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Newly constructed Connecticut Route 8, a Federal-aid primary facility, north of Waterbury.

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Labor usage in highway construction.

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U.S. DEPARTMENT OF COMMERCE

LUTHER H. HODGES, Secretary

BUREAU OF PUBLIC ROADS

REX M. WHITTON, Administrator

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Traffic Approaching Cities

Reported by WALTER G. HANSEN,
Highway Research Engineer

BY THE HIGHWAY PLANNING DIVISION
BUREAU OF PUBLIC ROADS

This article is an extension of work previously done on the subject of the distribution of traffic approaching cities. It confirms previous findings on the distribution of through and central business district traffic and presents the results of an examination concerning the stability of these traffic distributions over a period of years. In addition, it analyzes the distribution of approaching traffic to various concentric rings about the city center and draws several conclusions concerning the general nature of highway facilities required to serve this traffic.

INFORMATION concerning the proportion of traffic bound to and beyond cities was first published by the Bureau of Public Roads in 1944.[1] This information has since been revised and expanded to show the proportion of such traffic destined to the central business district (CBD) as well as the proportion of through traffic, and has appeared in numerous publications during the past decade. The fact that the proportion of through traffic varies inversely with city size is now well recognized and has been a major influence on policy decisions regarding circumferential routes around cities.

In view of the increasing traffic problems in urban areas and the relatively high expenditures required for the construction of urban expressways and arterials, it is especially desirable to reexamine available data to provide up-to-date and, if possible, additional items of information concerning the composition of traffic approaching cities.

Source Material

This analysis is based on traffic information for 193 cities. These data, summarized in table 1, were obtained from studies, conducted by the several State highway departments, which obtained the origin and destination of traffic crossing a cordon line around each of the urban areas. In general, the cordon lines were located at the periphery of the contiguous urban development. Although there was undoubtedly some intraurban or commuter traffic crossing the cordon lines as a result of scattered residential development outside of the study areas, the proportion of such traffic was considered to be small and therefore the preponderance of the traffic studied was intercity or rural-urban in character.

The cities used in this examination varied in size from Davis, Okla., with a population of 1,700, to the Detroit, Mich., metropolitan area with a population of approximately 3 million. The distribution, by size, of the cities used in this study is shown in table 1. City size is based on an estimate of the number of people residing within the cordon area at the time the traffic surveys were conducted. The cities were well distributed throughout the country and the results of this analysis are believed to be representative of average conditions.

The dates at which the individual traffic surveys were conducted varied from 1944 to 1954. A previous, unpublished examination of traffic information for 367 cities indicated that there were no significant trends in the distribution of traffic approaching cities; that is, the proportions of traffic destined to and beyond cities within each population group remained stable over the 10-year period, from 1944 to 1954. A summary of the findings of this examination is shown in table 2.

Based on the findings of the examination, the data used in the remainder of this analysis were aggregated without regard to date of survey. Furthermore, it is felt that the characteristics of traffic approaching cities as presented in this report are fairly representative of existing traffic patterns.

Table 2.—Proportion of total approaching traffic which passes through a city [1]

Population group	Percentage of through traffic by year of survey			
	Prior to 1945	1946–49	1950–54	Average of all surveys
0–5,000	54	48	50	49
5,000–10,000	41	34	50	42
10,000–25,000	34	33	37	35
25,000–50,000	20	25	26	25
50,000–100,000	13	23	18	19
100,000–250,000	15	17	21	17
Over 250,000	10	9	10	9

[1] Based on an analysis of traffic approaching 367 cities.

It should be pointed out that the various presentations in this report represent average or overall conditions and are not necessarily applicable to any specific city. Considerable variation about these average conditions was found in all population groups. The extent of this variation is illustrated in figure 1, which shows the proportion of the total approaching traffic which passes through the individual cities. The curve showing the relationship between city size and the proportion of through traffic is a freehand line based on the weighted average values for the nine population groups shown in table 1. For the most part this is the manner in which the reported relationships were developed.

It is worth noting that separate analyses, not presented here, were performed using the data for the cities in each of five geographical regions. Although there was some variation between the average values and relationships found in the several regions, the deviation of the individual cities about the average values was not significantly improved.

The Analysis

The distribution pattern of highway traffic approaching cities is shown in figure 2. It

[1] Interregional Highways, H. Doc. No. 379, January 1944. See fig. 29 and table 14, p. 60.

Table 1.—Summary of traffic approaching 193 cities

Population group	Number of cities	Average city size	Average daily traffic per city											
			All roads				Interstate system routes				Other roads			
			Total	Through	CBD	Other local	Total	Through	CBD	Other local	Total	Through	CBD	Other local
0–5,000	11	3, 130	7, 290	3, 930	1, 670	1, 690	5, 320	3, 210	1, 120	990	1, 970	720	550	700
5, 000–10, 000	29	7, 800	8, 630	4, 520	2, 040	2, 070	4, 730	2, 710	990	1, 030	3, 900	1, 810	1, 050	1, 040
10. 000–25, 000	43	16, 270	11, 740	4, 520	3, 050	4, 170	6, 310	2, 980	1, 440	1, 890	5, 430	1, 540	1, 610	2, 280
25, 000–50, 000	36	35, 780	16, 600	4, 430	4, 110	8, 060	7, 490	2, 590	1, 850	3, 050	9, 110	1, 840	2, 260	5, 010
50, 000–100, 000	25	78, 790	24, 600	5, 340	5, 320	13, 940	9, 020	2, 820	1, 910	4, 290	15, 580	2, 520	3, 410	9, 650
100, 000–250, 000	31	139, 500	32, 930	5, 890	6, 650	20, 390	11, 490	3, 010	2, 200	6, 280	21, 440	2, 880	4, 450	14, 110
250, 000–500, 000	6	376, 700	43, 370	4, 660	9, 260	29, 450	17, 010	2, 250	3, 790	10, 970	26, 360	2, 410	5, 470	18, 480
500, 000–1,000, 000	9	741, 300	63, 470	5, 470	7, 910	50, 090	24, 650	2, 430	2, 920	19, 300	38, 820	3, 040	4, 990	30, 790
Over 1, 000, 000	3	1, 653, 000	126, 920	13, 030	12, 110	101, 780	27, 420	4, 040	2, 620	20, 760	99, 500	8, 990	9, 490	81, 020

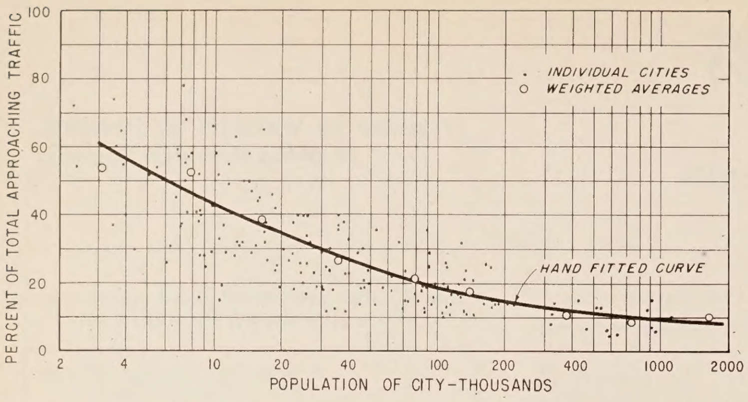

Figure 1.—Percent of traffic passing through a city.

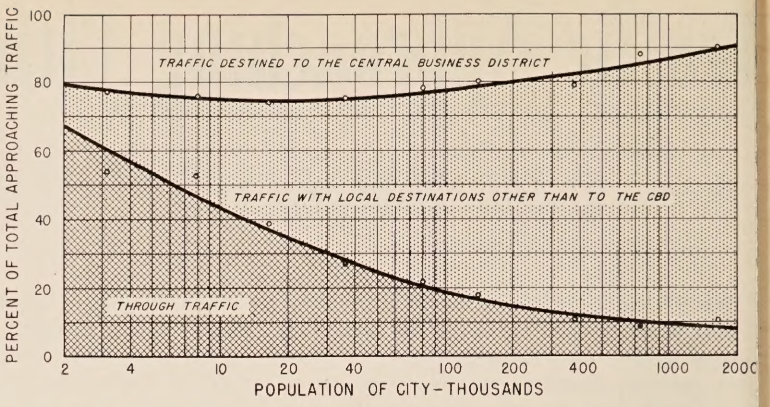

Figure 2.—Distribution of traffic approaching cities.

will be noted that in cities of more than 40,000 population over one-half of the total approaching traffic was destined to local areas other than the CBD. In urban areas of 1 million population, approximately three-quarters of the total traffic was in this category. This traffic is obviously of major significance to highway and transportation planning in medium and larger size cities.

In order to obtain a better understanding of the distribution pattern of this type of traffic, detailed analyses were made of the traffic approaching 11 cities. These cities were selected on the basis of obtaining a range in population size and on the availability of data.

Each of the 11 cities was divided into 4 concentric areas, rings 1–4. These ring areas were centered on the CBD, each with a width of one-fourth of the average distance between the CBD and the cordon line. The proportion of the approaching traffic with destinations in each of these ring areas was then determined for each city. The pattern is illustrated for a typical metropolitan area of 1 million population in figure 3.

The results of this analysis are shown in figure 4. The percentage of the approaching traffic with local destinations to the area bounded by each ring is shown for each of the individual cities. As would be expected, there was considerable variation in results obtained in the 11 cities; however, when arranged by city size, as they are in figure 4, the individual points produced a definite pattern. As city size increased, the proportion of the total traffic destined to the inner concentric area, ring 1, decreased; correspondingly, rings 2, 3, and 4 attracted an increasing proportion of the total trips. This general pattern is approximated by the lines in figure 4 delineating the relative trip attraction of the various rings.

