	5.2	114	1.19	111	1.16	440.2	4,585
Pedestrian:									
Persons outside their vehicles	61	2.2	3.3	65	1.07	11	0.18	15.3	251
Trespassers	153	5.6	8.3	154	1.01	12	0.08	40.0	261
Total pedestrian	214	7.8	11.6	219	1.02	23	0.11	55.3	258
Other	[1] 39	1.4	2.1	42	1.08	30	0.77	75.2	1,928
Total single vehicle	1,842	66.9	100.0	2,097	1.14	1,423	0.77	3,887.6	2,111
Multiple vehicle:									
Rear-end collision	411	14.9	45.1	504	1.23	667	1.62	2,006.6	4,882
Head-on collision:									
Wrong-way driver	131	4.8	14.4	230	1.76	222	1.69	416.6	3,180
Vehicles from opposing lanes	164	5.9	18.0	243	1.48	417	2.54	783.3	4,776
Other	14	0.5	1.5	22	1.57	25	1.79	57.5	4,107
Total head-on collision	309	11.2	33.9	495	1.61	664	2.15	1,257.4	4,069
Broadside collision	65	2.4	7.1	81	1.25	129	1.98	197.8	3,043
Sideswipe	127	4.6	13.9	149	1.17	184	1.45	434.5	3,421
Total multiple vehicle	912	33.1	100.0	1,229	1.35	1,644	1.80	3,896.3	4,272

[1] Primarily, vehicles that struck other objects or non-motor vehicles on the road, and accidents in which occupants fell from vehicles.

assumed that relatively few of the pedestrians were *trespassers* as distinguished from persons who had left their vehicles for one reason or another. To test this assumption, the two groups were coded separately in the study reported here. Of the 219 pedestrian fatalities, 154, or 70 percent, were actually *trespassers.* (See table 1.)

Collisions with properly parked vehicles are classified as single-vehicle accidents. Collisions with vehicles standing on the traveled way are classified as other types of accidents, depending on the position of the vehicle struck. In both years, accidents in which vehicles ran off the road and did not collide with another vehicle were the most frequent. This type of accident is discussed later in detail.

Fatalities and injuries

The 2,754 accidents resulted in 3,326 fatalities or 1.21 deaths per accident. Single-vehicle accidents resulted in an average of 1.14 fatalities per accident, which corresponded to 1.35 fatalities per accident in multiple-vehicle accidents. These rates did not differ significantly from those for 1967. Head-on collisions caused by wrong-way drivers produced the highest fatality rate, 1.76 per accident.

There were 1.14 nonfatal injuries per fatal accident reported in 1968, a somewhat lower average than that for 1967. Total injuries in all fatal accidents were 3,067.

Accident costs

To estimate the economic loss in fatal accidents, the following figures suggested by the National Safety Council (*2*) have been used for fatalities and injuries. It is recognized that there are numerous other figures widely used for this purpose and any different values can be substituted by simple multiplications.

Table 2.—Fatal accidents on completed sections of the Interstate System, 1968—accident types and light conditions

Type of accident	Total	Light condition					
		Daylight	Darkness			Dawn or dusk	Not reported
			Total	Unlighted	Lighted		
Total accidents, all types:							
Number	2,754	1,173	1,453	1,177	276	113	15
Percent	100	43	53	43	10	4	(1)
Single vehicle:							
Number	1,842	777	982	792	190	74	9
Percent	100	43	53	43	10	4	(1)
Ran off road:							
Number	1,462	646	746	593	153	67	3
Percent	100	44	51	41	10	5	(1)
Pedestrian:							
Number	214	58	152	123	29	2	2
Percent	100	27	72	58	14	1	(1)
Multiple vehicle:							
Number	912	396	471	385	86	39	6
Percent	100	44	52	43	9	4	(1)
Rear-end collisions:							
Number	411	139	249	205	44	20	3
Percent	100	34	61	50	11	5	(1)
Head-on collisions:							
Number	309	153	138	115	23	15	3
Percent	100	50	45	38	7	5	(1)
Wrong-way driver:							
Number	131	38	89	73	16	4	----------
Percent	100	29	68	56	12	3	----------
Vehicles from opposing lanes:							
Number	164	110	42	35	7	10	2
Percent	100	68	26	22	4	6	(1)

[1] Accidents not reported are excluded from percentage distributions.

Table 3.—Fatal accidents on completed sections of the Interstate System, 1968—vehicle types and total travel [1]

Type of vehicle	Vehicle miles [2]		Accidents		Fatalities		Injuries	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
	Million							
Total, all types	111,368	100.0	2,754	100.0	3,326	100.0	3,067	100.0
Passenger vehicles	88,784	79.7	2,243	81.4	2,745	82.6	2,649	86.4
Property-carrying vehicles:								
Combinations	11,399	10.2	253	9.2	291	8.7	205	6.7
All single-unit trucks:								
Panels and pickups	7,563	6.8	181	6.6	----------	----------	----------	----------
Other single units	3,622	3.3	77	2.8	----------	----------	----------	----------
Total single-unit trucks	11,185	10.1	258	9.4	290	8.7	213	6.9
Total property-carrying vehicles	22,584	20.3	511	18.6	581	17.4	418	13.6

[1] Includes the one vehicle primarily responsible for each accident, as indicated by police investigation reports.
[2] Estimates (1967) by Public Roads Office of Planning.

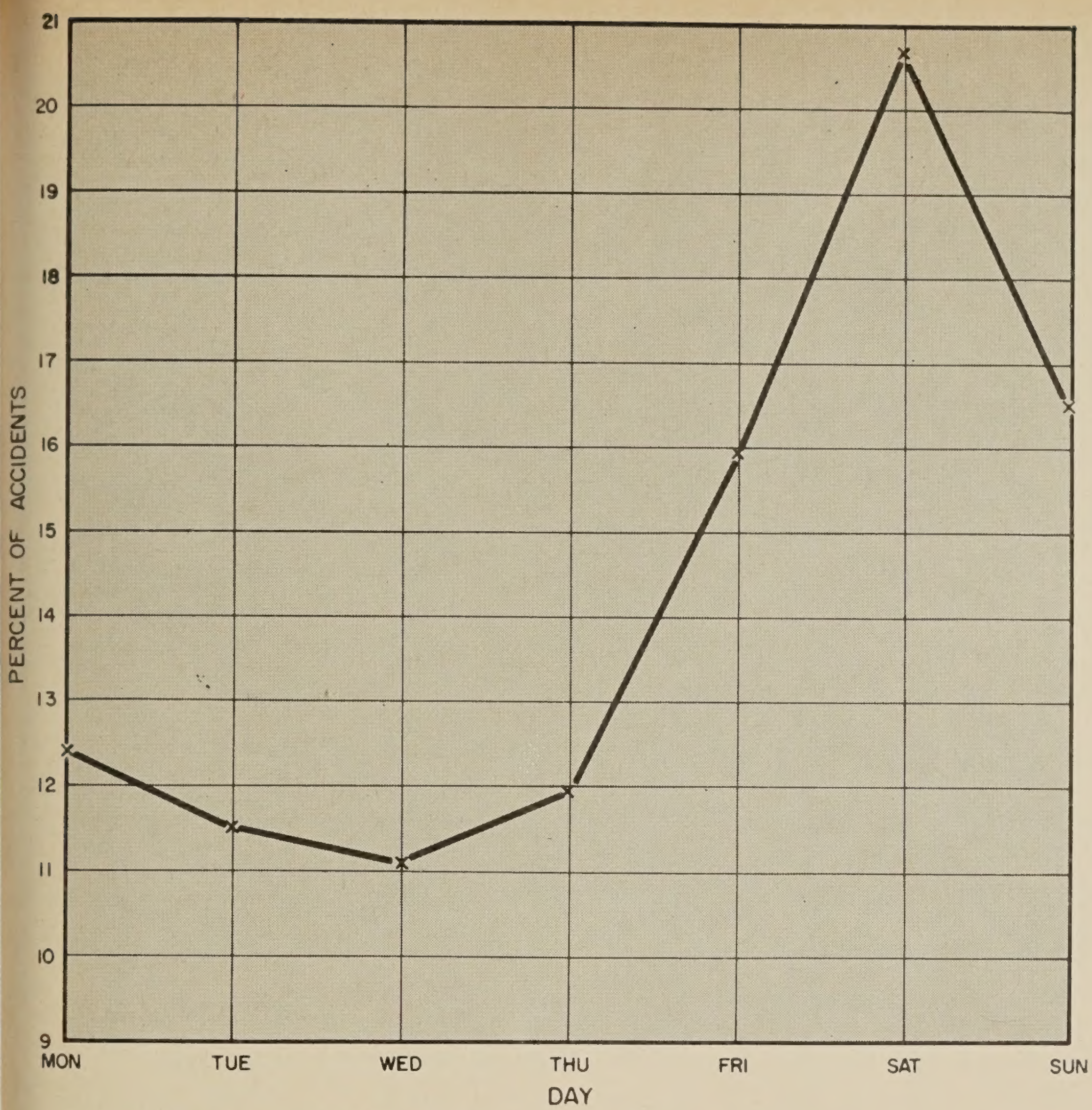

Figure 1.—Fatal accidents on the Interstate System, 1968—day of occurrence.

Estimated economic loss in fatal accidents:

	Loss
3,326 fatalities at $38,500	$128, 051, 000
3,067 nonfatal injuries at $1,377 (weighted on the basis of the three degrees of severity of injury in general use)	4, 223, 259
Property damage (see text below)	7, 783, 900
Total	140, 058, 159
Per accident	50, 856

The estimate for property damage includes both the cost of vehicle damage and the cost of replacing highway appurtenances such as guardrails, signs, light poles, etc. Typically, police investigation reports contained cost estimates of repairing the damaged vehicles, but when the estimates exceeded current retail values of the vehicles (*3*), the amounts were reduced to the latter figures. Also, the values of commercial-vehicle cargoes damaged in accidents were often inadequate for precise estimates of property damage.

Day and Time of Occurrence

The distribution of fatal accidents by day of the week is shown in figure 1. The maximum frequency occurred on Saturday when 20.7 percent of the accidents were recorded. The low point was on Wednesday when 11.1 percent of the accidents occurred. Over half, 53.1 percent, of the accidents occurred on weekends, Friday through Sunday.

The highest percentage of single-vehicle accidents for any interval occurred between 2 and 3 a.m. (fig. 2). The peak for multiple-vehicle accidents was 3 hours earlier, beginning at 11 p.m. Of the total accidents, 6.4 percent occurred in the 2 a.m. hour. The proportion for single-vehicle, off-the-road accidents was slightly higher—7.0 percent. The smallest percentages occurred in the 9 a.m. and 11 a.m. hours for multiple- and single-vehicle accidents, respectively.

Accident Environment

Light conditions

More than half the accidents, 53 percent, occurred at night and only a fifth of these were on lighted sections of highway. (See table 2.) This might be expected because lighting on the Interstate System is largely limited to urban sections and interchanges. A higher percentage, 72 percent, of the pedestrian accidents occurred at night, and although precise information was not available, numerous investigation reports cited dark clothing and intoxication as factors in these accidents. Also, collisions caused by wrong-way drivers occurred more frequently during hours of darkness, although the opposite was true in collisions caused by vehicles that crossed medians.

Weather and pavement conditions

Four-fifths of the accidents occurred during clear or cloudy weather, 15 percent in rainy weather, 3 percent during snow, and 2 percent in fog. There were no significant deviations from this pattern for the different types of accidents except rear-end collisions, 5 percent of which occurred in fog. Investigation reports noted a few accidents in which strong wind was a factor in off-the-road accidents, principally those involving small foreign cars.

As might be expected, the pattern of accidents related to pavement conditions was essentially similar to that related to weather conditions. About a fifth of the accidents occurred on wet pavements, and 4 percent on ice or snow. The outstanding exception was that more than half, 52.2 percent, of the head-on collisions that resulted from out-of-control vehicles crossing medians happened on wet or icy pavements. Somewhat unexpected was the fact that fewer than a fourth of the single-vehicle, off-the-road accidents occurred on slippery roads.

Highway alinement

More than three-fourths, 78 percent, of the fatal accidents took place on straight sections of highway, and the remainder were nearly equally divided between right and left curves. Single-vehicle, off-the-road accidents occurred more frequently on curved sections, 29 percent of the total, and again they were nearly equally divided between right and left curves. A third of the accidents were on grades—two-thirds on straight sections, and the remainder on curves. In the several individual types of accidents there were no major deviations from these patterns except in rear-end and head-on collisions, nine-tenths of which were on straight sections.

Vehicles

Vehicle types

To assess the importance of different types of vehicles in these accidents, it was necessary to assign the primary *responsibility* for each accident to an individual vehicle.[2] Although an element of judgment was involved, significant errors appeared minimal. In two-thirds of the accidents, only one moving vehicle was involved (see table 1). Eleven percent of the accidents were head-on collisions resulting

[2] *Responsibility* does not necessarily imply violations by the drivers involved.

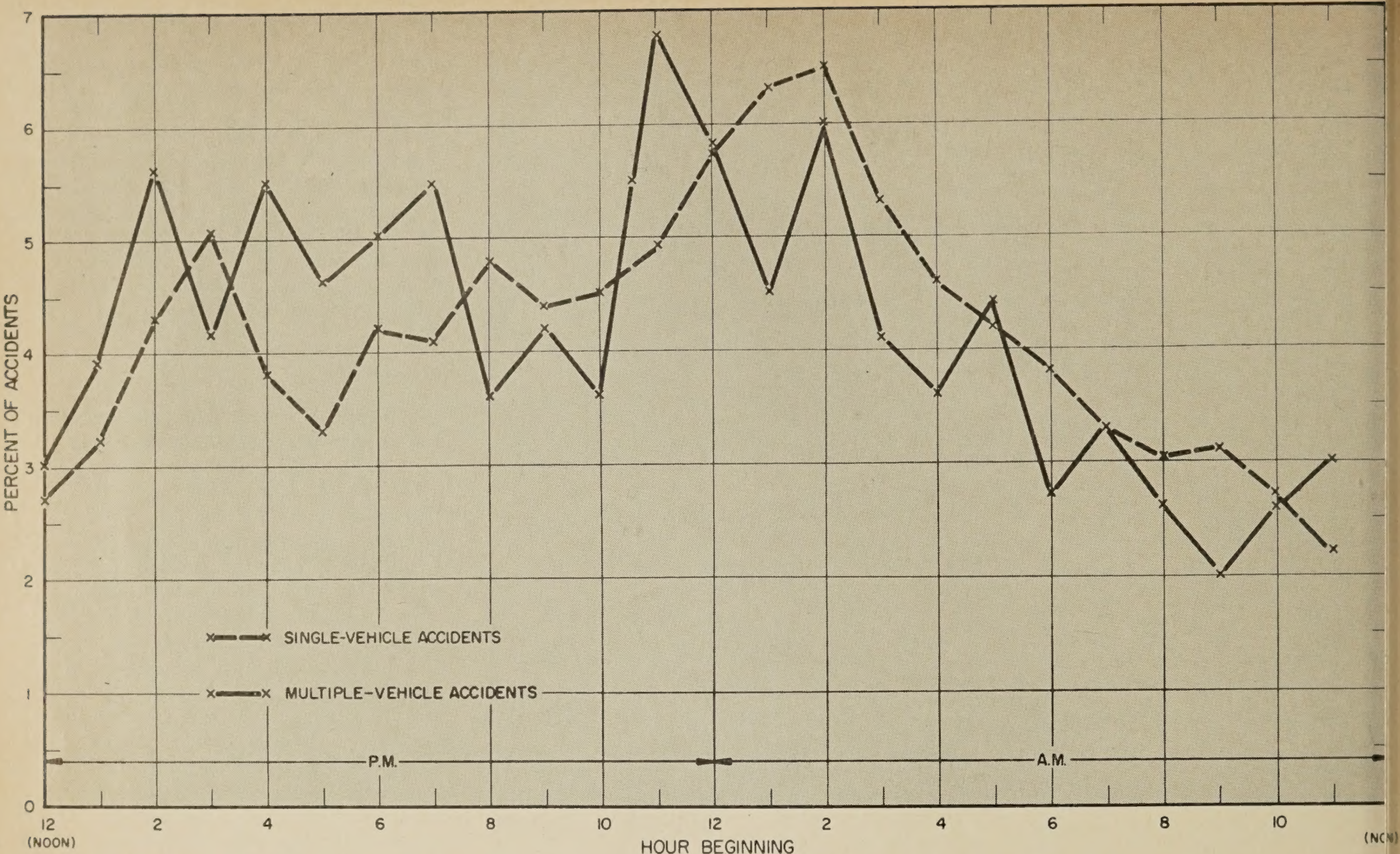

Figure 2.—Fatal accidents on the Interstate System, 1968—hour of occurrence.

from wrong-way drivers or out-of-control vehicles from opposing lanes—accidents in which there is little or no question of responsibility. Rear-end collisions are usually, but not always, the responsibility of the striking vehicle. In these accidents, as well as in broadside collisions and sideswipes, responsibility was assessed on the basis of the details of investigation reports, including the narratives, diagrams, notations of violations, and related data.