The proportion of traffic destined to the innermost ring decreased from about 60 percent for cities of 100,000 population to 20 percent in cities of 3 million population. The proportion of traffic destined to ring 2 tended to be relatively stable, increasing from 25 percent to about 40 percent over the same population range. The traffic attracted to the outer areas, rings 3 and 4 combined, increased from 15 percent to slightly more than 40 percent. This distribution of traffic with local destination to the various rings was used to modify the information shown in

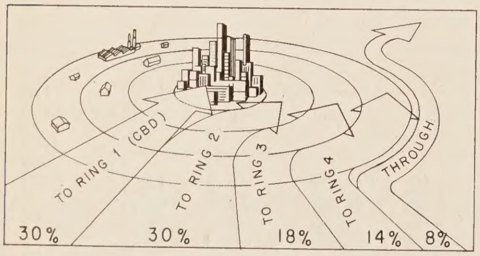

Figure 3.—Distribution of traffic approaching a typical metropolitan area of 1 million population.

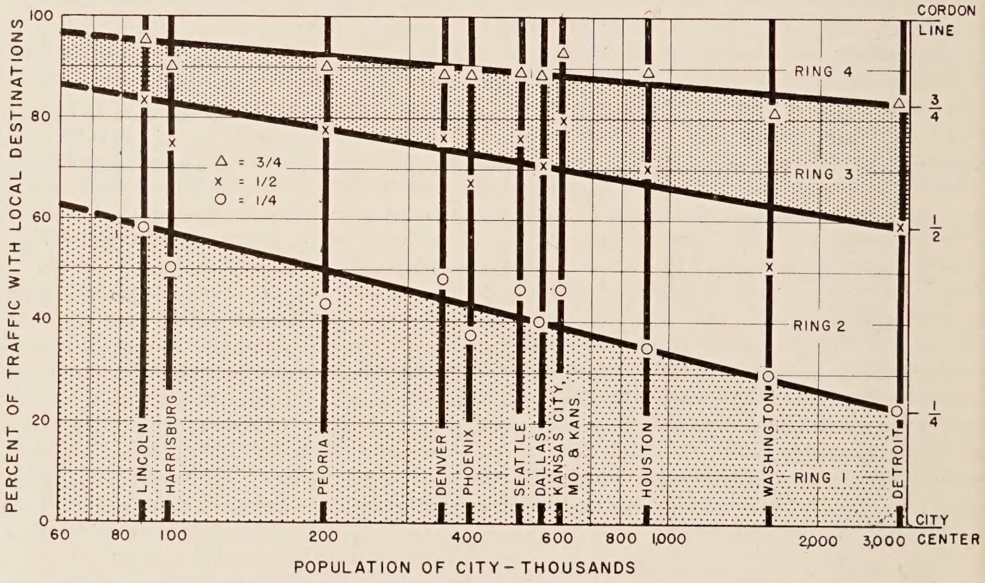

Figure 4.—Local destinations of traffic approaching cities.

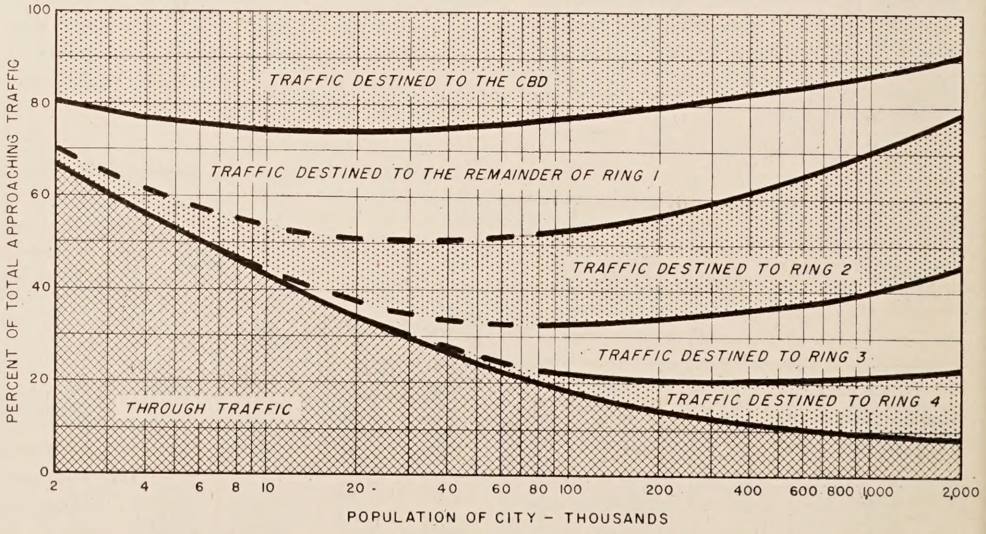

Figure 5.—Distribution of traffic approaching cities.

figure 2. The adjusted chart, indicating the distribution of local as well as through traffic, is shown in figure 5.

The proportion of through traffic, of course, remains as shown in figures 1 and 2. The major point revealed by figure 5 is the dominance of ring 1 (with the exception of the smallest and largest cities), which includes the CBD, as an attractor of traffic from outside the city. In cities between 10,000 and 100,000, this area was the destination of almost one-half of the total approaching traffic. As city size increased to 1 million, this area remained the single most important attractor, although the proportion decreased to about one-third of the approaching traffic.

It is also significant to note the increasing proportion of trips destined to the outer areas, rings 3 and 4, in the larger cities. These areas were the destination of almost one-third of the total traffic approaching cities of 1 million or more.

The proportional distribution of traffic shown in the figures so far presented could be somewhat misleading; therefore, this same distribution is presented in figure 6 in terms of the actual volumes of vehicles involved. This figure shows that the total approaching traffic increased quite rapidly as city size increased; however, the bulk of this increase was made up of vehicles with destinations within the city. The actual volume of through traffic remained relatively stable, increasing only gradually with city size. The volumes of traffic destined through and to each of the local areas in cities of various sizes are shown in the left side of table 3, the values being taken from the curves in figure 6.

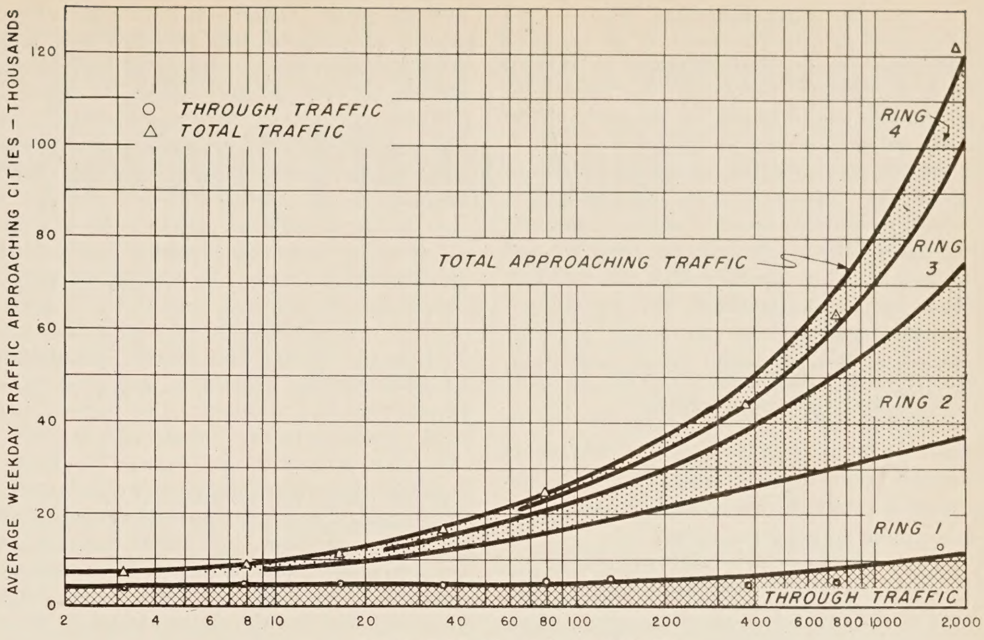

Figure 6.—Destinations of traffic approaching cities.

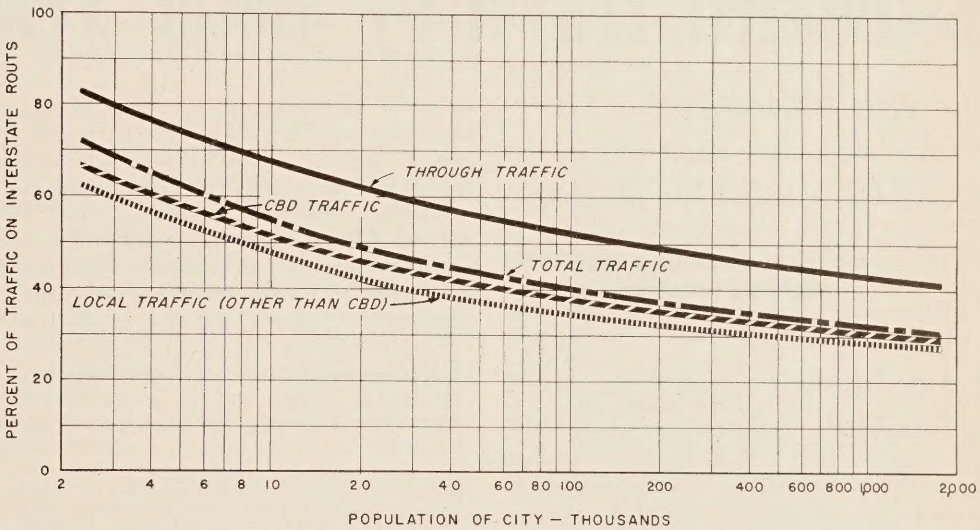

Figure 7.—Proportions of traffic approaching cities on Interstate highways and other roads.

Traffic on the Interstate System

A final examination of the data was made to determine whether or not the traffic on roads in locations designated as Interstate System routes exhibited characteristics similar to those found in the previous analysis of the total traffic approaching cities. It should be pointed out that at the time of the origin-destination surveys on which this analysis is based, the Interstate program had not yet been started. The designated Interstate routes have been used in this study because they provided a convenient means of analyzing the traffic using major highway facilities approaching a city, as distinct from all approaching roads.

While the same pattern of a decreasing proportion of through traffic with increasing city size was noted on the Interstate routes, the proportion of through traffic tended to be slightly larger on Interstate routes than on other roads, throughout the range of city sizes. Stated in a slightly different manner, the Interstate routes carried a larger proportion of the total through traffic approaching cities than they did of the total traffic with local destinations. The percentage of each type of traffic carried by the Interstate routes, by city size, is shown in figure 7.

As shown in figure 7, the proportion of the total of each type of traffic that is carried by the Interstate routes decreased as city size increased. For example, in cities of 10,000 population the Interstate routes carried a little over 50 percent of all traffic approaching the city and destined for the CBD; while in cities of 1 million population the corresponding value is about 30 percent. Thus, although the actual volume of traffic on the Interstate routes approaching cities increased with city size, the rate of this increase was much lower than that shown for total approaching traffic in figure 6. The average volume of traffic on the Interstate routes approaching cities of various sizes is shown in the right side of table 3, the values being taken from figures 6 and 7. Of particular interest is the fact that the volume of through traffic carried by the Interstate routes was found to remain almost constant, at approximately 3,000 vehicles per day, throughout all population groups.

Table 3.—Distribution of traffic on all roads and on Interstate routes approaching cities [1]

City size (population)	Average daily traffic volumes									
	All roads						Interstate routes			
	Total	Through	Ring 1	Ring 2	Ring 3	Ring 4	Total	Through	Ring 1	Rings 2, 3, 4,
10,000	10, 000	4, 400	4, 600	1, 000	------	------	5, 700	2, 900	2, 400	400
50,000	20, 000	5, 000	9, 800	3, 400	1, 800	------	8, 800	2, 800	4, 000	2, 000
100,000	27, 000	5, 100	12, 400	5, 700	2, 700	1, 100	10, 800	2, 700	4, 700	3, 400
500,000	57, 000	6, 800	20, 500	15, 400	9, 200	5, 100	20, 000	3, 100	6, 800	10, 100
1,000,000	82, 000	7, 400	25, 500	24, 600	14, 700	9, 800	26, 200	3, 200	7, 900	15, 100

[1] Estimated from figs. 6 and 7.

Conclusions

It would be unwise to attempt to develop recommendations regarding the need for specific highway facilities on the basis of the traffic patterns shown in figures 5, 6, and 7. In the first place, the individual cities exhibited considerable variation from the calculated average conditions; second, and more important, many factors affecting the need for and desirability of a specific type of highway facility serving a community have not entered into this analysis—in particular, local or intraurban traffic needs have not been considered.

However, with the above limitations in mind, the information presented in this report warrants several statements regarding the general nature of highway facilities needed to serve traffic approaching cities.

As city size increases it becomes increasingly desirable to have major highway routes penetrate to the central areas of the cities. The average daily volume of the approaching traffic destined to this area increases from about 5,000 vehicles in cities of 10,000 population to over 20,000 vehicles in cities of 500,000 population. The corresponding volumes of through or bypassable traffic increase from about 4,000 vehicles to almost 7,000 vehicles.

It is not possible to pinpoint the city size at which it becomes desirable to provide penetrating as opposed to bypass routes. It would appear, however, that in the majority of cases this point would be reached in cities of between 25,000 and 50,000 population. In cities ranging upward in size from 8,000 population, the proportion of approaching traffic destined to the central area is greater than the proportion of bypassable traffic; however, the actual volumes of traffic destined to the central area of cities with under 25,000 population are less than 6,000 vehicles per day. In most cases, volumes of this magnitude would not justify the relatively high expenditures required for the construction of major highway facilities to the central areas.

In cities of over 50,000 population, the movement to the central area constitutes the largest single proportion of the total approaching traffic. In terms of actual volume this movement increases from about 10,000 vehicles per day for cities of 50,000 population to more than 25,000 vehicles per day in cities of 1 million or more.

As city size exceeds 100,000 there is an increasing and sizable proportion of the total approaching traffic destined to the peripheral areas of the city. When coupled with the through traffic, this movement would seem to warrant consideration of a circumferential route to act as a distributor for the traffic with local destinations and as a bypass for through traffic. The through traffic plus that local traffic with destinations in peripheral areas (rings 3 and 4) constitutes approximately 40 percent of the total traffic approaching cities of 1 million population, an average daily volume of about 32,000 vehicles. Penetrating routes would, of course, still be required.

Estimated Travel by Motor Vehicles in 1959

BY THE HIGHWAY PLANNING DIVISION BUREAU OF PUBLIC ROADS

Reported by ALEXANDER FRENCH, Highway Research Engineer

MOTOR-VEHICLE TRAVEL in the United States in 1959 totaled 700.5 billion vehicle-miles, an increase of 5 percent over the travel in 1958. Total travel for 1960 is estimated at 720 billion vehicle-miles, a 3-percent increase over 1959, based on information for the first 11 months of the year.

The travel and related information for 1959 is shown in table 1 by road system and vehicle type. Data for Alaska and Hawaii are included for the first time, and a separate tabulation for the 48 contiguous States and the District of Columbia is provided for continuity with data published for preceding years.[1]

The proportions of travel by road system and by vehicle type changed little from 1958 to 1959. Of the 1959 travel, 40 percent was performed on main rural roads comprising 14 percent of the Nation's total of 3.5 million miles of roads and streets. Another 46 percent of the travel was on urban streets, which comprise only 11 percent of the total mileage. Local rural roads accounted for only 14 percent of the travel but make up 75 percent of the total mileage.

Passenger cars represented 83 percent of the vehicles and performed 82 percent of the travel in 1959. Trucks and truck combinations accounted for 16 percent of the vehicles and 17 percent of the travel while similar figures for buses were less than 1 percent.

Average vehicle performance in 1959 differed so little from that reported for 1958 that the changes are not considered significant. The average motor vehicle traveled 9,720 miles in 1959, almost half of it in cities, and consumed 782 gallons of fuel at a rate of 12.43 miles per gallon. The average passenger car traveled 9,529 miles and consumed 666 gallons of fuel, at a rate of 14.30 miles per gallon. A modest increase appeared in average annual mileage traveled and fuel consumed by commercial buses and trucks, but their fuel consumption rates remained about the same as in 1958.

Table 1.—Estimate of motor-vehicle travel in the United States, by vehicle types, in the calendar year 1959

Vehicle type	Motor-vehicle travel: Main rural road travel	Motor-vehicle travel: Local rural road travel	Motor-vehicle travel: Total rural travel	Motor-vehicle travel: Urban travel	Motor-vehicle travel: Total travel	Number of vehicles registered	Average travel per vehicle	Motor-fuel consumption: Total	Motor-fuel consumption: Average per vehicle	Average travel per gallon of fuel consumed
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Thousands*	*Miles*	*Million gallons*	*Gallons*	*Miles per gallon*
50 STATES:[1]										
Passenger cars[2]	219, 234	75, 919	295, 153	277, 823	572, 976	60, 132	9, 529	40, 056	666	14. 30
Buses:										
Commercial	896	148	1, 044	1, 842	2, 886	76	37, 974	621	8, 171	4. 65
School and nonrevenue	602	594	1, 196	266	1, 462	189	7, 735	202	1, 069	7. 24
All buses	1, 498	742	2, 240	2, 108	4, 348	265	16, 408	823	3, 106	5. 28
All passenger vehicles	220, 732	76, 661	297, 393	279, 931	577, 324	60, 397	9, 559	40, 879	677	14. 12
Trucks and combinations	59, 661	19, 634	79, 295	43, 859	123, 154	11, 671	10, 552	15, 453	1, 324	7. 97
All motor vehicles	280, 393	96, 295	376, 688	323, 790	700, 478	72, 068	9, 720	56, 332	782	12. 43
48 CONTIGUOUS STATES:[1]										
Passenger cars[2]	218, 546	75, 817	294, 363	276, 727	571, 090	59, 892	9, 535	39, 923	667	14. 30
Buses:										
Commercial	893	147	1, 040	1, 836	2, 876	76	37, 842	621	8, 171	4. 63
School and nonrevenue	600	593	1, 193	266	1, 459	188	7, 761	202	1, 074	7. 22
All buses	1, 493	740	2, 233	2, 102	4, 335	264	16, 420	823	3, 117	5. 27
All passenger vehicles	220, 039	76, 557	296, 596	278, 829	575, 425	60, 156	9, 566	40, 746	677	14. 12
Trucks and combinations	59, 479	19, 592	79, 071	43, 675	122, 746	11, 622	10, 562	15, 411	1, 326	7. 96
All motor vehicles	279, 518	96, 149	375, 667	322, 504	698, 171	71, 778	9, 727	56, 157	782	12. 43

[1] Includes the District of Columbia. [2] Includes taxicabs and motorcycles. There were 565,000 motorcycles registered in the 50 States, and 561,000 registered in the 48 contiguous States.