The volume of travel and the number of accidents, fatalities, and injuries for each of the principal types of vehicles primarily responsible for the accidents are shown in table 3. Accident responsibility was determined from the investigation reports, as outlined in the preceding paragraph. Passenger vehicles are shown as a single group because the estimates of vehicle-miles of travel were not available for individual types. The percentages of travel, accidents, and injuries for the several types of vehicles agree closely. In gener[illegible] the proportions of accidents for propert[illegible] carrying vehicles are slightly less than t[illegible] corresponding percentages for vehicle mi[illegible] of travel. The differences for fatalities and in[illegible]ries are slightly larger, probably a result of t[illegible] lower average human occupany of car[illegible] vehicles.

Elaboration of this aspect of the accide[illegible] pattern is given in tables 4 and 5. The relati[illegible] importance of each vehicle type in each pr[illegible]

Table 4.—Fatal accidents on completed sections of the Interstate System, 1968—types of vehicles involved in each type of accident[illegible]

Type of vehicle [2]	Total accidents	Single-vehicle accidents [3]				Multiple-vehicle accidents [3]				
		Total	Ran off road	Pedestrian	Collision with parked vehicle	Total	Rear-end collisions	Head-on collisions: Total	Head-on collisions: Wrongway	Head-on collisions: Vehicle fro[illegible] opposite lan[illegible]
Total, all types.........number	2,754	1,842	1,462	214	96	912	411	309	131	16[illegible]
Percent distribution:										
Passenger:										
Sedans	66.8	67.9	69.1	69.6	59.4	64.6	56.0	77.0	79.5	76.[illegible]
Convertibles	5.6	7.0	8.0	2.3	6.3	2.7	3.2	2.9	2.3	3.[illegible]
Station wagons	7.0	7.4	7.8	4.7	4.2	6.4	6.4	6.1	3.8	7.[illegible]
Motorcycles	1.1	1.0	0.8	------	1.0	1.3	1.9	------	------	------
Other [4]	0.9	0.8	0.7	1.0	1.0	1.1	1.1	0.7	0.7	0.[illegible]
Total passenger vehicles	81.4	84.1	86.4	77.6	71.9	76.1	68.6	86.7	86.3	88.[illegible]
Property carrying:										
Combinations	9.2	7.5	6.5	9.4	19.8	12.5	19.5	2.9	------	4.[illegible]
Panels and pickups	6.6	5.8	5.7	6.5	3.1	8.2	7.5	9.1	13.0	4.[illegible]
Single unit trucks [5]	2.8	2.6	1.4	6.5	5.2	3.2	4.4	1.3	0.7	1.[illegible]
Total property carrying	18.6	15.9	13.6	22.4	28.1	23.9	31.4	13.3	13.7	11.[illegible]

[1] This table is the converse of table 5.
[2] Includes the one vehicle primarily responsible for each accident, as indicated by police investigation reports.
[3] Types of accidents that occurred less frequently (see table 1) not shown separately.
[4] Includes eight small (less than 10 passenger) buses, seven large buses, one school bus, [illegible]d eight campers.
[5] Includes a few highway maintenance vehicles.

Table 5.—Fatal accidents on completed sections of the Interstate System, 1968—types of accidents in which each vehicle type was involved[1]

Type of accident	Passenger vehicles[2]						Property-carrying vehicles[2]			
	Total	Sedans	Convertibles	Station wagons	Motorcycles	Other[3]	Total	Combinations	Panels and pickups	Single-unit trucks
Total, all types .... number	2,243	1,839	155	194	31	24	511	253	181	77
Percent distribution:										
Single vehicle:										
Ran off road	56.3	54.9	75.5	59.3	35.5	41.7	38.9	37.5	46.4	25.9
Overturn on road	1.1	0.9	--------	1.5	19.4	--------	1.2	(4)	0.6	5.2
Collision—parked vehicle	3.1	3.1	3.9	2.1	3.2	4.2	5.3	7.5	1.6	6.5
Pedestrian	7.4	8.1	3.2	5.1	--------	8.2	9.4	7.9	7.8	18.2
Other	1.2	1.0	1.3	2.1	3.2	4.2	2.5	1.6	2.2	6.5
Total single vehicle	69.1	68.0	83.9	70.1	61.3	58.3	57.3	54.9	58.6	62.3
Multiple vehicle:										
Rear-end collision	12.6	12.5	8.4	13.4	25.8	20.8	25.2	31.6	17.2	23.4
Head-on collision:										
Wrong-way driver	5.0	5.7	1.9	2.6	--------	4.2	3.5	--------	9.4	1.3
Vehicle from opposite lane	6.5	6.8	3.9	6.7	--------	4.2	3.7	3.2	4.4	3.9
Other	(4)	(4)	--------	0.5	--------	--------	0.7	(4)	1.6	--------
Total head-on collision	11.9	12.9	5.8	9.8	--------	8.3	8.0	3.6	15.4	5.2
Broadside collision	2.5	2.5	0.6	3.1	3.2	12.5	1.6	1.6	1.6	1.3
Sideswipe	3.9	4.1	1.3	3.6	9.7	--------	8.0	8.3	7.2	7.8
Total multiple vehicle	30.9	32.0	16.1	29.9	38.7	41.7	42.7	45.1	41.4	37.7

[1] This table is the converse of table 4.

[2] Includes the one vehicle primarily responsible for each accident, as indicated by police investigation reports.

[3] Includes eight small (less than 10 passenger) buses, seven large buses, one school bus, and eight campers.

[4] Less than 0.5 percent.

Table 6.—Age and sex of drivers in fatal accidents on completed sections of the Interstate System, 1968[1]

Age	Total accidents			Single-vehicle accidents			Multiple-vehicle accidents		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Drivers, all ages[2] .... number	2,315	411	2,726	1,533	287	1,820	782	124	906
Percent distribution:									
Under 25:									
15 and under	0.5	--------	0.4	0.5	--------	0.4	0.5	--------	0.3
16	0.9	0.7	0.9	1.1	1.1	1.1	0.5	--------	0.4
17	1.3	1.5	1.4	1.5	1.7	1.5	1.0	0.8	1.0
18	4.2	4.9	4.3	5.0	4.2	4.9	2.5	6.5	3.1
19	4.4	2.2	4.0	5.2	2.1	4.7	2.6	2.4	2.6
20–24	22.4	19.2	21.9	24.5	21.6	24.1	18.3	13.7	17.7
Total under 25	33.7	28.5	32.9	37.8	30.7	36.7	25.4	23.4	25.1
25–34	22.1	21.9	22.0	21.5	25.1	22.0	23.3	14.5	22.1
35–44	17.8	21.9	18.4	17.6	20.5	18.0	18.3	25.0	19.2
45–54	13.8	11.9	13.5	12.3	9.4	11.9	16.8	17.7	16.9
55–64	7.5	9.2	7.8	6.3	9.8	6.9	9.8	8.1	9.6
65–74	3.7	5.6	4.1	3.3	3.8	3.3	4.7	9.7	5.4
75 and over	1.4	1.0	1.3	1.2	0.7	1.2	1.7	1.6	1.7

[1] Data in this table refer to the one driver primarily responsible for each accident, as indicated by police investigation reports.

[2] Excludes 28 drivers whose ages were not reported.

ipal type of accident is shown in table 4.[3] Of he vehicles involved in off-the-road accidents, 66.4 percent were passenger cars. The cor- esponding percentage for tractor-trailer com- inations was only 6.5. Wrong-way drivers of assenger vehicles caused 86.3 percent of the ead-on collisions of this type, whereas vrong-way drivers of panels and pickups aused only 13.0 percent. Cargo vehicles, owever, were involved more frequently in ead-end collisions.

The distribution of accident types in which ach vehicle category was involved is shown n table 5, which is the inverse of the relation hown in table 4. In single-vehicle accidents, 9.1 percent of the passenger vehicles and 7.3 percent of the property-carrying vehicles vere involved. Compared to 31.6 percent of he tractor-trailer combinations, only 12.6 ercent of the passenger cars were involved in ear-end collisions.

[3] Vehicles deemed primarily responsible for each of the ccidents.

Table 7.—Fatal accidents on completed sections of the Interstate System, 1968—condition of drivers, as reported by investigators[1]

Driver condition	Total accidents	Single-vehicle accidents			Multiple-vehicle accidents	
		Total	Ran off road	Collision with parked vehicle	Total	Rear end
Total drivers, all conditions:						
Number	2,754	1,842	1,462	96	912	411
Percent	100	100	100	100	100	100
Condition not reported:						
Number	684	445	391	21	239	97
Percent	25	24	27	22	26	24
Condition reported:						
Number	2,070	1,397	1,071	75	673	314
Percent	100	100	100	100	100	100
Normal:						
Number	1,504	933	648	44	571	249
Percent	73	67	61	59	85	79
Total defects reported:						
Number	566	464	423	31	102	65
Percent	100	100	100	100	100	100
Asleep:						
Number	433	368	342	20	65	46
Percent	77	79	81	65	64	71
Fatigued:						
Number	52	32	25	6	20	14
Percent	9	7	6	19	19	21
Ill:						
Number	46	35	32	3	11	4
Percent	8	8	7	10	11	6
Other:						
Number	35	29	24	2	6	1
Percent	6	6	6	6	6	2

[1] Data in this table refer to the one driver responsible for each accident, as indicated by police investigation reports.

Table 8.—Fatal accidents on completed sections of the Interstate System, 1968—sobriety of drivers, as reported by investigators [1]

Driver sobriety	All accidents	Single-vehicle accidents			Multiple-vehicle accidents			
		Total	Ran off road	Collision with parked vehicle	Total	Head-on collisions		Rear-end collisions
						Total	Wrong-way drivers	
Total drivers, all conditions:								
Number	2,754	1,842	1,462	96	912	309	131	411
Percent	100	100	100	100	100	100	100	100
Sobriety not reported:								
Number	723	493	445	24	224	85	38	88
Percent	26	27	30	25	25	28	29	21
Sobriety reported:								
Number	2,031	1,349	1,017	72	688	224	93	323
Percent	100	100	100	100	100	100	100	100
Not drinking:								
Number	1,382	931	660	49	451	121	24	230
Percent	68	69	65	68	66	54	26	71
Had been drinking:								
Number	649	418	357	23	237	103	69	93
Percent	32	31	35	32	34	46	74	29
Intoxicated:								
Number	187	101	84	8	86	42	31	28
Percent	9	7	8	11	13	19	33	9
Impaired:								
Number	70	41	34	3	29	9	6	10
Percent	4	3	3	4	4	4	7	3
Not impaired:								
Number	29	27	21	1	2	1	1	1
Percent	1	2	2	2	(2)	(2)	1	(2)
Extent of impairment not reported:								
Number	363	249	218	11	120	51	31	54
Percent	18	19	22	15	17	23	33	17

[1] Data in this table refer to the one driver responsible for each accident, as indicated by police investigation reports.
[2] Less than 0.5 percent.

Table 9.—Fatal accidents on completed sections of the Interstate System, 1968—age and sobriety of drivers, as reported by investigators [1]

Age	Total number of drivers	Drivers not reported		Total number reported	Reported as drinking		
		Number	Percent of all drivers		Number	Percent of all drivers	Percent of reported drivers
Number of drivers, all ages	3,972	807	20.3	3,165	700	17.6	22.1
Under 25:							
17 and under	93	13	14.0	80	8	8.6	10.0
18	146	31	21.2	115	29	19.9	25.2
19	137	31	22.6	106	32	23.4	30.2
20–24	742	166	22.4	576	175	23.6	30.4
Total under 25	1,118	241	21.6	877	244	21.8	27.8
25–34	925	149	16.1	776	177	19.1	22.8
35–44	789	146	18.5	643	144	18.3	22.4
45–54	565	129	22.8	436	91	16.1	20.9
55–64	336	70	20.8	266	28	8.3	10.5
65–74	143	28	19.6	115	11	7.7	9.6
75 and over	42	11	26.2	31	2	4.8	6.5
Not reported	54	33	61.1	21	3	5.6	14.2

[1] This table includes drivers of all vehicles involved in the accidents as opposed to table 8, which includes only one driver for each accident.

Vehicle defects

Police investigation reports gave little information on the condition of vehicles involved in accidents. Some of the report forms had no provision for information on vehicle condition. Many times this information was only one of several items listed in a general category for reporting circumstances that apparently contributed to the accident. The other items referred to driver condition, road defects, excessive speed, weather conditions, etc. Seldom was more than one item checked, and often none was checked, except when an obvious violation was involved.

Information on vehicle condition usually is lacking in these reports because the immediate and urgent responsibility of investigating officers is to injured persons and to restoration of traffic, leaving little or no opportunity for detailed inspection of the vehicles on the scene. Consequently, only 10 percent of the reports referred to apparent vehicle defects and nearly three-fourths of these referred to tires—usually to inadequate tread depth rather than to actual tire failures. A very few reports listed defective brakes or lights. The proportion of vehicles reported to have defects was essentially the same as that in the 1967 study, and was not inconsistent with a National Safety Council finding that defective vehicles were involved in 7 percent of the fatal accidents on turnpikes in 1966 (*4*).

Seat belts

Information on seat-belt availability and use was reported for three-fifths of the drivers involved in the 2,754 fatal accidents. Althoug belts were available to 45 percent of thes drivers, only half used them. There wa no significant difference between the numbe of male and female drivers who used belt The foregoing percentages are affected by th number of cargo vehicles, about a fifth of th total, relatively few of which were equippe with restraining devices.

Vehicle Drivers

Age and sex of drivers

More than four-fifths of the drivers pr marily responsible for the fatal accidents[4] wer males. According to Public Roads estimate (*5*), males constituted 58.5 percent of a licensed drivers, but any comparison of thi figure with accident involvement is misleadin because relative exposure was not considerec Also, males were overrepresented, as few carg vehicles were driven by females. There wer no significant differences between the propo tions of males and females involved in th several types of accidents.

Compared with 28.5 percent of the female slightly more than a third of the male drive were less than 25 years old (table 6). In th age group, more drivers, both male and femal were involved in single-vehicle accidents tha in multiple-vehicle accidents. According t Public Roads estimates, approximately 2 percent of all licensed drivers are in th under-25 age group, compared with the 32 percent involved in these accidents. Agai this comparison is deceptive as it ignor relative exposure. Younger drivers are almo certainly overrepresented in total traff volumes, although no statistical document tion exists to support this fact. Conversel drivers 65 years old and older constitu nearly 8 percent of the licensed drivers, b these drivers were involved in only 5.4 perce of the accidents.

There were some significant differences the age distributions of drivers in specif types of accidents. Drivers under 25 years age, for example, were responsible for almo 40 percent of the single-vehicle, off-the-ro accidents and for only 25.1 percent of t multiple-vehicle accidents. Drivers 65 yea old or older caused 15 percent of the head- collisions, which resulted from driving wrong lanes of divided highways, but th were involved in fewer than 5 percent of t single-vehicle accidents.

Physical condition of drivers

The physical condition of three-fourths the drivers responsible for the 2,754 acciden was reported by investigating officers (tab 7). No physical defect was recorded in percent of the reports that contained this i formation. The condition most frequent reported was sleep or dozing—77 percent the defects recorded for all accidents a

[4] Primary responsibility for drivers was determined the procedure outlined under *Vehicles*. Undoubtedly, some pedestrian fatalities, victims rather than drivers primarily responsible.

Table 10.—Characteristics of single-vehicle, off-the-road fatal accidents on completed sections of the Interstate System, 1968

Type of accident	Total		Vehicles leaving the road			
			Left side of road		Right side of road	
	Number	Percent	Number	Percent	Number	Percent
Total accidents, all types	1,462	100.0	695	100.0	767	100.0
Struck fixed object:						
Total	1,208	82.6	540	77.7	668	87.1
Overturned	480	32.8	230	33.1	250	32.6
Overturned only	245	16.8	152	21.9	93	12.1
All overturns	725	49.6	382	55.0	343	44.7
Off the road only	9	0.6	3	0.4	6	0.8

1 percent for drivers involved in off-the-road ccidents. Presumably, there is no clear line f demarcation between the drivers who were sleep or dozing and those who were fatigued. 'atigue constituted an additional 9 percent f the driver defects reported. Particularly gnificant is the fact that 92 percent of the rivers responsible for rear-end collisions who 'ere reported as having defects were asleep r fatigued. The percentage for collisions with arked vehicles was slightly smaller. Eight ercent of the defects reported involved lness; most frequently mentioned were ardiac conditions and effects of medication. Iost of the remainder, 6 percent, were rivers with bodily handicaps and those who 'ere distracted, principally by events within ie vehicles.

obriety of drivers

Police investigation reports, completed iortly after accidents occur, are not conusive sources of information on alcohol in ccidents. The available reports indicated iat 23.6 percent of the drivers responsible or the accidents had been drinking. As shown i table 8, this percentage is equivalent to 32 ercent of the drivers whose sobriety was reorted, which is well below the proportion eferred to in many individual sample studies i which alcohol is reported to be a contributig factor in at least half the fatal motorehicle accidents. There are several possible xplanations for this apparent inconsistency:

- Sobriety was not reported for 26 percent f the drivers primarily responsible for the ccidents discussed in this report.
- Results of blood alcohol tests, if given, ere not available at the time the accident eports were completed.

Table 11.—Fixed objects struck first in single-vehicle, off-the-road fatal accidents on completed sections of the Interstate System, 1968

First object struck	Number	Percent
Total, all objects	1,208	100.0
Guardrail [1]	364	30.1
Bridge or overpass	217	18.0
Sign	97	8.0
Embankment	86	7.1
Curb	72	6.0
Divider [2]	71	5.9
Pole [3]	63	5.2
Ditch or drain	57	4.7
Culvert	51	4.2
Fence [4]	28	2.3
Tree	26	2.2
Other	76	6.3

[1] Includes cable type.
[2] Includes rail, concrete, and chainlink.
[3] Principally light poles.
[4] Principally right-of-way fences.

- Administration of tests was refused by coroners or hospitals.
- Insufficient evidence for prosecution.

Undoubtedly, the lack of information was due, in part, to inadequate investigating and reporting, as was evident from the proportions of drivers, from zero to 75 percent, whose sobriety was not reported in the several States. A tabulation was made of data from 12 States in which the sobriety of at least 90 percent of the drivers was reported. The reports from these 12 States were the most complete and detailed of available reports and were not concentrated in any section of the country. The result showed that, of the 1,276 drivers whose sobriety was reported, 22.8 percent had been drinking, a figure slightly under the 23.6 percent reported for all States.

The data shown in table 8 may, therefore, be reasonably representative of the actual situation. As indicated in the table, 32 percent of the drivers whose sobriety was reported had been drinking and 9 percent were obviously intoxicated. There was a relatively large proportion, 18 percent, whose extent of impairment was not reported because no sobriety test was administered or tests results were unavailable when initial reports were completed. More than half, 52.5 percent, of all wrong-way drivers, or 74 percent of those whose condition was reported, had consumed some alcohol. With respect to other individual types of accidents, there were no significant deviations from the general pattern.

According to a tabulation of the reported sobriety of all drivers involved in the accidents, the highest proportion of drinking drivers was in the 20–24 age group (table 9), which agrees closely with the age distribution of all male drivers responsible for the accidents (table 6). The highest proportion of drinking female drivers however was in the 25-34 age group.

None of the studies on the role of alcohol in fatal accidents reviewed was specifically concerned with the Interstate System. There are certain traffic characteristics of the Interstate System which differ from those on most other highways. In 1967, the fatal accident rate on the Interstate System was slightly more than half the rate for all other highways. Presumably this was largely a reflection of the superior design of the Interstate System. But factors other than highway design seem to be involved. Most trips on the Interstate System are probably longer than those on other highways and, except in highly urbanized areas, they tend to be for somewhat different purposes. Travel to and from social functions and places of entertainment where alcoholic beverages are served may be less common on the Interstate System. Moreover, alcoholic beverages, obtainable from taverns and bars located at frequent intervals on other types of highways, are not obtainable on Interstate highways.

Accordingly, there may be a lower rate of drinking and driving on the Interstate System than is suggested in certain studies usually used as a basis for conclusions concerning drinking and driving.

able 12.—First and second fixed objects struck in single-vehicle, off-the-road fatal accidents on completed sections of the Interstate System, 1968

First object struck	Guardrail	Bridge or overpass	Sign	Embankment	Curb	Divider	Pole	Ditch	Culvert	Fence	Tree	Other
Second object struck:												
None	151	181	76	58	16	47	44	46	38	9	21	53
Bridge	102	16	6	2	10	2	4	1	2	1	1	3
Embankment	36	4	2	2	4	1	2	5	2	5	-	1
Guardrail	18	4	2	1	17	10	3	-	2	-	-	3
Pole	17	3	3	1	11	2	1	1	-	3	-	1
Sign	14	-	-	-	4	5	2	-	-	-	-	6
Ditch	6	4	3	-	3	1	4	1	1	3	1	1
Culvert	3	-	1	4	1	-	-	2	-	1	-	1
Curb	3	1	-	1	2	-	-	-	-	-	-	-
Divider	3	1	1	2	-	1	1	-	-	-	-	1
Fence	4	1	1	6	1	2	2	-	1	2	-	-
Tree	2	-	-	5	2	-	-	1	3	3	3	4
Other	5	2	2	4	1	-	-	-	2	1	-	4
Total, all collisions	364	217	97	86	72	71	63	57	51	28	26	76

Single-Vehicle, Off-the-Road Accidents

More than half, 53.1 percent, of the 2,754 accidents involved vehicles that ran off the road and did not collide with another vehicle; they constituted almost four-fifths of the single-vehicle accidents. A summary of the characteristics of these accidents is given in table 10. More than four-fifths of the vehicles struck fixed objects after leaving the road and two-fifths of these subsequently overturned. Another 16.8 percent overturned but did not strike a fixed object—this does not include the 31 vehicles which overturned without leaving the road. Overturns occurred in half the accidents of this type. Fewer than one percent of these off-the-road vehicles neither struck a fixed object nor overturned; in several of these accidents the fatalities resulted from ejection of the occupants.

Of all the vehicles that left the road, slightly more than half went off the right side. These vehicles struck fixed objects more frequently, as more fixed objects are generally placed on the right side of the road than in medians. The placement of fewer objects in medians presumably is the reason for the larger proportion of vehicles that ran off to the left and overturned without striking a fixed object.

The frequency with which different types of fixed objects were struck first by vehicles involved in these accidents is shown in table 11. Guardrails ranked first, 30 percent of the total, because they are usually the closest targets for out-of-control vehicles. Dividers are shown separately despite the similarity of their function to that of guardrails.

Of the 1,208 vehicles that left the road and struck a fixed object, 468, or nearly two-fifths of the total, subsequently struck some other type of fixed object. For example, 102 of the vehicles that first struck a guardrail subsequently hit a bridge or overpass element. (See table 12.) Where initial impacts involved bridge or overpass elements, relatively few vehicles subsequently struck other objects, as might be expected because of the substantiality of bridge and overpass structures. Virtually none of the reports distinguished the fixed-base signs and poles struck from those that have breakaway features.

REFERENCES

(*1*) *Fatal and Injury Accident Rates on Federal-aid and Other Highway Systems/1967* U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads (1968 edition in preparation).

(*2*) *How to do a Cost-Benefit Analysis of Motor Vehicle Accident Countermeasures*, by J. L. Recht, National Safety Council, September 1966, p. 20.

(*3*) *Official Used Car Guide*, current issue National Automobile Dealers Used Car Guide Co., Wash., D. C.

(*4*) *Accident Facts*, National Safety Council Chicago, Ill., 1967 edition, p. 49.

(*5*) *Highway Statistics 1967*, U.S. Department of Transportation, Federal Highwa Administration, Bureau of Public Road p. 43.

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The following highway research and development reports are available from the Clearinghouse for Federal Scientific and Technical Information. Sills Building, 5285 Port Royal Road, Springfield, Va. 22151. Paper copies are priced at $3 each and microfiche copies at 65 cents each. To order, send the stock number of each report desired and a check or money order to the Clearinghouse. Prepayment is required.

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PB 173962	The Impact of Traffic on Residential Property Values and Retail Sales in Champaign-Urbana, Illinois, February 1965.
PB 173963	Sixth Street Freeway Traffic Study (1966). (Kansas City, Mo.).
PB 173964	Simulation of Traffic Flow as a Basis for Interchange Design.
PB 173965	Offtracking Calculation Charts for Trailer Combinations, January 1966.
PB 173966	Bolted Hybrid Joints, September 1966. (Pa.).
PB 173967	Class I Bituminous Mixtures, September 1966. (Ky.).
PB 173968	Interim Performance Report—Experimental Use of Thermoplastic Pavement Striping Materials, Report No. 4, September 1966.
PB 174001	Influence of Load History on Cracking in Reinforced Concrete, August 1966.
PB 174005	Deformation Characteristics of Granular Materials Subjected to Rapid, Repetitive Loading, March 1966.
PB 174006	The Exploration of Factors Determining t Fatigue Strength of Composite Beams wi a Reduced Number of Shear Connectors Highway Bridges, June 1966.
PB 174007	Prestressed Concrete Durability and C rosion (1966).
PB 174008	The Exploration of Economic, Safety, Ma tenance and/or Operation of Paved vers Unpaved Shoulders, June 1966. (N.C.).
PB 174009	Evaluation of Identification Factors.
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PB 174013	A Study of Develop Methods for Improvi the Training of Construction and Materi Inspectors.
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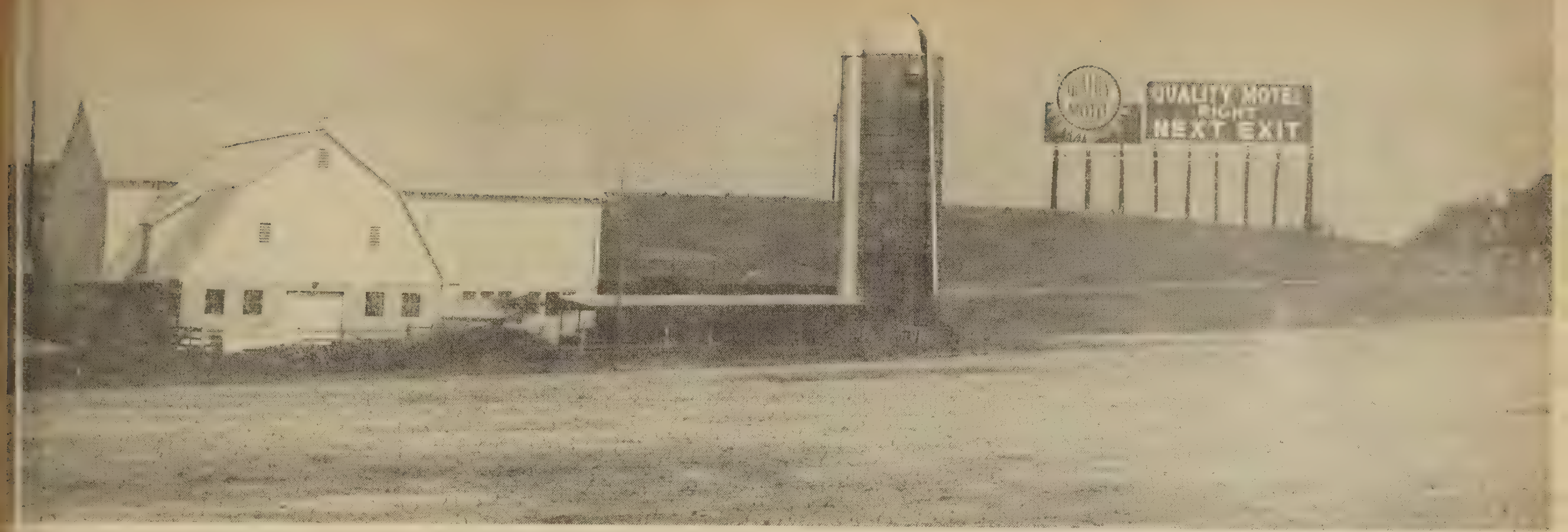
PB 174015	An Analytical Study of Eight Differ Types of Highway Bridge Structur September 1966.
PB 174016	Final Report, October 1966—Effect of Te perature on Asphaltics Concrete at t Time of Mixing Vol. I
PB 174017	Vol. II
PB 174128	Behavior of a Skew Steel-Deck Bridge Un Static and Dynamic Loads, June 19 (Calif.).
PB 174129	The Protected Paste Volume Concept Us New Air Void Measurement and Distrib tion Techniques.
PB 174130	Evaluation of Nuclear Moisture and Dens Gages, June 30, 1966.
PB 174131	Exploration of Methods to Determine Optimum Use of Indigenous Materials Highway Construction, June 1966.

(*Continued on p. 238*)



On the rural landscape, giant billboards may rival large farm structures.

Billboards and Motorists' Needs

BY THE FEDERAL HIGHWAY ADMINISTRATION

Reported by[1] FLOYD I. THIEL, Economist
Office of Policy Planning

Introduction

ROADSIDE conditions along the highways today not only are complex, but some aspects of the involved roadside environment—continual littering, encroachment of vehicles on medians and other landscaped areas, proliferation of billboards in some areas, and appearance of jumbo billboards four times larger than their predecessors—seem discouraging. But amid the seemingly hopeless marring and cluttering of the landscape, there are a few hopeful signs, particularly concerning billboards. There seem to be fewer billboards, at least along some highways, especially those billboards that do not serve motorists' needs.

In the past, more attention seems to have been given to the number of billboards than to the type of information on the signs. For example, billboard regulation is much more concerned with the number of billboards permitted on the roadside than with the content of the sign messages themselves. Yet some signs deserve the attention of motorists more than others. Both critics and supporters of highway-billboard advertising can agree that billboards with gas, food, and lodging messages are more likely to serve motorists' needs than those that contain other messages. Also, it is fairly obvious that some billboards, regardless of regulations, will remain available for advertising in the future. What is not at all clear is the extent to which the available billboard space will be used to serve motorists' needs. Fragmentary information, however, indicates that billboard space, especially on the giant-size billboards that are springing up, is being used increasingly for highway-oriented messages rather than for general product advertising.

Some Disadvantages of Giant Billboards

Even though giant billboards now seem to be used primarily for highway-oriented advertising and may be more acceptable to motorists than if they were used for advertising that does not serve motorist needs, general use of these giant signs would be disadvantageous. Many of the esthetic objections to conventional billboards would be magnified if larger billboards were used. Furthermore, the proliferation of giant billboards tends to stymie other ways of communicating with motorists, like information sites, that would be less harmful to the landscape. A definite disadvantage would be the increased difficulty that small groups, like civic or service clubs and chambers of commerce, with small advertising budgets, would have in getting their messages to motorists because of the more expensive space on giant-size billboards. According to a study on motorists' information needs (*1*),[2] the cost of renting space on a giant-size billboard is $230 to $350 per month.

Changes in Highway Advertising

Highway billboard advertising is undoubtedly influenced by several factors, including billboard regulation. Some obvious changes in billboard-advertising practices usually can be traced to their causes. Others are harder to perceive or interpret, and their causes cannot be traced with any confidence, largely because the sample of information available for analysis is a small part of all the relevant information. The magnitude of the total information available is illustrated by the fact that about 1.1 million advertising signs have been erected along nearly 300,000 miles of Interstate and other primary highways by nearly 4,000 establishments that use outdoor advertising. The nature and size of the outdoor advertising industry is described in a Public Roads staff report issued in 1967 (*2*).

The large billboards, which are about 20 by 40 feet or more, giant size (12 by 24 feet regular size), and which are appearing some distance from roadsides in rural areas, are among the more recent developments in highway advertising. These signs seem to be beyond the 660-foot limit of the right-of-way referred to in the 1958 and 1965 legislation to control billboard advertising. They represent a disadvantage or a failure of

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[1] The work of several members of the Public Roads Office of Research and Development, especially John Yasnowsky and George Broderick, was used in this discussion.

[2] Italic numbers in parentheses identify the references listed on p. 229.

360-847—69——2

Giant billboards seem longer and higher than many rural buildings.