[1] See previous articles on motor-vehicle travel data in PUBLIC ROADS; the most recent article, for 1958 data, appears in vol. 30, No. 12, February 1960.

Evaluation of Phosphoric Acid for the Stabilization of Fine-Grained Plastic Soils

BY THE PHYSICAL RESEARCH DIVISION
BUREAU OF PUBLIC ROADS

Reported[1] by JAMES A. KELLEY and EARL B. KINTER,
Highway Research Engineers

This article reports a laboratory study of the effects of phosphoric acid and an amine, in small percentages, on the engineering properties of six fine-grained plastic soils. Pronounced increases in unconfined compressive strength of soaked specimens were obtained for most of the soils when treated with acid alone, and slight additional increases in strength resulted when the amine was also used. In general, plastic properties were only moderately affected by the additives, and there was little change in moisture-density relations. Volume change was reduced to a satisfactory level for five of the soils.

Addition of 2 percent of phosphoric acid resulted in satisfactory compressive strengths for two soils, neither of which had any strength before treatment. Compressive strengths were considerably increased for two other soils by this rate of acid, but not to a satisfactory level. Strength gains for the remaining two soils were not of practical magnitude. The gains for four of the six soils tested were quite sufficient to indicate that phosphoric acid offers considerable promise as a stabilizer for a wide variety of fine-grained plastic soils.

IN 1954 the Bureau of Public Roads, in an effort to stimulate interest in the development of chemical products for use in the stabilization of soils, invited chemical manufacturers to aid in the search for suitable chemicals. The ultimate criteria for such chemical additives are simple: They must be suitable for practical use in road construction, and must be more effective or cheaper, or both, than the materials already commonly in use, which include portland cement, bitumens, and lime.

Agreements were made with a number of companies under which chemicals would be subjected to preliminary laboratory testing by the manufacturer and, if found promising, submitted to the Bureau of Public Roads for further laboratory testing and possible subsequent recommendation to State highway departments for full-scale trials in the field. As one result of this program, phosphoric acid was proposed by the Monsanto Chemical Co. and has been tested for use in the stabilization of fine-grained plastic soils.

This article presents some of the results of the laboratory evaluation of the effects of phosphoric acid on six fine-grained plastic soils, conducted by the Bureau of Public Roads between 1955 and the present time.

Conclusions

The Public Roads experiments showed that phosphoric acid produced marked increases in the unconfined compressive strength of two fine-grained plastic soils, the addition of 2 percent of the acid bringing the strength of these soils to over 100 p.s.i., a level considered satisfactory for practical stabilization. With four other fine-grained plastic soils, treated with 2 percent of the acid, compressive strength was not developed to a satisfactory level.

In the one experimental soil containing calcium carbonate, the acid was not effective in strength development.

The addition of phosphoric acid had varying effects on properties other than compressive strength. Values of volume change and moisture absorption were generally brought to satisfactory levels, but changes in moisture-density relations were slight. The liquid limit was greatly lowered for some soils, but for others there was little effect. Plastic limits were practically unchanged. Consequently, changes in the plasticity index corresponded closely to changes in the liquid limit.

For most of the soils used, the addition of an amine compound to the phosphoric acid moderately increased the compressive strength and produced moderate decreases in the liquid limit. In the case of one highly plastic soil, however, the addition of amine caused a pronounced decrease in the liquid limit.

It was found for one soil that the effectiveness of the acid in increasing compressive strength was appreciably reduced by too long an interval between the mixing and the compaction operations.

Other Studies

During the time that the Bureau of Public Roads has pursued its laboratory evaluation of the effectiveness of phosphoric acid in soil strength development, other researchers have also conducted studies of the material and some of their reports have been published. The successful use of phosphoric acid with one fine-grained plastic soil was first reported in 1957 by J. W. Lyons (*1*),[2] who obtained unconfined compressive strengths ranging from 110 to 200 p.s.i. (depending on the length of the curing period) for compacted soil specimens containing about 2 percent of the acid. Lyons also found that the addition of 0.5 percent or less of a compound, identified as amine ODT, facilitated mixing, practically eliminated the critical dependence of the strength of the soil on the water content at the time of compaction, and also rendered the soil water-resistant early in the curing period.

Michaels, Williams, and Randolph (*2*), working with five soils of varying texture, also obtained substantial increases in unconfined compressive strengths as a result of treatment with phosphoric acid or its equivalent of phosphoric anhydride, and with a number of other acidic phosphoric compounds. These three authors also found that a small amount of a primary aliphatic amine would accelerate curing and improve strength retention upon immersion of the specimen in water, although ultimate strengths were somewhat reduced.

Michaels and Tausch (*3*), in studying supplementary additives for improving or reducing the cost of the stabilization of soils with phosphoric acid, found orthorhombic phosphorous pentoxide and phosphate rock plus sulfuric acid to be effective. They also found that, supplemental to phosphoric acid treatment, ferric chloride and octylamine were effective in waterproofing soils.

Demirel, Benn, and Davidson (*4*) found that phosphoric acid increased the unconfined compressive strengths of a number of soils, and showed that calcium carbonate in soils reduced or eliminated strength gains because of the consumption of the phosphoric acid by the carbonate.

[1] Presented at the 40th Annual Meeting of the Highway Research Board, Washington, D.C., January 1961.

[2] Italic numbers in parentheses refer to the list of references on page 161.

Public Roads Experiments

The experimental work by the Bureau of Public Roads reported here was conducted with two grades of liquid phosphoric acid supplied by the Monsanto Chemical Co. One of these was a reagent grade furnace acid, containing 85 percent H_3PO_4; the other was a "wet process" acid, containing 40 to 45 percent H_3PO_4. In preliminary tests the wet process acid was found to produce higher values of unconfined compressive strength in soil-acid mixtures than the reagent grade acid, and the wet process acid was therefore used exclusively in subsequent testing. An organic compound identified as SA-4 amine, used as a supplementary additive, was also supplied by the Monsanto Chemical Co.

Six soils—Penn, Jordan, Keyport, Pierre, Hagerstown, and Sassafras—were selected for the experiments. Their characteristics are shown in table 1. As indicated in the table, these fine-grained plastic soils contained a wide range of clay minerals, but are not necessarily considered as representative of all clay soils.

The several tests applied to the raw soils are listed in table 2. These tests, except for the mechanical analysis test, were also applied to the soil-acid mixtures. Table 2 also lists the test values selected as criteria to evaluate whether a given soil had been satisfactorily improved by the stabilizing treatment with phosphoric acid and amine additives.

Mixtures of soil, water, and the chemicals were prepared with a mechanical mixer. Air-dry soil was placed in the mixer bowl and the calculated percentage of chemical (based on dry weight of soil), in water solution, was slowly added while the mixer was in operation. The mixing time was 5 minutes. Atterberg limit tests were performed on a portion of the mixture cured in a high-humidity chamber at room temperature for 8 days.

Volume change specimens were made and tested in accordance with AASHO T 116. Triplicate cylindrical test specimens, 2 inches in diameter and 4 inches in length, were compacted at maximum dry density and optimum liquid content.

Moisture absorption and unconfined compressive strength were measured for each of these specimens after curing for 5 days at room temperature and high humidity, followed by immersion in water for 2 days. If an immersed specimen showed no evidence of slaking, it was surface dried and weighed to determine the moisture absorption. If complete disintegration of the specimen occurred, measurements of both moisture absorption and compressive strength obviously were impossible. If there was more than a trace of slaking, the moisture absorption could not be accurately measured. After soaking and weighing, the usable specimens were tested for unconfined compressive strength.

The 2- by 4-inch cylindrical specimens were prepared by the use of an impact compaction device very similar to that developed by the U.S. Waterways Experiment Station (*5*). This device employs a 4-pound hammer with a 12-inch drop. Depending on the type of soil being tested, from 8 to 14 blows were required to produce specimens having the same maximum density as obtained in the AASHO T 99 standard method.

Results and Discussion

The effects of the stabilization treatment on the unconfined compressive strength of soaked specimens of three soils—Keyport, Jordan, and Penn—are shown by the data in table 3. Phosphoric acid was added at rates of 1, 2, and 3 percent, with and without the

Table 1.—Characteristics of experimental soils

Property	Test data for experimental soils [1]					
	Penn	Jordan	Keyport	Pierre	Hagerstown	Sassafras
Clay mineral	Illite, chlorite.	Montmorillonite.	Montmorillonite.	Montmorillonite.	Kaolinite, illite.	Kaolinite, vermiculite.
pH	5.0	7.6	4.6	7.0	5.4	5.7
Calcium carbonate...percent	0	10	0	0	0	0
Percentage passing—						
No. 10 sieve	100	100	100	100	100	100
No. 40 sieve	81	99	93	99	99	94
No. 200 sieve	62	91	62	98	98	75
Silt (0.05 to 0.005 mm.) percent	28	44	21	34	25	23
Clay (smaller than 0.005 mm.) percent	45	36	36	61	72	49
Liquid limit	48	34	46	79	78	48
Plasticity index	22	10	24	46	48	23
Maximum dry density,[2] lb./cu. ft	110	100	111	92	91	108
Optimum moisture[2]...percent	18	21	17	26	27	19
Classification (AASHO)	A-7-6(11)	A-4(8)	A-7-6(12)	A-7-5(20)	A-7-5(20)	A-7-6(15)

[1] Sample of Penn soil was from C horizon; samples of other soils were from B horizon.
[2] AASHO T 99-57, Method A.