Table 1.—Billboards and highway mileage, 1966

	Illinois [1]		Iowa [1]		U.S. total [1]	
	Interstate	Other Federal-aid primary highways	Interstate	Other Federal-aid primary highways	Interstate	Other Federal-aid primary highways
Billboards [2] ....number..	4,000	60,000	360	98,000	75,000	1,000,000
Mileage [3] ....miles..	890	11,000	380	10,000	21,000	223,000
Billboards per mile (both sides)..number..	4	5+	1	10	3+	4

[1] Figures are rounded.
[2] *Number of Off-Premise Advertising Signs Along the Interstate and Federal-aid Primary Highways*, Bureau of Public Roads, Office of Planning.
[3] *The National System of Interstate and Defense Highways*, improvement status of system mileage as of January 1, 1966, Bureau of Public Roads, Office of Engineering.

existing regulatory legislation. Regardless of what may happen to these giant billboards in the future, existing practice in States with billboard regulation differs noticeably from that in States without billboard regulation. Changes occurring in Texas, a State without billboard control, are discussed later.

Number of Billboards

The most obvious change in billboard activities is the decrease in the number of billboards along some types of highways. Along all Interstate highways inventoried in 1966, for example, billboards on both sides of the road averaged about three per mile. Along other Federal-aid primary (FAP) highways, they averaged about four per mile. (See table 1.) In selected States the difference in sign frequency along Interstate and other Federal-aid primary highways was very noticeable. In Iowa, there was an average of only one billboard per mile along Interstate highways, but nearly 10 per mile along other Federal-aid primary highways. (See table 1.) Of course, statistics on average numbers of signs per mile are misleading as signs often appear in clusters rather than at regular intervals.

An additional indication of changes occurring in highway-advertising practice was provided by a 1969 inventory taken at driving speed along a part of Interstate 80 in Iowa and Illinois. Along 200 miles of this road in Iowa there was an average of about one sign every 2 miles, nearly all giant billboards. (See table 2.) Between 1966 and 1969, the number of billboards along Interstate Highway 80 in Iowa declined from about one sign per mile to about one sign every 2 miles. (See table 3.) The State of Iowa has agreed to regulate billboard advertising under the Highway Beautification Act of 1965.

Although the number of billboards along Interstate Highway 80 in Iowa seems to have declined, in Illinois the number may have increased, but only slightly. (See table 3.) Along rural Interstate Highway 80 in Illinois, there is an average of nearly two billboards per mile, about 15 percent of which are giant size. The numbers of giant- and regular-size billboards on this road are shown in table 2. Illinois does not yet have an agreement to control billboards under the 1965 legislation, but it is one of the States that is qualifying for the bonus to control billboards under the 1958 legislation, which permits a number of exceptions for previously existing right-of-way, crossroad right-of-way, etc.

Analysis of recent experience in Texas provides some helpful insight into highway-advertising practices in a State that has no billboard control. Along nearly 1,000 miles of Texas rural Interstate highway, the number of signboard structures increased more than 17 percent from 1966 to 1968. There was no apparent change in the amount of space used to advertise motorist services, there were no giant-size billboards set back from the highway, but there was a substantial shift from the use of smaller signs to the use of larger signs.

Along Interstate routes on new locations in Texas, the number of billboards increased from 2.6 to 3.8 signs per mile, or nearly 50 percent in the period 1966–68. Along old routes the increase was from about eight signs per mile in 1966 to nine per mile in 1968. Along 30 miles of Interstate Highway 45 between Houston and Galveston, a suburban area, the number of signs with their own supports increased 3[illegible] percent in the same 2- year period to more than 10 per mile. There were an additional five plus signs per mile without their own support— on fences, utility poles, etc., which "were alternately torn, tattered, rusty, and bent." (*3*)

Table 2.—Size of billboards along rural sections of Interstate 80 in Illinois and Iowa, 1969

	Illinois	Iowa
Billboards inventoried....number..	175	91
Regular-size billboards..........do....	148	3
Giant-size billboards..........do....	27	88
Average billboards per mile...do....	2	[1] 0.5
Interstate mileage surveyed...miles..	95	203

[1] According to a 1967 inventory of the Des Moines-to-Davenport, 165-mile segment of Interstate 80, there was an average 0.6 signs per mile—85 giant-size signs, 25 standard-size signs and three trailers used as signs. The inventory included both urban and rural portions of I-80 and was taken during a round-trip drive. The 1969 inventory reported here was taken during a one-way drive.

Table 3.—Number of billboards along rural areas of Interstate 80 in Illinois and Iowa, 1966 and 1969

	Inventoried in 1966 [1]		Inventoried in 1969 [2]	
	Total	Signs per mile [3]	Total	Signs per mile [3]
Illinois ....number..	220	1.5	300	1.8
Iowa ....do...	230	[4] 1	145	0.5

[1] 1966 sign inventory by State Highway Departments and the Bureau of Public Roads.
[2] Both sides of the right-of-way included in signs per mile. The 1969 figures are expanded from an unsystematic sample of approximately 60 percent of the I-80 mileage in Illinois and 66 percent in Iowa.
[3] Approximate mileage involved—150 in Illinois and 300 in Iowa.
[4] Based on estimated 250 miles opened to traffic.

Table 4.—Motorist exposure to advertising signs on Federal-aid primary highways, 1966 [1]

	Number of signs	Highway oriented advertising (gas, food, lodging)	Other advertising
Signboards inventoried—U.S., total........number..	1,100,000	....	....
Interstate:			
Signs [2] ....do....	75,000	[3] 40,000	[3] 35,000
Signs per mile ....do....	3+	2	1.5
Other Federal-aid primary highways:			
Signs [4] ....do....	1,000,000	[5] 250,000	750,000
Signs per mile ....do....	4	1	3

[1] 1966 inventory, State Highway Departments and Bureau of Public Roads. Signs inventoried included small signs.
[2] About 21,000 miles.
[3] Assuming that about 55 percent of the signs are highway oriented, as along Interstate 80 in Illinois in 1966.
[4] About 223,000 miles.
[5] Assuming that about 25 percent of the signs are highway oriented, as determined in a sample of 14 States.

Billboards Serving Motorists' Needs

There are indications that more billboard spaces are being used for motorists' needs than for general advertising, as suggested previously. According to logic, when fewer billboard spaces are available to communicate with passing motorists, more space will be used to convey gas-food-lodging messages that motorists may need, and less space to advertise tobacco, alcohol, fertilizer, insurance, and other products that motorists, as motorists, do not need.

Motorists' exposure to signboards, particularly the nonhighway or general types, seems to differ between highway systems and as time progresses. It was indicated by the 1966 sign inventory of all the States that nonhighway-oriented advertising appeared about one and a half times per mile of Interstate and about three times per mile for other Federal-aid primary highways (See table 4.) Of course many of the signs on Federal-aid primary highways were older and smaller than those on Interstate routes.

Along rural sections of Interstate Highway 80 in Illinois and Iowa, motorists are now apparently exposed to nonhighway-oriented advertising less frequently than they were before 1966. In 1966, a motorist could travel about 2.7 miles along I-80 in Iowa, and about 1.5 miles in Illinois, without seeing a nonhighway-oriented sign. In 1969, he can travel nearly 100 miles in Iowa and 5 plus miles in Illinois, without seeing such signs (table 5). Interstate routes are handling an increasing share of motor vehicle travel, which indicates that motorists' exposure to nonhighway-oriented billboards may be declining. Of course, Interstate Highway 80 may not be typical of all Interstate highways; its traffic seems to be increasing at a faster rate than is normal for most Interstate routes—35 percent and more compared with 6 to 8 percent for the U.S. overall. Motorists have better visibility on I-80 in Iowa and Illinois than on many other Interstate routes, but giant billboards beyond 660 feet are appearing even in areas like Maryland and Virginia where visibility sometimes is restricted by terrain or forests.

Motorists can make better economic and driving choices if they have enough useful information, but they cannot assimilate very many messages in a limited period of time. Consequently, some sign messages serve motorists' needs better than others, a concept that is supported by motorists' responses to queries about what types of messages they prefer or find acceptable. In one study, respondents were about twice as favorably

Strategically located billboards often appear in approaching motorist's direct view, although location is apparently 660 feet from the roadside.

Closeup view of giant billboard under construction shows relative size of normal-size man. According to the number of 4- by 8-foot plywoo sheets and the size of supporting structure, the completed sign will be 84 feet long and 20–24 feet wide.

Table 5.—Motorist exposure to highway-oriented messages[1] and other messages along rural I-80 in Illinois and Iowa, 1966 and 1969

	Illinois		Iowa	
	Highway-oriented messages	Other messages	Highway-oriented messages	Other messages
1966				
Signs inventoried .... number	120	100	140	90
Length of highway inventoried .... miles	150	150	250	250
Signs per mile .... number	0.8	0.7	0.6	0.4
Distance between signs .... miles	1.2	1.5	1.8	2.7
1969				
Signs inventoried .... number	157	18	89	2
Length of highway inventoried .... miles	95	95	200	200
Signs per mile .... number	1.6	0.2	0.5	0.01
Distance between signs .... miles	0.6	5+	2.2	100

[1] Gas, food, and lodging primarily.

disposed toward highway service signs (51 percent) as they were toward signs advertising other products (27 percent) (*4*). In another study, 18 percent of the respondents regarded billboards in general as very useful, and 45 percent thought hotel and motel billboards were very useful (*5*). Respondents disapproved most billboard messages that do not serve motorists' needs.

In the past, approximately a quarter of all the advertising messages pertained to motorist services. According to the Public Roads Staff Report, p. 41 (*2*), in three separate analyses by Texas A&M University, the University of Tennessee, and the Bureau of Public Roads, the percentages of billboards used for motorists' needs were determined to be 22, 33, and 26 respectively. Along rural Interstate Highway 80 in Illinois and Iowa, the 1966 inventory indicated that a higher percentage of billboards were used for highway-oriented messages—about 55 percent in Illinois and 60 percent in Iowa—and the 1969 survey along I-80 in Illinois and Iowa indicated that nearly all the classified billboard spaces were being used for motorists' needs. In fact, except for a Maytag message in Iowa, virtually 100 percent of the space on giant billboards is being used for highway-oriented messages like gas, food, and lodging. In another study in Iowa (*1*), it was also noted that most giant billboards were being used for motorist services. In 1966, a few signs that were larger than standard size ha appeared in Iowa.

In table 6 the types of messages on bill boards surveyed in 1969 along Interstat Highway 80 can be compared with message on signs inventoried along I-80 and elsewher in 1966. Highway oriented messages account for about 25 percent on all Federal-aid high ways, for 55–60 percent on I-80 in 1966, an for 88–100 percent on I-80 in 1969. In table 7 sign messages along Interstate Highway 80 i Illinois and Iowa can be compared with thos along all Federal-aid highways. As might b expected, a higher percentage of Interstat signs are being used for motorists' needs.

The increasing use of billboard space f motorists' needs is apparent when the 196 and 1969 data for Interstate Highway 80 a compared. (See table 8.) The percentage signs used for motorists' needs increased fro 58 percent in 1966 to more than 90 percent i 1969, a difference that is unlikely to ha occurred by chance—apparently less than o chance in five, as the difference tests signi cance at the twenty percent level. (See footnot in table 8.) Indications that these appare differences are a result of cause rather th chance obviously does not reveal what t cause is. A combination of causes is probab involved here—billboard regulation resulti in fewer and more expensive sites; insufficie time for signs to be erected on some n highways; industry's improved perception what is needed, what is profitable, and wh will be tolerated; and other changes in ma

'able 6.—Sign messages on certain Interstate and other Federal-aid primary highways

Survey or sample [1]	Signs used for motorist needs
1966 group	
	Percent
Federal aid primary highway in 14 States [2]	26
Texas Federal-aid primary highway [3]	22
Tennessee Federal-aid primary highway [4]	33
Interstate 80, rural:	
Illinois [5]	55
Iowa [5]	60
1969 group [6]	
Illinois, I-80, rural signs:	
Regular size	88
Giant size	100
Iowa, I-80, rural signs:	
Regular size	100
Giant size	98

[1] Differences between the two groups are significant at 1e 5 percent level, using a Wilcoxon-Mann-Whitney test.
[2] Based on a Bureau of Public Roads sample, 1 percent of a 966 highway sign inventory from 14 States: Alabama, laska, California, Colorado, Connecticut, Indiana, Louisiaa, Maryland, Michigan, Minnesota, Mississippi, Missouri, Iontana, and Tennessee.
[3] *Economic Effects of the Highway Beautification Program*, '. G. Adkins, W. F. McFarland, G. H. Meuth, J. T. Wynn, 'exas A&M University, 1966.
[4] *The Economic Impact of the Highway Beautification Act 1 the Outdoor Advertising Industry, Landowners, and Selected cenic Attractions in Tennessee*, L. S. Pipkin and F. L. Iendrix, University of Tennessee, 1966.
[5] All signs on I-80 shown on 1966 inventory of signs outside orporate boundaries.
[6] From 1969 sample of 60+ percent of I-80 mileage, taken at ruising speed.

enance and in improved lighting that are occurring in the industry.

Conclusions

Although billboard practice appears to be changing, the apparent changes cannot be interpreted with any confidence because information is limited. Developments like giant billboards seem contrary to the intent of the highway beautification program. Efforts to ban billboards from the motorist's view rather than to restrict them within a limited distance of the highway, such as 660 feet, raise a question as to how long these billboards may exist. Even if they are permitted to remain on the landscape, current practice indicates that billboard regulation may cause most of the space to be used to serve motorists' needs.

Table 7.—Sign messages—Interstate and other Federal-aid primary highways

Survey or sample [1]	Signs used for motorist needs
Group 1—Federal-aid primary highways, including Interstate	
	Percent
All Federal-aid primary highways, 1966	26
Texas Federal-aid primary highways, 1966	22
Tennessee Federal-aid primary highways, 1966	33
Group 2—Interstate 80, Illinois and Iowa	
Illinois, I-80:	
Rural, regular-size signs, 1966	45
Rural, regular-size signs, 1969	80
Rural, giant-size signs, 1969	100
Iowa, I-80:	
Rural, regular-size signs, 1966	55
Rural, regular-size signs, 1969	100
Rural, giant-size signs, 1969	98

[1] Differences between the two groups are significant at the 5 percent level. For sources, see table 6.

Whether a large proportion of the giant billboards would continue to be used for motorist needs, if these giant billboards are permitted to proliferate, is questionable; however, attention needs to be given now to the increasing number of them and, perhaps, to assuring that messages serving motorists' needs are given perference at locations where billboard space may remain available in the future.

REFERENCES

(1) *Information Needs: The Interstate Highway Motorist in Iowa*, prepared by Aurthur D. Little, Incorporated, for the Iowa State Highway Commission, 1967.

(2) *Economic Impact of the Highway Beautification Act*, Staff Report, Bureau of Public Roads, Office of Research and Development, 1967.

(3) *Texas Studies Relating to the Highway Beautification Program*, by W. G. Adkins et al., Texas Transportation Institute, Texas A & M University, 1968.

(4) *Estimates of the Impact of Sign and Billboard Removal Under the Highway Beautification Act of 1965*, by James B. Cloonan et al., University of Missouri, 1966.

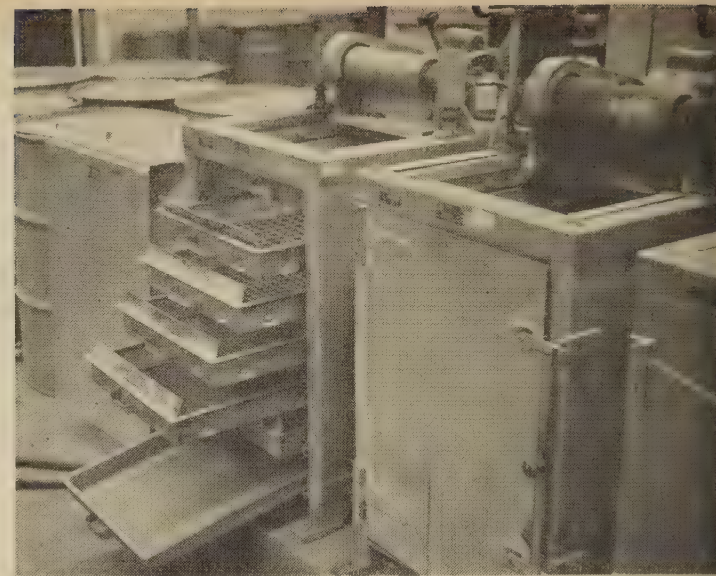
(5) *Traveler Attitudes Toward Highway Billboard Advertising, A Survey of Selected Wyoming Motel Patrons*, by Dwight M. Blood, University of Wyoming, 1969.