Table 2.—Tests and criteria for evaluating raw soils and soil-acid mixtures

Test	AASHO designation	ASTM designation	Criterion [1]
Mechanical analysis.	T 88	D 422	
Liquid limit	T 89	D 423	Not over 30.
Plastic limit	T 90	D 424	
Plasticity index	T 91	D 424	Not over 6.
Compaction	T 99-57	D 698-58	
Volume change	T 116		Not over 2½ percent.
Moisture absorption.[2]			Not over 2 percent.
Unconfined compressive strength.[3]			100 p.s.i. or more.

[1] Test value for satisfactory material.
[2] See text, p. 160.
[3] Rate of loading in machine=0.05 inch per minute.

Table 3.—Effect of concentration of phosphoric acid alone, and with SA-4 amine additive, on the unconfined compressive strength of three soils

Treatment		Unconfined compressive strength		
Acid	Amine	Keyport	Jordan	Penn
Pct. [1]	*Pct.* [1]	*P.s.i.*	*P.s.i.*	*P.s.i.*
0	0	0	0	0
1	0	75	13	(2)
2	0	113	15	170
3	0	156	14	202
1	0.5	78	(2)	(2)
2	.5	118	34	184
3	.5	165	(2)	226

[1] Based on dry weight of soil (110° C.).
[2] Not determined; insufficient material for testing.

Table 4.—Effect of phosphoric acid and SA-4 amine on the properties of six soils

Soil	Treatment: Acid	Treatment: Amine	Unconfined compressive strength	Volume change	Moisture absorption	Optimum moisture	Maximum density	Liquid limit	Plastic limit	Plasticity index
	Pct.	*Pct.*	*P.s.i.*	*Pct.*	*Pct.*	*Pct.*	*lb./cu. ft.*			
Penn	0	0	0	9.7	(2)	18	111	48	26	22
	2	0	170	(1)	1.0	17	114	(1)	(1)	(1)
	2	.5	184	(1)	0.1	18	111	(1)	(1)	(1)
Jordan	0	0	0	9.0	(2)	20	104	34	24	10
	2	0	15	1.1	2.4	23	101	40	24	16
	2	.5	34	1.5	2.9	23	99	36	25	11
Keyport	0	0	0	9.2	(2)	17	111	46	22	24
	2	0	113	1.5	1.0	15	114	43	22	21
	2	.5	118	.3	1.2	18	110	40	24	16
Pierre	0	0	0	21.7	(2)	26	92	79	33	46
	2	0	2	.7	(2)	24	91	68	34	34
	2	.5	8	1.2	(2)	25	91	56	36	20
	4	0	28	(1)	7.0	24	92	56	35	21
	4	.5	77	(1)	6.0	25	91	50	36	14
Hagerstown	0	0	5	3.9	4.2	27	91	78	30	48
	2	0	37	(1)	.7	26	88	52	30	22
	2	.5	38	(1)	3.9	26	86	51	33	18
Sassafras	0	0	31	1.0	1.0	19	108	48	25	23
	2	0	74	0	.2	20	107	33	22	11
	2	.5	85	0	1.1	20	103	35	25	10

[1] Insufficient amount of material for testing.
[2] Specimen completely or partly disintegrated when immersed.

addition of 0.5 percent of SA–4 amine. Considerable strength was developed in the Keyport and Penn soils, the effect increasing with increasing rates of acid addition. In contrast, very little strength was developed in the Jordan soil. This may be largely attributed to its calcium carbonate content, which was more than sufficient to prevent the desired soil-acid reaction and, therefore, the strength development (*4*). The strengths developed in the Keyport and Penn soils, with 2 percent of acid, more than met the 100 p.s.i. criterion selected as satisfactory. Small additional strength increases resulted from the addition of the amine.

Since satisfactory strengths were developed when 2 percent of the phosphoric acid was added to two of the three soils initially tested, this percentage rate was used for most of the subsequent experiments. The data in table 4 show the effects of the addition of 2 percent of the acid, with and without the addition of 0.5 percent of the amine supplement, on the six soils included in the tests. In the case of the Pierre soil, as shown in the table, data were also obtained for treatment with 4 percent of acid, with and without 0.5 percent of amine.

The effectiveness of the acid varied considerably, depending on the soil and the particular soil property under consideration. Compressive strength was well above the selected criterion of 100 p.s.i. for the treated Penn soil, slightly above for the Keyport soil, slightly below for the Sassafras soil, considerably below for the Jordan and Hagerstown soils, and extremely low (at the 2-percent acid rate) for the Pierre soil.

Volume change and moisture absorption values in most cases were brought to satisfactory levels, by the addition of acid, but maximum density, optimum moisture, and the plastic limit were not greatly affected. The use of acid brought about marked reductions in the liquid limit for the Pierre, Hagerstown, and Sassafras soils, but had little effect on the liquid limit of the Keyport soil and actually raised that of the Jordan soil. Inasmuch as the addition of the acid had little effect on the plastic limit, the changes in plasticity index corresponded closely to the changes in liquid limit.

In the case of the Pierre soil, the reduction of the liquid limit values brought about by the 2-percent rate of acid application was accompanied by a considerable decrease in volume change, but the acid had little effect on other properties of this soil. The use of acid at the 4-percent rate further decreased the liquid limit and increased compressive strength, particularly with the amine added. These pronounced effects on the properties of the Pierre soil were especially notable since this soil contained 61 percent of a high volume change clay (particles smaller than 0.005 mm.).

Supplementing the acid with 0.5 percent of amine appreciably reduced the liquid limit of the Pierre soil, but little change was noted in the plasticity values of any of the other soils. Additions of the amine also increased the compressive strengths of all of the soils tested, but the effect was pronounced only with the Pierre soil. The addition of the amine had little effect on any of the other soil properties studied.

A supplementary experiment was performed with the Keyport soil to determine the importance of the time interval between the preparation of the soil-acid mixture and the molding of the test specimens. Compressive strengths obtained for 15-minute, 6-hour, and 24-hour intervals between mixing and molding were 104, 80, and 70 p.s.i., respectively. These results indicate that for the development of maximum compressive strength, there should be very little delay between the mixing and compaction operations.

References

(*1*) *Stabilizing a problem soil—cheaply*, by J. W. Lyons. Engineering News-Record, vol. 159, No. 7, Aug. 15, 1957, pp. 101–106.

(*2*) *Acidic phosphorous compounds as soil stabilizers*, by A. S. Michaels, P. M. Williams, and K. B. Randolph. Industrial and Engineering Chemistry, vol. 50, No. 6, June 1958, pp. 889–894.

(*3*) *Phosphoric acid stabilization of fine-grained soils: improvements with secondary additives*, by A. S. Michaels and F. W. Tausch, Jr. Highway Research Board, Bulletin No. 282, 1961 (in press).

(*4*) *Use of phosphoric acid in soil stabilization*, by T. Demirel, C. H. Benn, and D. T. Davidson. Highway Research Board, Bulletin No. 282, 1961 (in press).

(*5*) *Resinous water repellents for soils.* U.S. Waterways Experiment Station, Vicksburg, Miss., Technical Memo. No. 217–1, May 1946.

New Publications

Four new publications by the Bureau of Public Roads are now available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

Highway Progress, 1960

Available at 35 cents a copy is the Annual Report of the Bureau of Public Roads, Fiscal Year 1960, entitled *Highway Progress, 1960*. The annual report presents the Federal-aid highway programs, including the Interstate System, and the research and activities of the Bureau.

The 1961 Interstate System Cost Estimate

Four reports, requested by the Congress, were submitted by the Bureau of Public Roads to the Congress, through the Secretary of Commerce, in January 1961.

A new estimate of the total cost of completing the National System of Interstate and Defense Highways was reported to Congress on January 13, 1961. The report, titled *The 1961 Interstate System Cost Estimate*, has been printed as House Document No. 49, and may be purchased from the Superintendent of Documents at 20 cents per copy.

The new cost estimate, made by the State highway departments under the guidance of the Bureau of Public Roads, and resulting from almost a full year's effort, covered all Interstate System work not financed as of January 1, 1960, and showed the total of work remaining to be undertaken as $32.9 billion. Since $1.4 billion of the total is expected to be financed as toll facilities or entirely by States and municipalities, the net cost of work remaining to be done with Federal aid as of January 1, 1960, was $31.5 billion.

Prior to January 1, 1960, the estimate cutoff date, $7.2 billion of Federal-aid and State matching funds had already been spent or obligated for Interstate System improvement. Including these previous expenditures, the total cost of completing the system, from the time of its undertaking in July 1956, becomes $41 billion when provision is made for segments of the system not yet finally located, and for administration, highway planning, and research. The estimated actual construction cost of the system is about $1 billion less than that reported to the Congress in January 1958.

Since the Federal Government is paying 90 percent of the cost of completing the Interstate System, the required Federal share of the $41 billion is $37 billion, of which $25.4 billion has been authorized by Federal legislation. Estimated additional Federal authorizations needed to complete the system thus amount to $11.6 billion.

The new cost estimate was reported to the Congress pursuant to section 104(b)5 of Title 23, U.S. Code, which requires periodic estimates to be made. The estimates serve as a basis for apportionment among the States of the Federal-aid Interstate fund authorizations.

The Highway Cost Allocation Study—2 reports

The final report of the 4½-year highway cost allocation study, conducted by the Bureau of Public Roads pursuant to section 210 of the Highway Revenue Act of 1956, was submitted to the Congress on January 13 and 19, 1961.

Parts I–V of the report have been printed in one volume under the title *Final Report of the Highway Cost Allocation Study*, as House Document No. 54, and is available at 70 cents per copy. Subjects of the five parts are: Introduction and summary of findings; general discussion of the study; allocation of Federal-aid highway cost responsibility between private and commercial users and other classes and interests; allocation of tax support of the

(*Continued on page 166, column 3*)

Highway Construction: An Employment Generator

BY THE CONSTRUCTION AND MAINTENANCE DIVISION
BUREAU OF PUBLIC ROADS

Reported by M. B. CHRISTENSEN, Chief, Construction and Maintenance Division, and DAVID A. GORMAN, Highway Engineer

Each billion dollars of Federal-aid highway construction generates on-site employment for 48,000 men with a weekly payroll of over $4.6 million. The relative proportions of the various kinds of labor used on highway construction projects do not vary much on the different Federal-aid systems.

Equipment operators as a group take the greatest share of the pay on highway construction projects, but average hourly earnings on steel bridge projects exceed those on all other types of highway work.

Increased productivity on grading projects, resulting from development and widespread use of equipment, has kept the increase in the price index of grading work moderate during the past two decades. On the other hand, structures, on which the usage of equipment is still relatively limited, have had a steep rise in price index.

EACH BILLION DOLLARS of Federal-aid highway work in active construction status generates the equivalent of a full year's on-site employment for approximately 48,000 men with a weekly payroll of about $4,650,000.

Of this working force, there are approximately 18,130 equipment operators and 2,605 equipment repair and servicemen. Weekly earnings of the equipment operators and servicemen total about $2,190,000, or $105 per man. On-site employment also includes 15,605 unskilled laborers, with total weekly earnings of approximately $1,150,000, or about $74 per man; and 11,660 men are engaged in miscellaneous skilled and semiskilled crafts and in professional, managerial, clerical, and service occupations.

These figures are based on data compiled by the Bureau of Public Roads from a survey made in cooperation with the State highway departments in 1958. The survey covered all employment during the 4-week period from July 13 through August 9, 1958, on 3,425 of the more than 6,600 Federal-aid highway construction contracts in active construction status at the time.

The 3,425 construction contracts studied included all types of highway construction and represented all stages of construction ranging from contracts that were just getting started to some nearing completion. A total of 17,033,561 man-hours of labor was used on these construction projects during the survey period; this labor was paid a total of $41,257,904 in wages, including overtime earnings.

Total contract value of the 3,425 contracts was $2,216,343,000. The dollar value of construction work actually performed on these projects during the 4-week period could not readily be determined, but it was estimated to be about $181 million, or about 8 percent of the total contract value. This estimate was based on figures reported to the Bureau indicating that employment on Federal-aid highway construction during 1958 averaged 94,138 man-hours for each million dollars of contract value.

Assuming that each man employed worked an average of 40 hours a week, the 17,033,561 man-hours of labor used during the 4-week period would mean that 106,460 men would have been at work on the construction contracts, which represents an average of 31 men per contract.

A substantial portion of the employees undoubtedly worked more than 40 hours a week inasmuch as many contractors operated on shifts longer than 8 hours a day, and for 6 days a week, in order to expedite the work and to take advantage of good weather, reduced overhead, and other favorable conditions. While this would suggest that fewer men than indicated were actually at work, it seems certain that another substantial percentage of the employees worked fewer than 40 hours a week because of equipment breakdowns, unfavorable weather, materials shortages, or other conditions making it necessary to suspend operations temporarily on all or certain phases of the construction. Assuming that this "undertime" employment of some workmen would approximately offset the "overtime" employment of others, the figure of 40 hours a week appears to be reasonably correct for an average.

Labor Usage in Construction

Employment on individual contracts undoubtedly varies considerably from the average of 31 men per contract because of varying stages of completion of work. On contracts just getting started or nearing completion, the working force is apt to be relatively small; on contracts operating at full capacity a much larger number of men would be at work. The size of the working force also varies considerably according to size of the contract and character of construction work involved.

Equipment operators as a group took the greatest share of pay, 41 percent, and accounted for 38 percent of the man-hours worked. Unskilled occupations accounted for

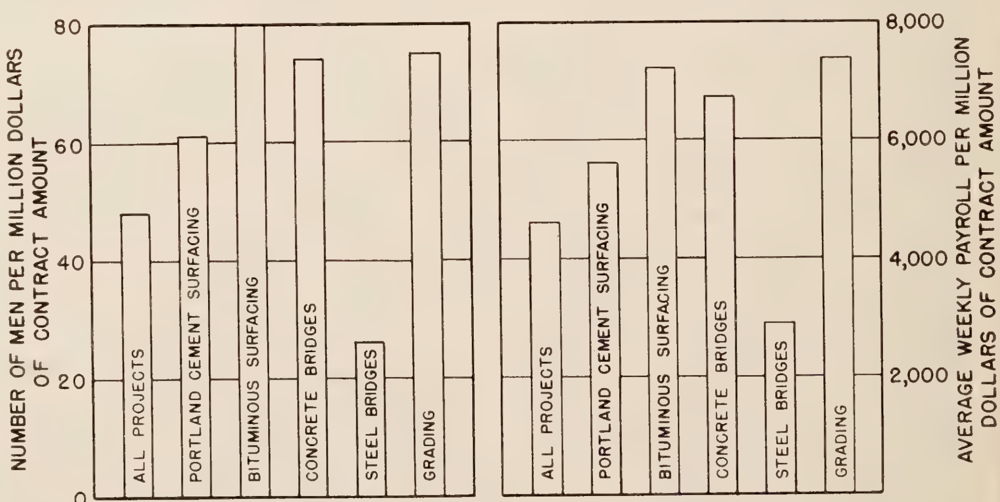

Figure 1.—Labor usage in highway construction on a national basis.

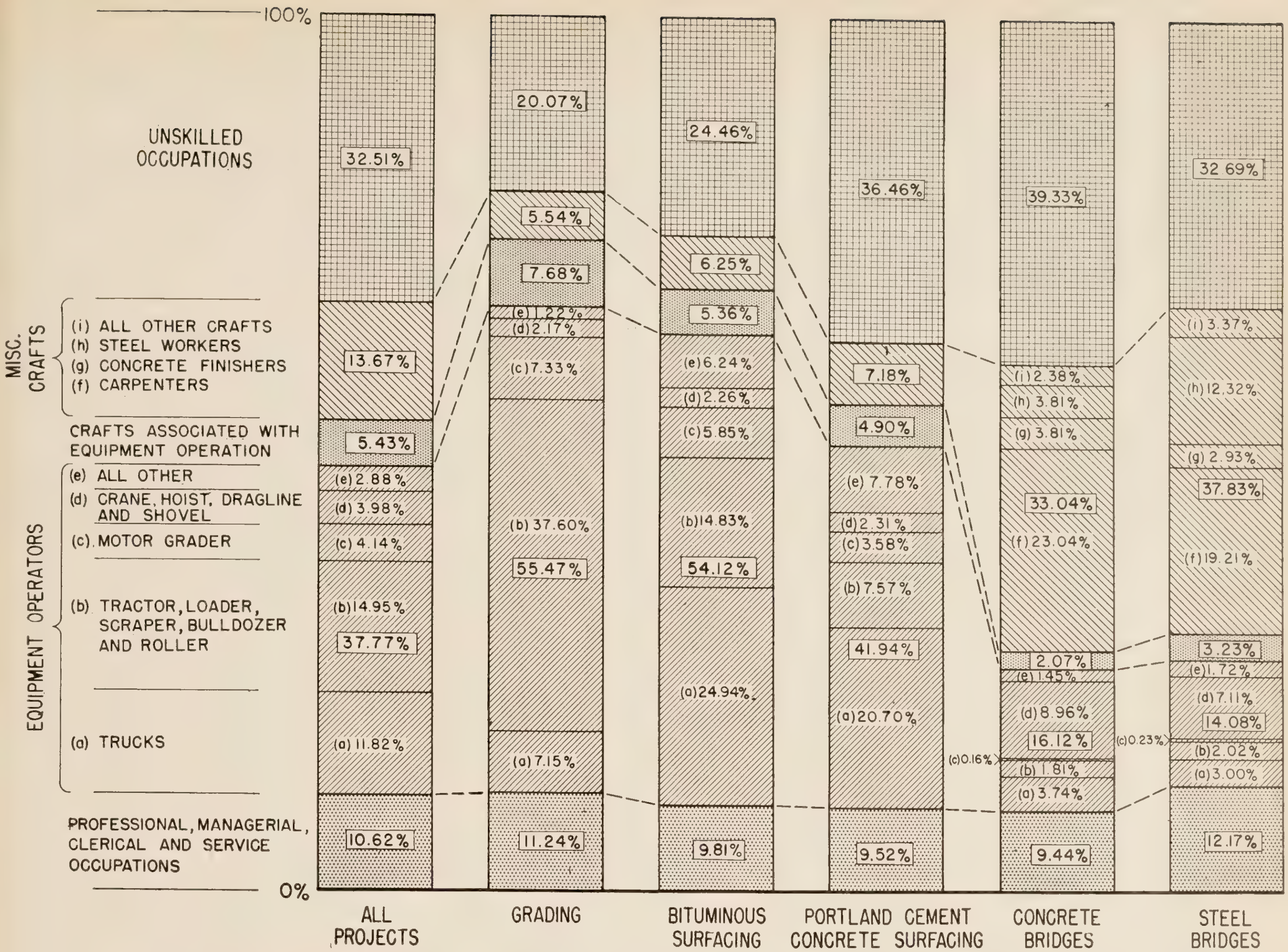

Figure 2.—Distribution of labor employed by contractors on Federal-aid highway construction.