Table 8.—Sign messages along rural sections of Interstate 80 in Illinois and Iowa, 1966 and 1969

Survey or sample [1]	Signs used for motorist needs
1966 group [2]	
	Percent
Illinois, all signs	55
Iowa, all signs	60
1969 group [3]	
Illinois:	
Regular size signs	88
Giant size signs	100
Iowa:	
Regular size signs	100
Giant size signs	98

[1] Differences between the two groups are significant at the 20 percent level.
[2] All signs on I-80 shown on 1966 inventory of signs outside corporate boundaries.
[3] From 1969 sample of 60+ percent of I-80 mileage, taken at cruising speed.

Quality Assurance in Highway Construction



Part 5— Summary of Research for Quality Assurance of Aggregate

Determining aggregate gradation by screen shaker (above) and sampling compacted aggregate base course (below)—two of the processes used to determine aggregate characteristics.

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BY THE OFFICE OF
RESEARCH AND DEVELOPMENT
BUREAU OF PUBLIC ROADS

This is the fifth part of an interpretative summary of the progress in Public Roads research program for the statistical approach to quality assurance in highway construction. Part 1.—Introduction and Concepts, Part 2.—Quality Assurance of Embankments and Base Courses, Part 3.—Quality Assurance of Portland Cement Concrete, and Part 4.—Variations of Bituminous Construction were presented in previous issues of PUBLIC ROADS. The remaining part, to be presented in the next issue, is Part 6.—Control Charts.

Introduction

A REVIEW of the evaluation by statistical techniques of highway aggregate characteristics is presented here as a condensed compilation of both historical data and data from designed quality-measurement projects in which the degree of conformance to specifications was statistically estimated. The historical data are not sufficient to determine the reason for any nonconformance to the specifications. However, the designed quality-measurement projects do provide data to determine quality at any point in a process, to disclose operations needing corrective action, and to give a valid estimate of specification conformance.

Reports from nine States on projects in which research data have been obtained are abstracted and summarized in this compilation to illustrate trends in gradation analysis, sampling and testing procedures, sand equivalent analysis as an alternate to gradation analysis, and soundness tests for aggregate quality.

Aggregate Base Course Characteristics

Specifications for base course aggregate usually contain limits for gradation, plasticity, soundness, and amount of deleterious material. Variations in gradation have been studied rather extensively to ascertain the degree of conformance obtained in construction. The data have been analyzed statistically to determine the variation in the material itself and that arising from sampling and testing. Most of the studies have been projects sponsored cooperatively by Public Roads and State Highway Departments, although some have been entirely State funded.

Nonuniformity of the final product has been disclosed by results of studies of gradation of different aggregate types including gravel, sand-gravel, and crushed stone. Differences in gradation were found between samples taken from the borrow pit or quarry plant, from the material after stockpiling, and again from the material after it had been processed and compacted in place on the roadway. Differences in test results on the aggregate often resulted from the sampling methods—sampling from a moving or stopped belt compared with sampling from a loaded truck. Representative sampling from an operation or placement also gave results that differed from those obtained by random sampling.

Combined variations frequently add up to a total variance of such magnitude that assurance of compliance with specifications is doubtful. However, with the knowledge provided by statistical analysis, it has been possible not only to pinpoint areas or operations requiring improvements, but also to

·termine when to take immediate corrective ·easures to assure better compliance.

ariance in historical data

Early statistical studies were made on data office files of completed projects. Although is type of data was not randomly selected, atistical analysis usually disclosed that easurements of base course characteristics llowed a normal distribution.

In table 1, which was extracted from a udy of historical data for 257 observations type A base in Louisiana, it is shown that r projects considered acceptable, the mean the distribution for all sieve sizes was well ithin design limits. However, the statistically mputed percentage of material within the ·sign limits varied for each sieve size. The west value was 82 percent for material ıssing the No. 40 sieve. The highest value ıs 99 percent for material passing the ·inch sieve.

ıriance of controlled research data

In the State of West Virginia, new construcon was evaluated statistically to determine ıriations from design gradations. Analysis variance disclosed that the material ıriance tended to be large and the sampling ıd testing variances small. According to the ıta, the magnitude of variance seemed to be rectly related to the amount on each sieve.

The data in table 2 are an example of many udies in West Virginia and other States in hich the components of variance are isolated statistical analysis of field data on aggreıte gradation characteristics. In figure 1, hich is a diagram from the West Virginia port, proposed 95 percent tolerance limits e shown. The tolerances are ±13 percent the sieve having approximately 50 percent the material passing, and taper in both rections toward 0 percent and 100 percent ıssing where the tolerances are ± 2 percent.

ariance caused by operators, sampling methods and equipment

Variance in the gradation of aggregate ixtures often is the result of sampling and sting procedures, as well as of the material self. Several States have made quantitative easurements of these parameters. In lichigan (*1*) [1] a field experiment was carried ıt to determine what part aggregate inıectors, screening sieves, and sampling ethods play in the uniformity of gradation sults. A mathematical model was prepared analyze the variations and ascertain hether (1) inspectors require further training sample and test aggregates, (2) testing ıuipment requires periodic calibration or aintenance, (3) improved precision is feasie in gradation analysis, and (4) significant teractions occur in the experimental work. he results of this study were as follows:

- Individual inspectors and methods of ımpling had a relatively small effect on adation results on the ⅜-inch sieve. According to an analysis of components of variance, an estimated 4 percent of the total variance was attributable to inspectors, 6 percent to sampling methods, and the remaining 90 percent to inherent material and experimental deviations.
- For material passing the No. 10 sieve, significant interaction effects among the main factors of the experiment were shown to exist. Variance of 0–8 percent was due to methods of selecting samples, variance of 7–18 percent was due to testing and the remaining variance was attributable to inherent material and experimental deviations.
- The results of the analysis of variance (see table 3) indicated that interaction effect was significant enough to reduce the accuracy of major comparisons. According to the data in table 3, the combined influence (interaction) of inspectors and screening kits affected the gradation results. Also, the State found that the difference between the two sampling methods was large enough to be of

[1] Italic numbers in parentheses identify the references ted on p. 237.

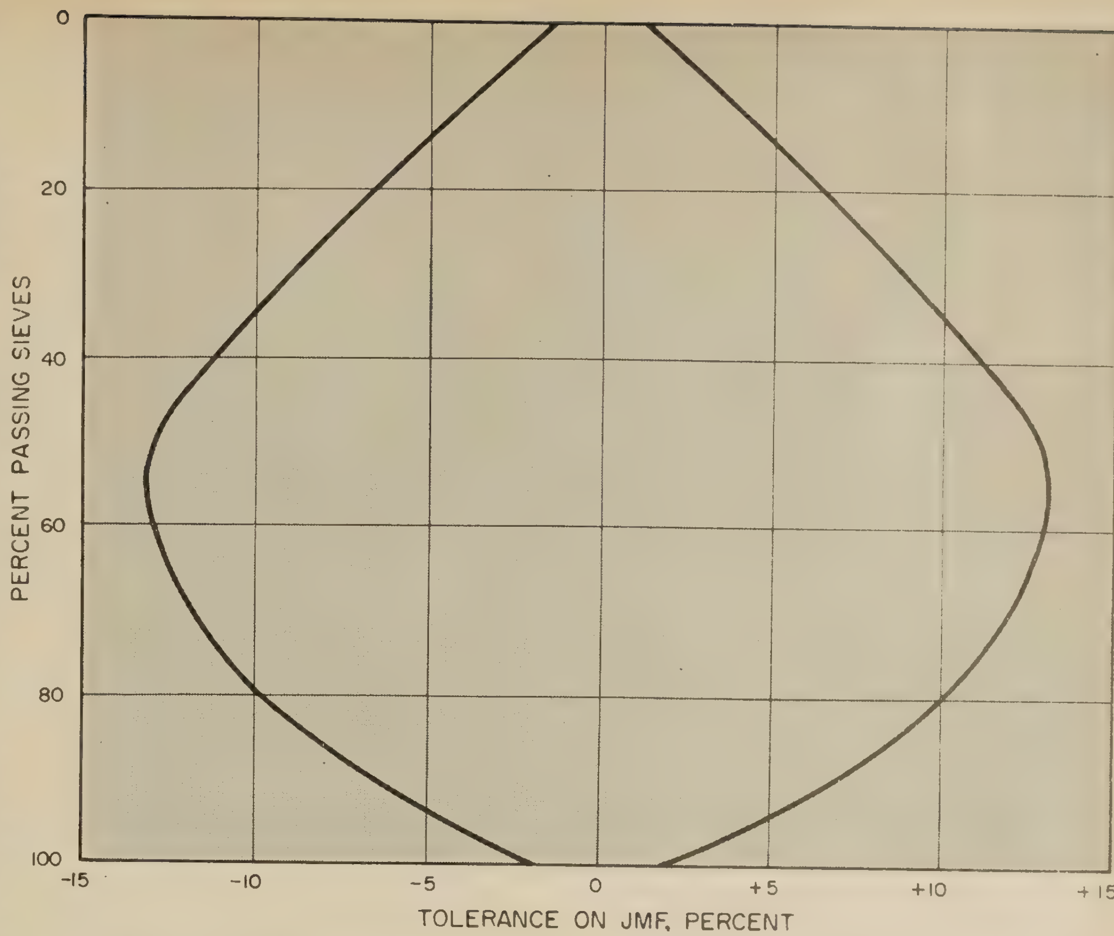


Figure 1.—Aggregate base course gradation characteristics, 95-percent probability tolerances on job-mix formula, West Virginia, 1966.

Table 1.—Base course analysis, gradation type A—historical data, Louisiana

Sieve size	Design limits	Mean distribution ($\bar{X}$)	Standard deviation (σ)	Compliance with design
	Pct.	*Pct.*	*Pct.*	*Pct.*
¾ in	75–95	90	2.5	99
No. 4	40–60	55	4.9	91
No. 40	20–45	37	6.3	82
No. 200	10–20	16	2.9	91

Table 2.—Base course gradation analysis—research data (n=136), West Virginia

Sieve size	Design limits	Mean distribution ($\bar{X}$)	Standard deviation (σ)	Variance		
				Material (σ_a^2)	Sampling (σ_s^2)	Testing (σ_t^2)
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1½ in	100	100	0.0	0.0	0.0	0.0
¾ in	40–85	80	3.9	9.6	5.8	0.2
⅜ in		50	5.2	18.3	6.4	2.4
No. 4	20–60	34	4.3	12.7	4.9	1.1
No. 16		20	3.6	9.1	3.1	0.6
No. 40	5–25	11	2.8	5.7	2.6	0.0
No. 100		6	2.7	4.8	2.9	0.0

Table 3.—Analysis of variance for passing No. 10 sieve, Michigan [1]

Nature of effect	Source of variance	Sum of squares	Degrees of freedom	Variance estimate	F	F tests: F 0.05	F tests: F 0.01
Main factors	M [2]	97.98	1	97.98	[3] 10.67	3.90	6.81
	I [4]	39.10	2	19.55	2.12	3.06	4.75
	S [5]	14.06	2	7.03	0.77	3.06	4.75
Interactions among factors	MI [2 4]	25.29	2	12.64	1.38	3.06	4.75
	MS [2 5]	3.61	2	1.80	0.20	3.06	4.75
	IS [4 5]	280.20	4	70.05	[3] 7.63	2.43	3.45
	MIS [2 4 5]	98.81	4	24.70	[6] 2.69	2.43	3.45
Replication	Residual	1,487.32	162	9.18			
	Total	2,046.36	179	11.43			

[1] Michigan Report No. R–571.
[2] M Sampling methods.
[3] Significant at the 1 and 5-percent levels (highly significant).
[4] I Aggregate inspectors.
[5] S Screening kits.
[6] Significant at the 5-percent level.

practical importance. The relative performance of aggregate inspectors was not consistent for all screening kits. These variances were significant, although not as large as the material variance, and it was presumed that, with training and corrective maintenance, the amount of testing and sampling variance could be reduced.

Methods of automatic aggregate sampling from a belt delivery system, and the variance resulting from the method used to prepare the test sample were studied in Idaho. Samples obtained with an automatic sampling device produced lower variance than those obtained manually, and the variance was more uniform. A direct relation was found between the splitting method and the testing variance of samples. Cross-split samples had a lower variance than those split only once. Cross-splitting is similar to quartering on a mat and combining the opposite quarters to form a single sample. Researchers tested 34 samples from Pit Le–111, collected by the manual method, and 25 samples from Pit Jr–2, obtained with an automatic sampling device. The variances for Jr–2 are relatively small and much more uniform than those for Pit Le–111. Part of the difference was attributed to the difference in the splitting techniques. The Idaho report was prepared to permit several cross comparisons of testing and sampling work. On the basis of these tests, 17 percent of the overall variance was due to testing variance whereas 30 and 53 percent, respectively, were due to sampling and material variances.

In Idaho, extensive research (*2*) was also conducted to ascertain whether the sand-equivalent test procedure was sufficiently reproducible to determine aggregate acceptability. The tests performed on cross-split samples at the Moscow laboratory resulted in a testing variance of 0.96, whereas the single-split samples at the Boise laboratory resulted in a testing variance of 1.85. For sand-equivalent determinations, considerable discrepancy existed between the results of the two laboratories; however, the test was considered satisfactory if the cross-split technique of the Moscow laboratory was used. As a result of the statistical analysis, improvements in both sampling and testing methods were initiated.

A study in California (*3*), was undertaken to evaluate the effectiveness and reliability of the sand-equivalent tests used for procedure control and for measuring the variation of the aggregate investigated. Tests were performed on 200 random samples from each of six projects. Gradation was determined for each sample, and the analysis of variance was reported for the results on several sieves. It was concluded that the sand-equivalent and sieve analyses, supplemented by the R-value results in borderline situations, can provide satisfactory control of base and subbase material. The variances for the test results on the base material were generally smaller than the variance for the subbase material, perhaps because of the greater selectivit used for base material. Although the samplir and testing variances were relatively sma for both materials, the testing variance wa significantly larger than the sampling varianc

The results of this research were used propose revision of California aggrega specifications. The proposed revisions, show in table 4, were designed so that prese specification limits could be retained by ba ing acceptance on a moving average of tl five most recent test results. Broader limi for individual test results were establishe Based on information available to him, t resident engineer is now authorized to acce the material, provided that the average inc cates that the process is in control, even thou a single test result may deviate from t broader limits.

According to the California report, class aggregate base had an average sand-equiv lent value of 44 with a pooled standard devi tion of 4.8, and class 2 aggregate subbase h an average sand-equivalent value of 32 with pooled standard deviation of 5.0. The propos specification requirements for the san equivalent test and gradation are shown table 4. It was stated in the report that:

". . . the proposed specifications are to used as guidelines only and are not intend to interfere with the present practice of desig ing specifications to meet local conditions f economic reasons. Once the gradation lims are established for a particular job, statis cal specifications can be designed using t

Table 4.—Digest of proposed specifications for class 2 base and subbase aggregates, California

Material	Sand-equivalent values (Test Method, California 217): Minimum average [1]	Not to be lower than [2]	Overall average [3]	Gradation values: Sieve size	Percent passing: Moving average	Individual test result
Base	30	25	36	1 inch		100
				¾ inch	95±5	95(+5) (−7)
				No. 4	45±10	45±15
				No. 30	20±10	20±13
				No. 200	5.5±3.5	5.5±4.5
Subbase	23	18	30	3 inch		100
				2½ inch	95±5	95(+5) (−10)
				No. 4	65±25	65(±35)
				No. 200	12.5±12.5	12.5(+17.5) (−12.5)

[1] Five consecutive tests, each performed on independent sample.
[2] No single sand equivalent result to be lower.
[3] Overall average should be maintained for 99.9 perc probability of acceptance of suitable material.

Table 5.—Summary statistics for magnesium sulfate soundness tests, New York

Sand No.	Arithmetic means [1]: Drying period 6-hour	Drying period 30-hour	Difference in variation [2]	Higher	Variance estimates [1]: Drying period 6-hour	Drying period 30-hour	Difference in variation [2]	Higher
	Pct.	*Pct.*			*Pct.*	*Pct.*		
1	5.64	5.90	Insignificant		0.23	0.24	Insignificant	
2	17.09	15.74	do		0.05	1.83	Significant	30-hour.
3	23.21	23.83	Significant	30-hour	0.06	0.24	Insignificant	
4	47.01	41.98	do	6-hour	1.37	2.88	do	
5	47.65	50.36	do	30-hour	2.13	0.40	Significant	6-hour.