33 percent of the hours worked and 25 percent of the wages paid. Table 3 shows the percentage distribution of hours worked and wages paid by occupational group, and the average hourly earnings, in detail (p. 165).

Job opportunities by type of construction

The number of jobs generated and the employment opportunities of each craft and occupational group was affected by the type of construction. Bituminous surfacing projects generated work for more workers per million dollars of contract amount than any of the other four types of construction shown. On the basis of a 40-hour week, bituminous surfacing projects generated employment for 80 men per million dollars of contract amount, compared to 48 men for all types of construction combined, as indicated in figure 1. Steel bridge projects required the least number of workers per million dollars of contract amount. Figure 1 indicates that for the same contract amount, bituminous surfacing created employment for about one-third more workers (31 percent) than portland cement concrete surfacing projects. It should be recognized that bituminous surfacing represents a broad range of work, from low-type bituminous surface treatment to high-type bituminous concrete.

The type and relative proportions of labor used, as shown in figure 2, differed according to the type of construction. It is noted that except for bridge construction contracts the largest single classification of labor used was equipment operators. On grading work, operators of equipment, together with the associated crafts (mechanics, oilers, firemen, and other workmen who repair and service equipment), represented 63 percent of the total working force. The same groups accounted for 59 percent of those employed in bituminous surfacing, and 47 percent of those in portland cement concrete pavement work. In contrast, workmen engaged in operating, repairing, and servicing equipment accounted for only about 18 percent of the working force on concrete and steel bridges.

The equipment operator classification consisted primarily of four main subclassifications: (1) truckdrivers; (2) operators of tractors with attachments and supplemental units, such as bulldozers, scrapers, loaders, rollers, and rippers; (3) operators of machines such as power shovels, cranes, draglines, hoists, and piledrivers; and (4) motor grader operators. This general classification also includes operators of equipment for: (1) crushing aggregates; (2) batching, mixing, placing, and finishing structural concrete, bituminous surfaces and bases, portland cement concrete bases and pavements, and other types of bases and subbases; and (3) drilling.

As shown in table 3, truckdrivers constituted the largest labor-cost factor among the many classifications of equipment operators employed in highway work. They led not only all other operators but also all other individual occupations, accounting for almost 12 percent of hours worked and 11 percent of wages paid. As shown in figure 2, bridge construction projects generated relatively minor demand for truckdrivers. Truckdrivers on concrete and steel bridge contracts accounted for less than 4 percent of the total time worked. On the other hand, surfacing jobs required a great number of truckdrivers. Truckdrivers accounted for 21 percent of the worktime on portland cement concrete surfacing jobs and 25 percent of the time on bituminous surfacing jobs.

Tractor, grader, scraper, and power crane operators each contributed from about 4 to 5 percent of man-hours worked and collected

Table 1.—Percentage distribution of the total hours worked among the various major occupational groups, on a regional basis

Occupational group	Percentage distribution of hours worked, on a regional basis [1]										
	All regions	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10
Professional and managerial occupations	9.40	11.29	11.08	9.05	8.26	9.39	8.01	10.36	10.41	9.08	13.09
Clerical occupations	.92	1.19	1.12	.55	.80	1.01	.53	.99	1.06	1.38	1.71
Service occupations	.30	1.04	.12	.14	.03	.42	.12	.09	.00	.32	.44
Equipment operators	37.77	31.25	34.52	29.53	38.00	45.50	37.44	35.77	53.42	40.83	44.39
Crafts associated with equipment operations	5.43	6.68	3.41	4.02	3.85	5.81	4.85	6.96	4.18	9.17	15.18
Miscellaneous crafts	13.67	15.04	17.88	13.45	15.08	10.99	13.85	19.24	11.22	13.86	8.96
Unskilled occupations	32.51	33.51	31.87	43.26	33.98	26.88	35.20	26.59	19.71	25.36	16.23

[1] For States included in each of the Bureau of Public Roads regions, see inside front cover.

from about 5 to 6 percent of the wages earned (table 3). Roller operators accounted for almost 2 percent of both hours and wages. The remainder of the operator classifications accounted for less than 1 percent each. Equipment operator apprentices were credited with 0.03 percent of man-hours and 0.02 percent of total wages.

Other crafts associated with equipment operation—oilers, mechanics, firemen, stationary engineers, and pile-drivermen—accounted for about 5 percent of hours worked and 6 percent of wages earned. Altogether, operation and care of equipment required 43 percent of the man-hours worked and consumed 47 percent of the payroll.

On a Bureau of Public Roads regional basis, as shown in table 1, contractors in the Northwestern States (region 8) were the largest users of equipment operators in proportion to the total number of hours worked. The percentage distribution of the total time accounted for by equipment operators in region 8 was 53 percent, compared to the national average of 38 percent. The Southeastern States (the Bureau's region 3) ranked the lowest in the proportion of equipment operator time. The percentage, however, was only slightly less than that for the Northeastern States (region 1).

Carpenters were the second largest single occupational group employed on highway construction, accounting for nearly 6 percent of hours worked and 8 percent of wages paid. Within the classification of miscellaneous crafts, carpenters accounted for almost 50 percent of the total hours worked.

Bridge projects produced more job opportunities for carpenters than did any other type of construction. Carpenters accounted for 23 percent of the hours on concrete bridge construction projects and 19 percent of the hours on steel bridge construction projects. On the other hand, surfacing and grading projects offer relatively few job opportunities for carpenters. Carpenters accounted for less than 2 percent of the time on surfacing and grading projects. Structural steel workers and welders naturally found their greatest job opportunities on steel bridge projects, accounting for 10 percent of the total hours.

Unskilled labor represented a substantial percentage of the working force on all types of construction, varying from 20 percent on grading work to 39 percent on concrete bridges. Unskilled labor accounted for a greater share of the total hours worked on highway construction in the Southeastern States (region 3) than anywhere else in the country.

From 9 percent to 12 percent of the working force was made up of professional, managerial, clerical, and service personnel, such as engineers, superintendents, foremen, timekeepers, clerks, cooks, flagmen, and watchmen.

Equipment use and construction costs

The development of new and better construction equipment and its widespread usage on grading and bituminous surfacing projects is indicated in figure 2 by the high proportion of equipment operators. These developments have no doubt had a significant effect upon productivity. The increased productivity, with its resultant savings in construction cost, has been particularly noticeable in the price index for grading. The increase in this price index has been moderate in comparison to the increase in the price index for concrete and steel structures during the past two decades, as shown in figure 3. On the other hand, the relatively small proportion of hours accounted for by equipment operators on bridge projects and the high proportion of hours accounted for by workers in the crafts and unskilled labor categories, approximately 70 percent of the total time, are indicative of the lesser degree of mechanization in structural work with consequent lower productivity for the labor-equipment combination and greater increase in unit costs than for grading and surfacing work. This, plus the increased cost of materials and wages, have apparently been responsible for the steep rise in the price index for structures over the past two decades.

Labor usage on highway systems

The relative proportions of different kinds of labor did not vary greatly for Interstate, primary, and secondary Federal-aid highway

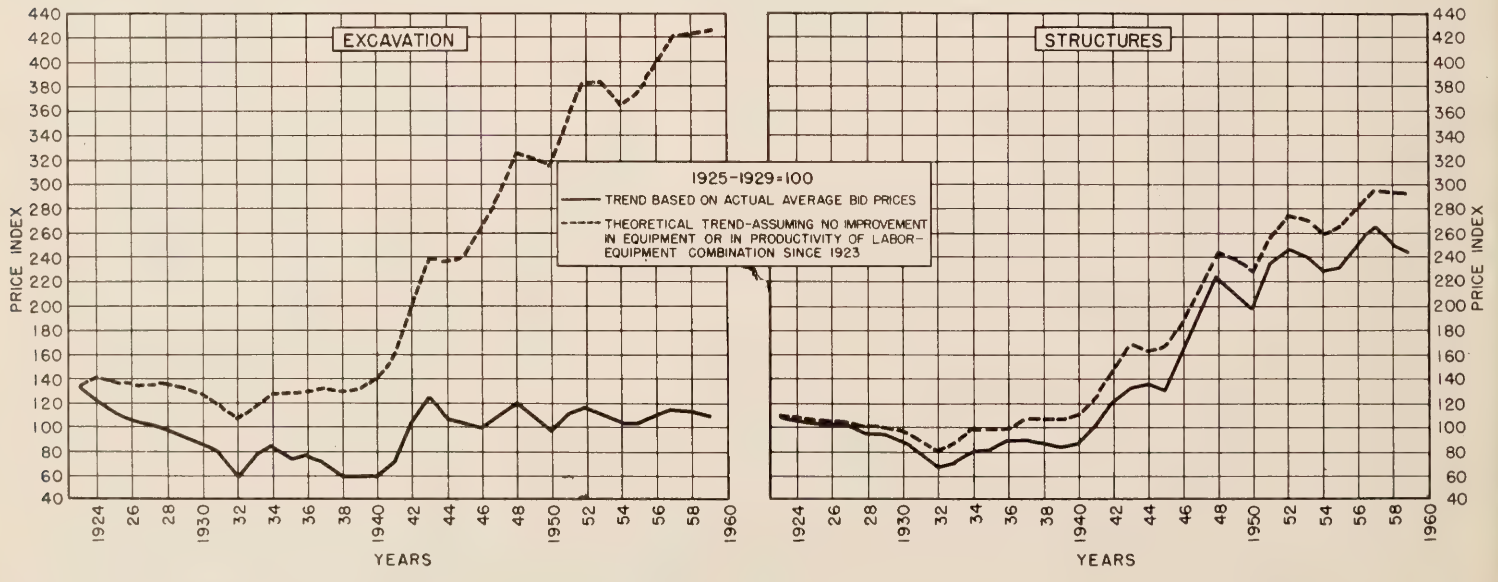

Figure 3.—Effect of improved equipment on highway construction prices for excavation and structures.