[1] Calculated from results of tests on two groups of three samples each.
[2] Statistical significance at 0.05 confidence level.

Table 6.—Results for surface mixture samples, South Carolina

Sieve size	Sample location	Specification limits percent passing	Control chart values		Standard deviation		Analysis of variance			
			Average ($\bar{x}$)	Total (σ)	Average ($\bar{x}$)	Total (σ)	Total (σ_{to}^2)	Material (σ_m^2)	Sampling (σ_s^2)	Testing (σ_t^2)
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
½ in	Plant [1]	87–97	92.0	2.88	91.8	3.10	9.62	2.45	0.0	7.60
	Spreader [1]		90.0	4.00	90.7	3.52	12.41	8.74	0.0	3.50
	Compacted [1]		92.2	3.30	92.1	3.16	10.02	0.0	2.18	6.19
No. 4	Plant	58–72	66.1	3.90	66.8	3.92	15.37	9.70	0.0	5.15
	Spreader		65.2	5.71	65.7	5.84	34.06	30.9	0.0	4.75
	Compacted		65.0	4.32	65.2	4.28	18.34	0.0	10.18	8.11
No. 10	Plant	42–58	52.0	3.45	52.6	3.69	13.59	8.33	1.76	3.69
	Spreader		53.0	4.98	52.7	5.60	31.35	28.15	0.0	5.04
	Compacted		54.3	3.92	54.5	4.01	16.11	0.0	11.36	7.39
No. 40	Plant	21–35	28.1	1.70	28.3	1.91	3.64	2.28	0.0	1.40
	Spreader		28.0	1.41	28.5	2.34	5.48	4.92	0.0	1.00
	Compacted		28.7	1.85	28.8	2.08	4.31	0.0	2.51	2.09
No. 200	Plant	4–10	5.7	1.06	5.8	1.15	1.32	1.15	0.0	0.18
	Spreader		5.7	1.20	6.34	1.38	1.91	0.0	0.0	1.44
	Compacted		6.5	1.04	6.4	1.03	1.05	0.30	0.48	0.20

[1] Number of tests performed: Plant = 40, Spreader = 24, Compacted = 128

tandard deviation as reported in this study, if o more accurate measurements are available."

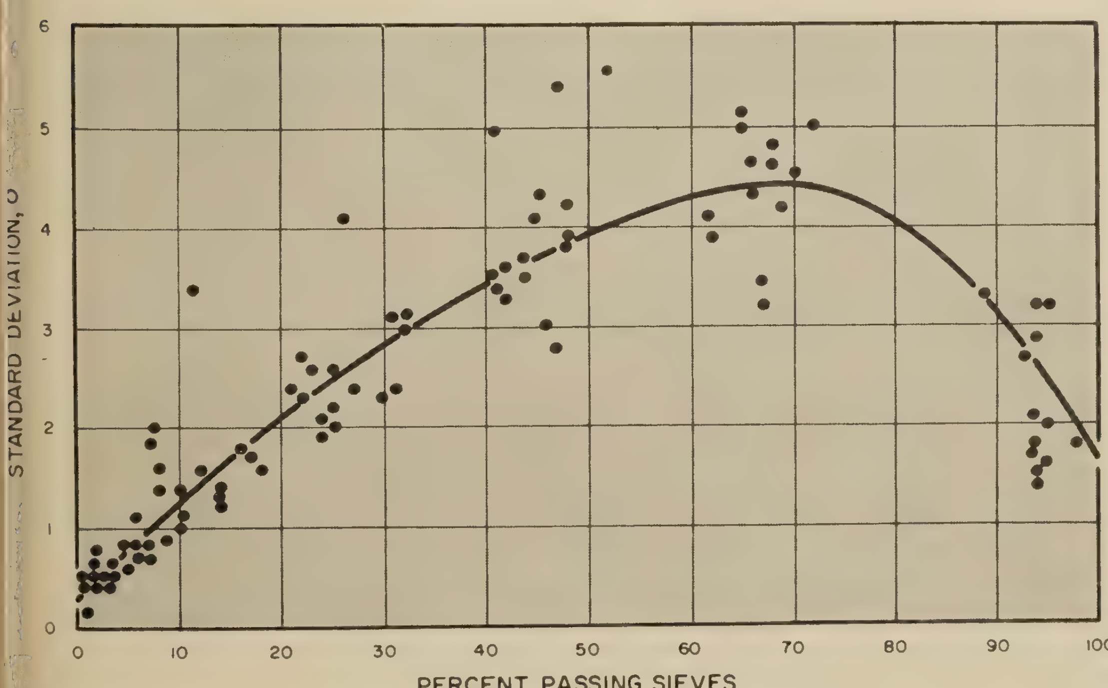
After publication of the report, the State ivision of Highways used similar specifica- ions in its construction of projects.

alt soundness test of aggregate

In certain uses, the quality of individual ggregate particles is an important character- stic, and owing to the composition of gravel or tone, the soundness of the aggregate pieces nust be determined by certain standardized ests. In a study of *Salt Soundness Tests for ine Aggregate* (*4*), the New York Department f Transportation used statistical concepts to nvestigate the procedures for determining oth the sodium and magnesium salt sound- ess of fine aggregate and the methods used to udge the acceptability of a source. Data were resented on (1) the effect of drying time on he magnitude and reproducibility of test esults, (2) overall reproducibility of the test vith sodium and magnesium sulphates, and (3) the combined effect of testing and production variations on the scatter of test results from single sources. The summary statistics for the soundness tests, with various drying periods, is shown in table 5.

The conclusions extracted from the New York study were "(1) that an increase in drying time in the test from 6 to 30 hours will result in no change in the magnitude or reproducibility of the test results, (2) the reproducibility of the test with sodium sulphate and the test with magnesium sulfate are not significantly different, and (3) that it is possible to place the acceptance of sources of fine aggregate on a sound statistical foundation." They recommended that "the magnesium sulphate soundness test continue to be performed at the rate of one cycle per day and that the test with sodium sulphate be discontinued."

Even though the results of the New York study of fine aggregates were generally acceptable as reproducible results, many States have not obtained satisfactory correlation between salt-soundness test results and performance. This is particularly true for coarse aggregates.



igure 2.—Relation of standard deviation to percentages passing sieves, asphaltic concrete wearing course, West Virginia, 1966.

Bituminous Concrete Aggregate Characteristics

Aggregate used in bituminous concrete mixtures is subjected to several manipulations and treatments that are not applied to base course aggregate. The aggregate is heated for drying and mixing with asphalt. Often, it is stockpiled or placed in storage bins before the mixing operations. The final mixture is spread by a mechanical spreader and then a high force is applied for final compaction and rolling. Thus, the finished layer has experienced many abrasive forces that could cause not only changes in gradation of the aggregate component, but also changes in density and stability. A more detailed analysis of variations in aggregates used in bituminous construction is contained in Part 4. However, the more important findings of individual projects are reported here.

In a study performed in South Carolina (*5*), random samples of asphalt mixtures were selected from trucks at the batch plant, from the roadway just behind the spreader, and from the roadway after compaction, to determine whether any progressive change occurred in the characteristics of the aggregate. A summary of this work is given in tables 6 and 7 in which the specification limits and analysis of variance for both surface and binder courses are also shown. The aggregate passing the No. 4 sieve in the surfacing mixture was within the job-mix formula only 50 percent of the time by routine control sampling and 66 percent of the time by random sampling. The material passing the No. 40 sieve was within the job-mix formula 76 percent of the time by control sampling and 88 percent of the time by random sampling. The test results shown in table 6 indicate that the average for the No. 4 material varied from 66.8 to 65.2 percent whereas the No. 40 material varied only from 28.3 to 28.8 percent, conforming more closely to the job-mix formula. The greatest standard deviation occurred on the samples from the spreader box.

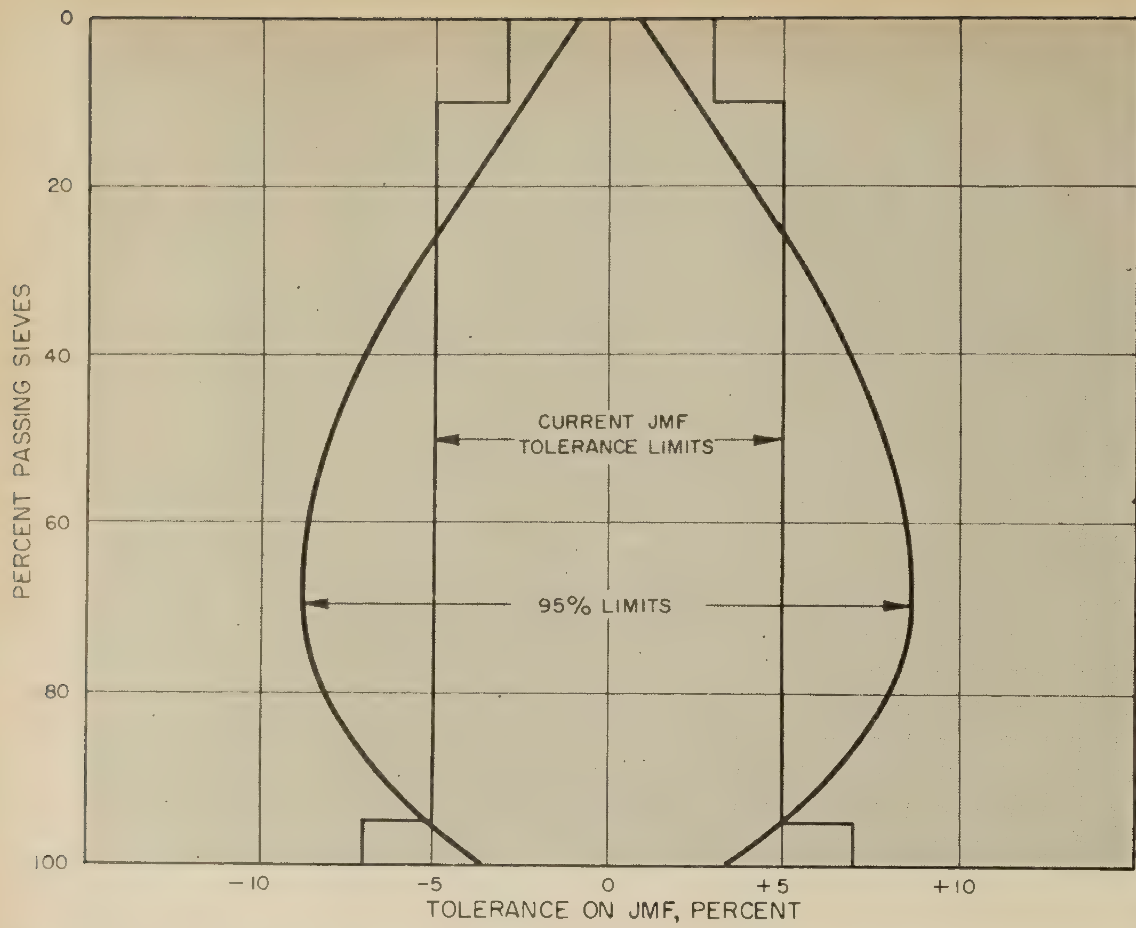


Figure 3.—Relation of 95-percent probability tolerances on job-mix formula to percent passing sieves, asphaltic wearing course, West Virginia, 1966.

The characteristics of aggregate used in bituminous mixtures were also explored in West Virginia (*6*). An analysis of the aggregate passing the No. 4 sieve is shown in table 8 for 10 bituminous projects. For the percent passing the No. 4 sieve, nine of the 10 projects had an average value that was within the specifications. However, the overall standard deviation for the individual projects was so large that many of the projects had a considerable amount of nonconforming material. Because of the large overall standard deviation, 4.4 percent, a change in the specified job-mix tolerances was recommended.

The following excerpts were taken from the West Virginia report:

"Tolerances for percentages passing other sieves may also require adjustment. Inspection of the data shows that the major component of the overall standard deviation, σ_o, is the materials variance, σ_a, and sampling and testing can be reduced to a negligible amount."

"The size of the standard deviation of the percent passing any sieve, neglecting sampling and testing error, depends to a large extent upon the value of the percentage passing that sieve" (fig. 2).

In the West Virginia report it was proposed that tolerances for gradation specifications be varied according to the percentage passing any sieve. The magnitude of variation to provide 95 percent probability tolerances on the job-mix formula is shown in figure 3.

Other States engaged in statistical studies of aggregate-gradation characteristics in bituminous mixtures have indicated that, for best uniformity and smallest standard deviations, control of gradation should be at the mixing plant. Job-mix tolerances for all gradations should be adjusted for the percentages expected to pass the specified sieves.

Portland Cement Concrete Aggregate Characteristics

Because structural concrete in highway construction is critical, the specified aggregate gradation should be assured. Several research projects were conducted to determine the best place to sample aggregate for control, permissible tolerances on various sieve sizes, and alternate methods or tests to establish gradation uniformity.

In California, a study was performed to determine the precision of current test methods and the feasibility of using statistical quality control procedures for portland cement concrete aggregate. Several conclusions were drawn from this study: Present controls and specifications for aggregate gradation need to be modified because of the high material variance and large percentages of out-of-specification gradation; sand-equivalent and cleanliness test methods were satisfactory; more efficient field control would be possible if control charts were used; better control of gradation could be obtained by using a *moving average* based on the results of the five most recent individual tests; material and testing variances were considerably larger than were anticipated (see fig. 4); and a relatively high percentage of the aggregate failed to meet the specification, which is shown by the diagram in figure 5.

A statistical analysis of variance in aggregate for portland cement concrete was made by Louisiana (7). The variations in gradation of fine and coarse aggregate sampled from different stockpiles as well as the differences be-

Table 7.—Results for binder mixture samples, South Carolina

Sieve size	Sample location	Specification limits percent passing	Control chart values		Standard deviation		Analysis of variance			
			Average ($\bar{x}$)	Total (σ)	Average ($\bar{x}$)	Total (σ)	Total (σ_{to}^2)	Material (σ_m^2)	Sampling (σ_s^2)	Testing (σ_t^2)
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1 in	Plant [1]	80–97	93.4	3.95	93.9	4.13	17.09	0.0	2.60	13.04
	Spreader [1]		93.8	5.19	93.3	4.07	16.56	3.35	0.0	12.25
	Compacted [1]		93.4	4.70	93.7	4.48	20.07	4.59	0.0	15.43
No. 4	Plant	35–50	40.6	4.76	40.8	4.61	21.25	8.47	5.37	7.52
	Spreader		40.1	6.79	41.3	6.01	36.14	21.20	0.0	12.87
	Compacted		43.1	4.42	42.9	4.54	20.60	4.23	7.36	8.67
No. 10	Plant	25–35	32.2	4.06	32.2	3.90	15.24	7.22	3.68	4.43
	Spreader		32.2	5.46	32.9	4.83	23.3	14.03	0.0	8.38
	Compacted		34.8	3.51	34.6	3.74	13.96	0.0	5.86	5.91
No. 40	Plant	None	18.0	2.09	18.1	2.18	4.74	2.17	1.14	1.46
	Spreader		18.3	2.66	18.5	2.34	5.48	3.18	0.0	2.37
	Compacted		19.7	2.00	19.9	3.62	13.15	2.24	0.0	10.87
No. 200	Plant	None	4.1	0.53	4.1	0.54	0.30	0.17	0.05	0.09
	Spreader		4.0	0.49	4.1	0.58	0.33	0.18	0.0	0.18
	Compacted		4.3	0.67	4.3	0.67	0.44	0.11	0.18	0.15

[1] Number of tests performed: Plant = 284, Spreader = 68, Compacted = 380.

able 8.—Analysis of variance of bituminous concrete aggregate for 10 projects in West Virginia

Project No.	Sample location	Number of samples (n)	Percent passing No. 4 sieve Specification 60–70				
			Average ($\bar{X}$)	Overall standard deviation (σ_o)	Standard deviation		
					Material (σ_a)	Testing (σ_t)	Sampling (σ_s)
			Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
38A1	Even	96	66.7	2.5	2.5	0.0	0.0
38A1	Odd	96	67.5	4.8	2.5	1.6	3.8
3235	Even	100	65.6	3.6	3.6	0.0	0.0
3235	Odd	100	64.8	3.3	3.3	0.0	0.0
3462	Truck	120	69.3	4.5	3.4	0.0	2.9
3462	Pavement	120	65.7	4.7	4.1	0.8	2.1
173 H(1) & (2)		200	70.0	4.8	3.6	1.5	2.2
204A & 204A(3)		180	72.1	5.1	4.4	1.8	1.7
284(C) & (4) SRC		120	61.7	4.0	3.9	0.8	0.3
284(C) & (4) AASHO		120	61.5	4.2	3.9	1.6	0.5
Average, all projects			66.5	4.4	3.7	1.2	1.9

able 9.—Analysis of variance on gradation of fine aggregate for portland cement, Louisiana
Percent passing No. 4 sieve

Source of variance	Sum of squares (SS)	Degrees of freedom (DF)	Mean squares (MS)	Estimate of mean squares [1] (EMS)	F.05
Between stockpiles	249.43	8	31.18	$\sigma_e^2+2\sigma_s^2+16\sigma_{st}^2$	[2] 8, 63
Between samples within stockpiles	52.44	63	0.83	$\sigma_e^2+2\sigma_s^2$	[2] 63, 72
Between subsamples within samples	14.35	72	0.20	σ_e^2	------
Total	316.22	143	------	---------------	------

[1] σ_e^2=.20(Testing) σ^2_{sample}=.32 (Sampling) $\sigma^2_{stockpile}$=1.90 (Material).
[2] Significant.

tween samples within stockpiles, were determined. According to the Louisiana report, "The largest component of variance is between stockpiles, which is reflective of material variance. The variation between samples within stockpiles can be attributed to either the stockpiling technique or sampling procedure." The actual results for the fine aggregate passing the No. 4 sieve are shown in table 9. The analysis of the coarse aggregate was similar to that of the fine aggregate. As shown in table 10, heavily loaded sieves had the greatest deviations and the largest amounts of material outside the specification limits. As a result of this study, the researchers prepared suggested acceptance limits and frequencies of measurement for aggregate used in portland cement. (See table 11.)

Quality control of aggregate used in portland cement concrete by sampling from the stockpiles and bins at the central plant was studied in Oklahoma (*8*). The dry aggregate was weighed at the bin site, the cement added, and the batch hauled by trucks to the road site where the concrete was mixed. Random samples were taken at a point in the stockpile nearest the bins. The analysis of the gradation indicated that the mean values for each sieve size were within the specification limits although many individual values were outside

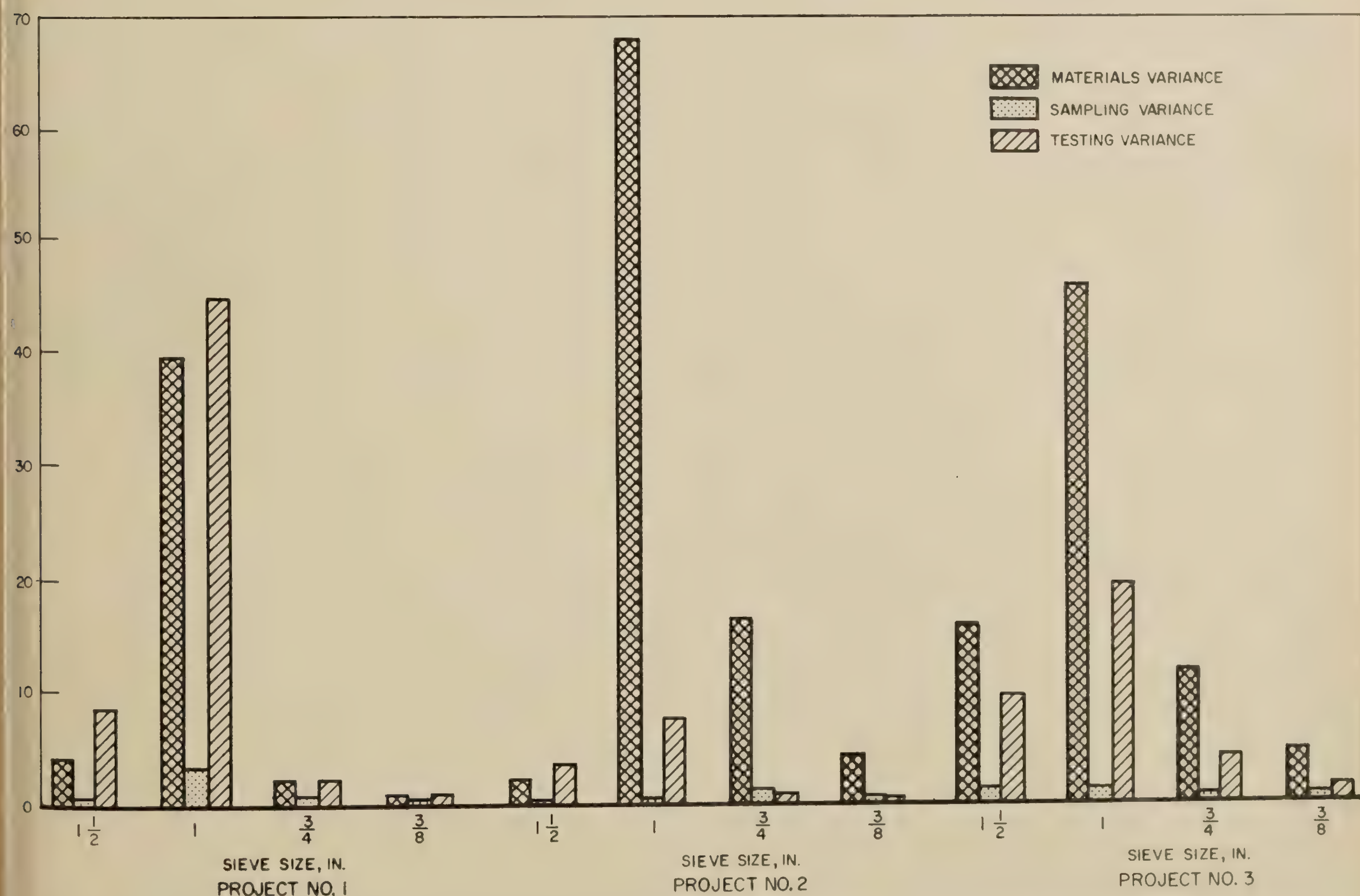


Figure 4.—Analysis of variance of portland-cement-concrete coarse aggregate for material passing different sieves, California.

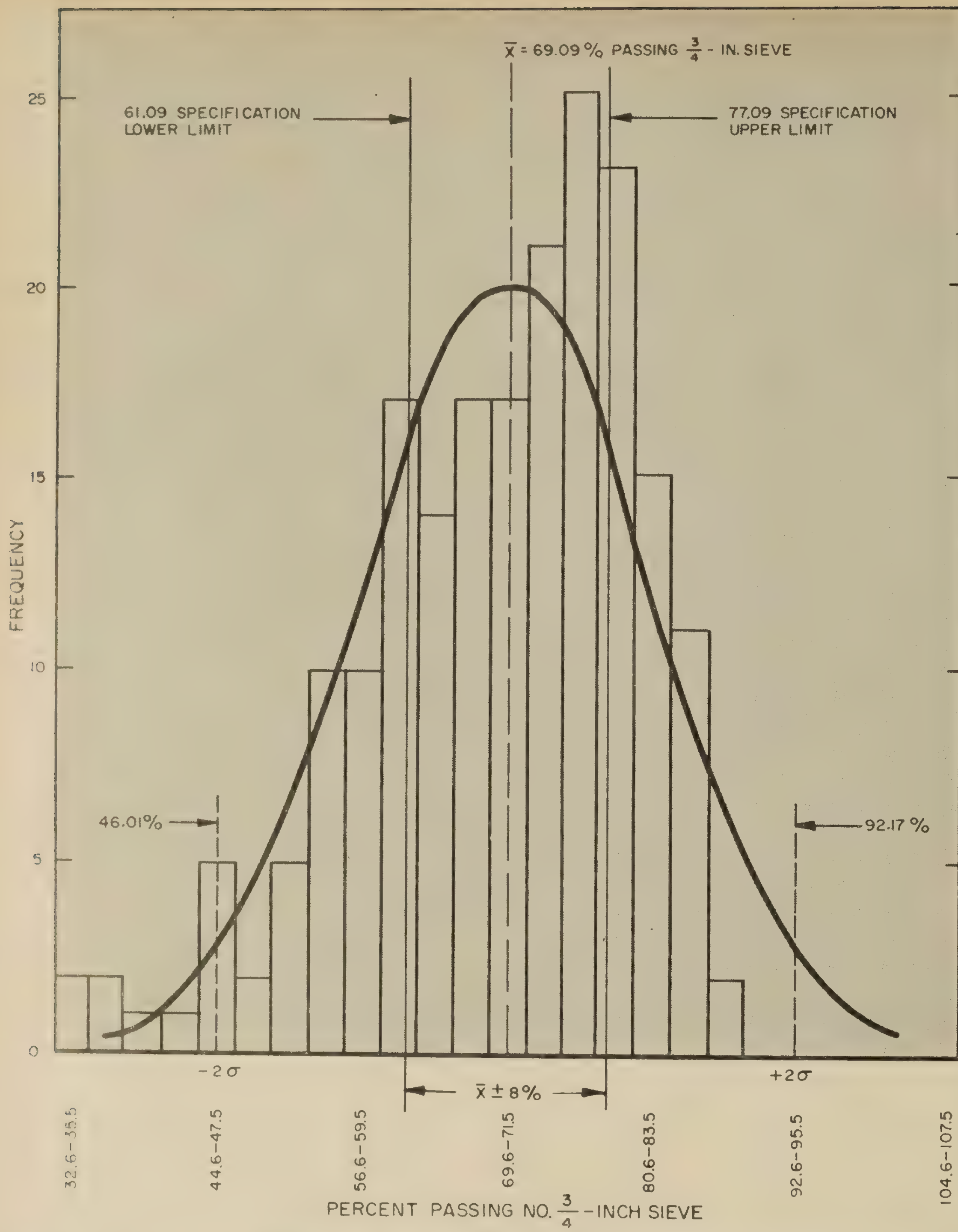


Figure 5.—Percent of material outside of specifications, portland-cement-concrete aggregate passing No. 3/4-in. sieve, project No. 2, California.

the upper and lower control limits. The Oklahoma Department of Highways recommended that the gradation determination be continued, but with certain modifications. Acknowledging that some plans provide for the sampling of aggregates at the batching bin, researchers pointed out in their report that sampling at the stockpiles permits early detection of undesirable or unacceptable aggregate, which is the purpose of quality control—to locate defective material as quickly as possible.

Summary

Some of the important findings from selected research on the characteristics of aggregate used in base courses and in bituminous and portland cement concrete mixtures have been presented here. More attention has been given to aggregate-gradation characteristics from source of supply to placement, than to othe characteristics. Early studies concentrated on historical data; more recent studies were conducted during actual field construction. Comprehensive plans were devised to study historical data and to measure variability during construction. The degree of conformance to gradation specifications was found to vary from step to step in the processing. Analysis of variance usually was applied during construction to determine causes of the variation and to locate conditions needin corrective action.

Generally, the largest deviations from specifications were in the material in the middl of a stack of sieves—where a large amoun of material is on individual sieves.

Knowledge of inherent material, sampling and testing variations enables the enginee to design specifications with tolerances tha are compatible with local conditions and thereby, to avoid unenforceable requirement or unreasonable expense and still obtain suitable aggregate.

For aggregate control, the sand-equivalen test rather than gradation is preferred i some States, and statistical research, con ducted to ascertain whether the sand-equiva lent test is informative and reproducible, ha

Table 10.—Summary of statistical results on portland cement concrete aggregate gradation, Louisiana [1]

Sieve size	Average (x̄)	Standard deviation (σ)	Minimum	Maximum	Outside specifications	Specification limits	Variance (σ²)		
							Test	Sample	Stockpile
Grade A course aggregate									
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*		*Pct.*	*Pct.*	*Pct.*
1 in.	95.6	3.8	82.7	99.9	7.3	90–100	0.84	5.65	9.97
3/4 in.	75.4	10.8	46.1	88.8	2.1	40–88	6.41	77.62	40.72
1/2 in.	35.5	12.7	4.6	60.2	13.5	15–55	9.18	132.04	26.72
No. 4	1.3	1.2	0.2	5.5	0.0	0–6	0.13	0.76	0.72
Fine aggregate									
No. 4	97.8	1.5	92.1	99.9	3.8	95–100	0.20	0.32	1.90
No. 16	79.2	7.9	56.6	91.6	9.7	45–90	0.70	10.72	57.69
No. 50	15.9	6.5	7.2	31.6	1.4	7–30	5.36	39.88	0.0
No. 100	2.1	1.3	0.3	5.7	0.0	0–7	0.04	0.40	1.34

[1] Louisiana Department of Highways Report, 1966.

Table 11.—Suggested acceptance limits for portland cement concrete aggregate [1]

Sieve size	Acceptance probability (P_a)	Rejection probability (P_r)	n	Acceptance limits: Mean LL	Acceptance limits: Mean UL	Acceptance limits: Individual $\bar{x}_a-$	Acceptance limits: Individual $\bar{x}_a+$	Measurement frequency
Gradation of fine aggregate, percent passing								
	Pct.	*Pct.*						
No. 4	99	90	4	95.90	99.75	3.93	3.93	One every 200 cu. yd.
No. 16	99	90	4	68.97	89.45	20.80	20.80	
No. 50	99	90	4	7.51	24.35	17.11	17.11	
No. 100	99	90	4	0.41	3.71	3.35	3.35	
Gradation of grade A coarse aggregate, percent passing								
1 in	99	90	4	90.63	100.00	10.10	10.10	One every 500 cu. yd.
¾ in	99	90	4	61.43	89.39	28.40	28.40	
½ in	99	90	4	19.08	51.84	33.27	33.27	
No. 4	99	90	4	0.0	2.70	3.20	3.20	

[1] Louisiana Department of Highways Report, 1966.

onfirmed its usefulness, although the amount f data at present is rather limited.

Statistical research on salt-soundness deter- iination indicated that drying time did not eed to be changed; that sodium sulfate esting could be discontinued, as magnesium ılfate testing is satisfactory; and that it is ossible to place acceptance of fine aggregate ources on a sound statistical foundation.

In statistically-oriented research on aggre- ate gradation for bituminous mixtures, formation similar to that for base courses as developed, and indicated that variation om the specifications differs according to e point of sampling. The research showed ıat the variation on certain sieve sizes is onsiderable, indicating either the need for nprovement in sieving operations or the stablishment of wide tolerances in the speci- cations to eliminate compliance disagree- ıent. The research also indicated that ampling at the hot bins was preferred for rocess control, whereas, sampling at the ompacted bituminous layer was best for stablishing uniformity of the mixture.

Data in various studies indicated that the ggregate used in portland cement concrete had a smaller standard deviation than the aggregate used in bituminous mixtures or in base courses, but that statistical analysis provided information for early detection of undesirable gradation or undesirable quality.

Based on their studies, highway departments in some States are revising their specifications and outlining specific sampling procedures. The use of statistically designed control charts is highly recommended for control of the characteristics of aggregate by these States. The moving average of five most recent individual test results is reported to be the most practical for controlling the construction processes.

REFERENCES

(1) *Highway Quality Control Program, Statistical Parameters,* Research Report No. R–572, Michigan Department of State Highways, March 1966, p. 41.

(2) *Quality Control,* Research Project No. 11, State of Idaho Department of Highways, May 1967, p. 16.

(3) *A Statistical Analysis of Untreated Base and Subbase Materials,* State of California Transportation Agency, Department of Public Works, Division of Highways, March 1967, pp. 22 and 23.

(4) *Salt Soundness Tests for Fine Aggregates,* New York State Department of Public Works, September 1964, p. 3.

(5) *Procedures for Using Statistical Methods for Process Control and Acceptance of Bituminous Mixtures,* prepared by Paquette-Mills, Consulting Engineers, Atlanta, Ga., for South Carolina State Highway Department, February 1966, pp. 78 and 79.

(6) *Determination of Statistical Parameters for Highway Construction,* Research Project No. 18, prepared by Materials Research and Development, Inc., Miller-Warden Associates Div., for the State Road Commission of West Virginia, November 1966, p. III–49.

(7) *Quality Control Analysis, Part III, Concrete and Concrete Aggregates,* by S. C. Shah, Lousiana Department of Highways, November 1966, p. 11.

(8) *Statistical Quality Control of Portland Cement Concrete Pavements,* prepared by Joakim G. Laguros, University of Oklahoma, for Oklahoma Department of Highways and U.S. Bureau of Public Roads, June 1968.

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PB 174319	67-3—Vibration of Concrete.
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PB 174324	Roadway Failure Study No. 1—Research Publication H-14.
PB 174325	Roadway Failure Study No. 1—Research Publication H-14, Appendices A and B.
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PB 174954	Instrumentation Report for Chadd Cre Culvert, March 1967. (Calif.).
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PB 174956	Beneficiation of Aggregates (1966). (Mont.)
PB 174958	Aggregate Absorption Factors as an Indicat of the Freeze-Thaw Durability of Stru tural Lightweight Concrete, Septemb 1966. (Tex.).
PB 174959	Peel Strength the Behavior of Vario Asphalt-Stone Adhesive Joints, June 1966.
PB 174960	Clay Mineralogy and Chemistry of Select Washington County, Arkansas Soils a Effects on Their Engineering Properties Technical Report No. 4, April 1967.
PB 174961	Final Report on a Laboratory Analysis o Composite Pavement Consisting of P stressed and Post-Tensioned Concr Panels Covered with Asphalt Concre, January 1967.
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PB 174963	Mixing Time Study—Bituminous Mi (1967).
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PB 174967	Soil Stabilization Methods for Minimizing Detrimental Effects of Frost Action Paved and Unpaved Roads in No Carolina, October 1966.
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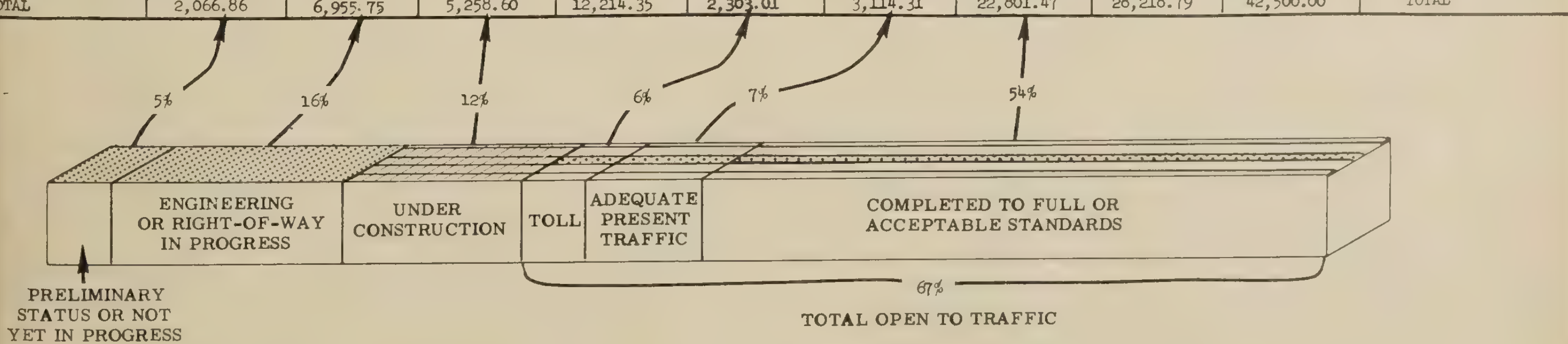
THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

IMPROVEMENT STATUS OF SYSTEM MILEAGE AS OF JUNE 30, 1969

TABLE I

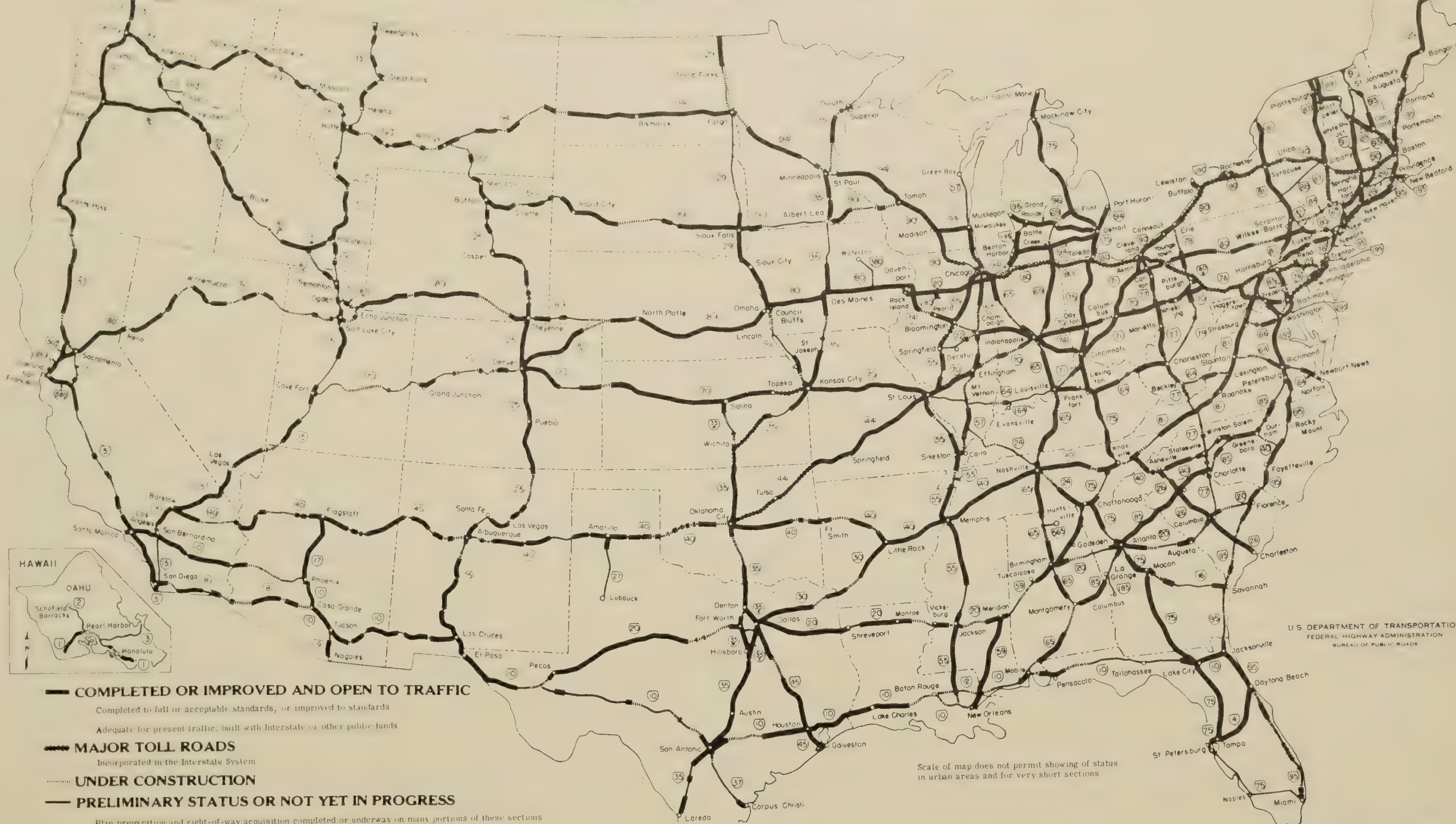
STATE	PRELIMINARY STATUS OR NOT YET IN PROGRESS 1/	WORK IN PROGRESS: ENGINEERING OR RIGHT-OF-WAY	WORK IN PROGRESS: UNDER CONSTRUCTION	WORK IN PROGRESS: TOTAL UNDERWAY	OPEN TO TRAFFIC: TOTAL FACILITIES	OPEN TO TRAFFIC: IMPROVED TO STANDARDS ADEQUATE FOR PRESENT TRAFFIC	OPEN TO TRAFFIC: COMPLETED TO FULL OR ACCEPTABLE STANDARDS	OPEN TO TRAFFIC: TOTAL OPEN TO TRAFFIC	TOTAL DESIGNATED SYSTEM MILEAGE	STATE
LABAMA	19.20	192.11	191.20	383.31	-	143.90	350.20	494.10	896.61	ALABAMA
RIZONA	5.90	157.83	201.30	359.13	-	226.04	581.10	807.14	1,172.17	ARIZONA
RKANSAS	-	24.87	86.25	111.12	-	41.29	367.14	408.43	519.55	ARKANSAS
ALIFORNIA	103.80	334.70	338.50	673.20	10.20	281.90	1,205.00	1,497.10	2,274.10 2/	CALIFORNIA
OLORADO	143.86	111.00	66.66	177.66	-	112.24	542.12	654.36	975.88	COLORADO
ONNECTICUT	51.60	23.08	11.20	34.28	16.40	47.37	197.50	261.27	347.15	CONNECTICUT
ELAWARE	-	9.40	2.07	11.47	14.30	0.92	13.92	29.14	40.61	DELAWARE
LORIDA	271.21	290.29	119.63	409.92	44.85	-	686.94	731.79	1,412.92	FLORIDA
EORGIA	38.80	278.17	156.56	434.73	-	6.94	666.71	673.65	1,147.18	GEORGIA
AWAII	11.60	21.68	3.46	25.14	-	1.57	13.54	15.11	51.85	HAWAII
DAHO	-	120.60	93.88	214.48	-	96.30	300.78	397.08	611.56	IDAHO
LLINOIS	83.82	264.57	272.53	537.10	155.66	148.05	798.63	1,102.34	1,723.26	ILLINOIS
NDIANA	14.00	164.12	175.34	339.46	156.90	15.39	603.37	775.66	1,129.12	INDIANA
OWA	74.80	109.24	79.71	188.95	3.57	-	516.47	520.04	783.79	IOWA
ANSAS	19.60	80.50	70.10	150.60	185.90	0.30	464.10	650.30	820.50	KANSAS
ENTUCKY	-	145.42	111.46	256.88	39.20	3.40	439.12	481.72	738.60	KENTUCKY
OUISIANA	30.00	168.67	178.44	347.11	-	6.35	319.76	326.11	703.22	LOUISIANA
AINE	1.75	32.78	2.38	35.16	57.70	99.16	118.45	275.31	312.22	MAINE
ARYLAND	25.21	7.16	30.56	37.72	53.04	70.89	173.25	297.18	360.11 3/	MARYLAND
ASSACHUSETTS	19.07	29.43	33.01	62.44	134.41	27.36	223.70	385.47	466.98	MASSACHUSETTS
ICHIGAN	41.33	167.00	44.39	211.39	4.77	44.41	872.40	921.58	1,174.30	MICHIGAN
INNESOTA	9.40	240.43	210.80	451.23	-	30.28	422.51	452.79	913.42	MINNESOTA
ISSISSIPPI	-	125.60	76.40	202.00	-	19.20	457.10	476.30	678.30	MISSISSIPPI
ISSOURI	26.60	242.30	43.40	285.70	0.30	160.80	672.50	833.60	1,145.90	MISSOURI
ONTANA	24.60	465.31	101.80	567.11	-	301.84	292.45	594.29	1,186.00	MONTANA
EBRASKA	1.90	72.84	31.75	104.59	0.22	13.58	359.18	372.98	479.47	NEBRASKA
EVADA	-	122.49	38.68	161.17	-	5.34	368.05	373.39	534.56	NEVADA
EW HAMPSHIRE	11.30	25.32	6.06	31.38	22.02	14.76	135.63	172.41	215.09	NEW HAMPSHIRE
EW JERSEY	46.00	90.60	62.40	153.00	46.30	26.40	113.50	186.20	385.20 4/	NEW JERSEY
EW MEXICO	37.49	149.09	114.40	263.49	-	61.05	636.27	697.32	998.30	NEW MEXICO
EW YORK	142.17	46.63	88.72	135.35	491.88	53.27	532.38	1,077.53	1,355.05	NEW YORK
ORTH CAROLINA	50.04	193.98	121.22	315.20	-	16.75	455.26	472.01	837.25	NORTH CAROLINA
ORTH DAKOTA	62.60	38.83	77.14	115.97	-	51.94	340.30	392.24	570.81	NORTH DAKOTA
HIO	8.80	154.25	178.50	332.75	206.37	54.98	931.20	1,192.55	1,534.10	OHIO
KLAHOMA	-	49.29	139.30	188.59	174.04	23.30	420.90	618.24	806.83	OKLAHOMA
REGON	24.73	54.90	12.62	67.52	-	111.16	531.52	642.68	734.93	OREGON
ENNSYLVANIA	41.86	96.69	286.06	382.75	360.18	8.35	781.33	1,149.86	1,574.47	PENNSYLVANIA
HODE ISLAND	26.50	7.63	15.43	23.06	-	13.81	36.82	50.63	100.19	RHODE ISLAND
OUTH CAROLINA	73.70	92.13	133.72	225.85	-	15.14	441.14	456.28	755.83	SOUTH CAROLINA
OUTH DAKOTA	-	161.39	93.20	254.59	-	60.28	364.36	424.64	679.23	SOUTH DAKOTA
ENNESSEE	7.50	254.65	116.55	371.20	-	119.40	547.00	666.40	1,045.10	TENNESSEE
EXAS	122.71	529.53	375.06	904.59	-	272.14	1,866.78	2,138.92	3,166.22	TEXAS
TAH	50.82	349.95	234.93	584.88	-	20.23	277.82	298.05	933.75	UTAH
ERMONT	-	96.32	51.06	147.38	-	4.43	168.57	173.00	320.38	VERMONT
IRGINIA	9.80	214.19	153.26	367.45	37.60	44.87	608.48	690.95	1,068.20	VIRGINIA
ASHINGTON	68.81	118.23	24.74	142.97	-	178.99	363.39	542.38	754.16	WASHINGTON
EST VIRGINIA	29.52	148.53	63.72	212.25	87.20	0.30	184.68	272.18	513.95	WEST VIRGINIA
ISCONSIN	105.47	1.73	39.14	40.87	-	24.71	392.10	416.81	563.15	WISCONSIN
YOMING	73.83	72.73	97.87	170.60	-	30.31	638.90	669.21	913.64	WYOMING
ISTRICT OF COLUMBIA	9.91	7.57	2.04	9.61	-	2.92	7.15	10.07	29.59	DISTRICT OF COLUMBIA
PENDING	45.25 5/								45.25 5/	PENDING
TOTAL	2,066.86	6,955.75	5,258.60	12,214.35	2,303.01	3,114.31	22,801.47	28,218.79	42,500.00	TOTAL



/ Public hearings have been held on route location, and location studies are underway on many portions of the mileage in this column.
/ Excludes the 17.20 mile Century Freeway (I-105) which was added to the system under the "Howard Bill."
/ Excludes 28.50 miles of the Baltimore-Washington Parkway (I-295) which was added to the system under the "Howard Bill."
/ Excludes 27.40 miles chargeable to the "Howard Bill" of the total 34.40 mile Trenton-Asbury Park Spur (I-195) which was added to the system under that bill.
/ Consists of mileage which has not been assigned to any specific route and is a reserve for final measurement of the system.

THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS

STATUS OF IMPROVEMENT AS OF JUNE 30, 1969



COMPLETED OR IMPROVED AND OPEN TO TRAFFIC

Completed to full or acceptable standards, or improved to standards

Adequate for present traffic, built with Interstate or other public funds

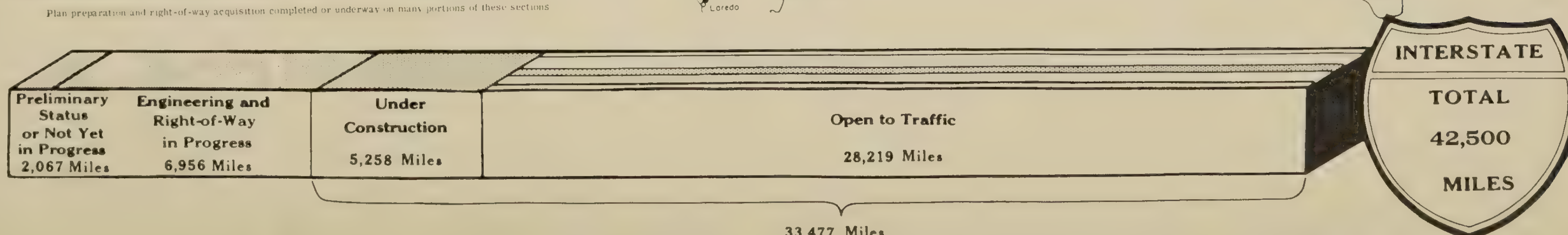
MAJOR TOLL ROADS

Incorporated in the Interstate System

UNDER CONSTRUCTION

PRELIMINARY STATUS OR NOT YET IN PROGRESS

Plan preparation and right-of-way acquisition completed or underway on many portions of these sections



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