Table 2.—Percentage distribution of the total hours worked among the various major occupational groups, on the different Federal-aid highway systems, on a national basis

Occupational group	Percentage distribution of hours worked on—		
	Interstate	Primary	Secondary
Professional and managerial occupations	9.35	9.45	9.39
Clerical occupations	.93	1.02	.71
Service occupations	.24	.38	.27
Equipment operators	34.75	38.10	44.09
Crafts associated with equipment operations	6.06	4.96	5.01
Miscellaneous crafts	16.66	12.82	8.38
Unskilled occupations	32.01	33.27	32.15

projects, as may be seen in table 2. Unskilled labor represented an average of from 32 percent to 33 percent and the administrative and service personnel represented about 10 percent of the working force on each class of highway. The hours worked by equipment operators and associated craftsmen ranged from 41 percent on Interstate projects to 43 percent on primary and 49 percent on secondary projects. The miscellaneous skilled and semiskilled crafts ranged from 17 percent of the hours worked on Interstate projects to 13 percent on primary and to 8 percent on secondary projects.

Average Hourly Earnings

Average hourly earnings based on actual payments made (including overtime) ranged from $1.58 an hour for service personnel such as watchmen and flagmen, to $4.07 an hour for master mechanics, as shown in table 3. Average earnings for unskilled labor were $1.84 an hour. Highly skilled craftsmen such as structural steel workers, electricians, stonemasons, carpenters, plumbers, and operators of heavy, complex equipment were, of course, among those having relatively high hourly earnings. It is possible, however, that a greater percentage of the highly skilled craftsmen's earnings were the result of overtime payments.

On a regional basis (excluding Alaska in which average hourly earnings were unusually high), as shown in figure 4, the average hourly earnings for all workmen combined varied from a minimum of $1.62 for the Southeastern States (region 3), to a maximum of $3.39 for region 7, the States of Arizona, California, Nevada, and Hawaii. Among the several types of projects (right side of fig. 4), the average hourly earnings on steel bridge projects exceeded those on all other types of work.

It is apparent that an increase in the wages of some crafts could have a very significant effect upon the cost of construction of certain types of work if those crafts account for a very large proportion of the hours worked. On the other hand, wage increases in some crafts may have very little effect upon the overall cost of the work if those crafts account for an insignificant share of the hours worked. Thus,

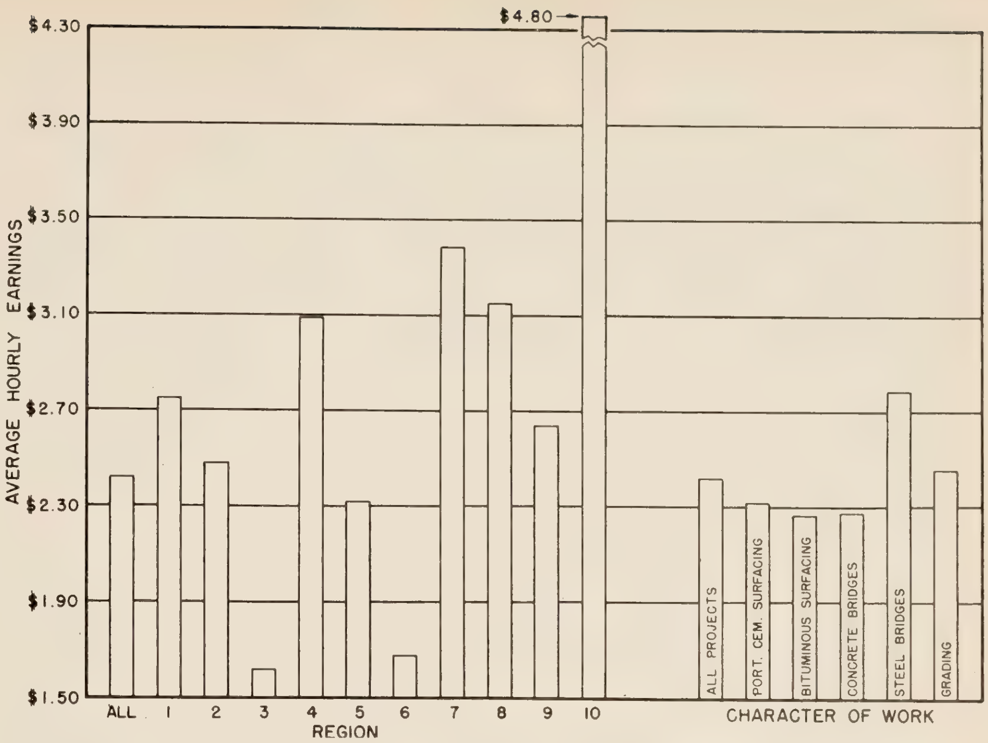

Figure 4.—Average hourly earnings in each region and for each character of work.

Table 3.—Labor usage in highway construction, on a national basis, construction contractor employees only [1]

Occupational group	Percentage distribution		Average hourly earnings [2]
	Hours worked	Wages	
Professional and managerial occupations:			
Foremen	5.98	7.10	$2.89
Superintendents	2.51	3.29	3.18
Civil engineers	.53	.68	3.12
Managerial and official occupations other than superintendents	.20	.27	----------
Office managers	----------	----------	2.48
Project managers	----------	----------	3.42
Surveyors	.17	.19	----------
Instrumentmen	----------	----------	2.31
Accountants	.01	.01	2.33
Subtotal	9.40	11.54	----------
Clerical occupations:			
Paymasters, payroll clerks, and timekeepers	.60	.50	2.04
Clerks, general office	.23	.22	1.97
Bookkeepers and cashiers	.05	.05	2.18
Miscellaneous	.04	.03	----------
Subtotal	.92	.80	----------
Service occupations:			
Watchmen, flagmen, and traffic officers	.29	.19	1.58
Cooks	.01	.01	2.92
Subtotal	.30	.20	----------
Equipment operators:			
Truckdrivers	11.82	10.50	2.23
Tractor operators and loaders	5.20	5.85	----------
Tractor operators	----------	----------	2.53
Front end loader operators	----------	----------	2.59
Motor grader operators	4.14	5.04	2.70
Scraper operators	4.07	4.80	2.62
Crane, hoist, dragline, and shovel operators	3.98	5.09	----------
Crane operators (crawler type)	----------	----------	2.78
Truck crane operators	----------	----------	3.02
Hoist operators	----------	----------	3.56
Dragline operators	----------	----------	2.57
Shovel operators	----------	----------	3.09
Bulldozer operators	3.85	4.57	2.63
Roller operators	1.83	1.78	2.16
Operators of concrete-mixing and concrete paving machines	.67	.67	----------
Concrete mixer operators	----------	----------	2.34
Concrete paver operators	----------	----------	3.21
Operators of asphalt plants and asphalt paving machines	.49	.54	----------
Asphalt plant operators	----------	----------	2.65
Asphalt paver operators	----------	----------	2.38
Batch plant operators	----------	----------	1.74
Concrete and asphalt finishing machine operators	.41	.61	2.47
Rock crusher and gravel plant operators	.40	.50	----------
Crusher operators	----------	----------	2.74
Piledriver operators	.34	.49	3.21
Off-highway hauling equipment operators	.27	.27	2.38

See footnotes at end of table.

(Continued on page 166)

Table 3.—Labor usage in highway construction, on a national basis, construction contractor employees only [1]—Continued

Occupational group	Percentage distribution: Hours worked	Percentage distribution: Wages	Average hourly earnings [2]
Equipment operators—Continued			
Subgrading machine, form grader, and stone spreader operators	0.17	0.17	----------
Subgrading machine operators	----------	----------	$2.49
Stone spreader operators	----------	----------	2.30
Other construction machinery operators not elsewhere classified [3]	.10	.12	----------
Trenching machine operators	----------	----------	2.56
Apprentices	.03	.02	----------
Subtotal	37.77	41.02	----------
Crafts associated with equipment operation:			
Oilers of machinery	2.38	2.39	2.43
Mechanics	2.50	3.07	----------
Mechanics	----------	----------	3.05
Master mechanics	----------	----------	4.07
Mechanic helpers	----------	----------	2.18
Firemen	.23	.25	2.43
Engineers, stationary	.22	.30	----------
Pump operators	----------	----------	3.03
Air compressor operators	----------	----------	3.03
Piledrivermen	.10	.12	3.39
Subtotal	5.43	6.13	----------
Miscellaneous crafts:			
Carpenters	6.55	7.78	2.86
Concrete finishers	2.06	2.28	----------
Concrete finishers	----------	----------	2.70
Concrete rubbers	----------	----------	2.18
Drillers and mudjack operators	1.05	1.06	----------
Drill operators	----------	----------	2.61
Air tool men	----------	----------	1.85
Structural steel workers and welders	1.01	1.42	----------
Structural steel workers	----------	----------	3.65
Welders	----------	----------	2.76
Reinforcing steel workers	.64	.75	2.86
Metal road form setters and form tamper operators	.56	.47	----------
Form setters, metal road forms	----------	----------	2.18
Bituminous paving occupations	.44	.42	----------
Asphalt rakers	----------	----------	2.34
Asphalt distributor operators	----------	----------	2.23
Pipelayers	.32	.27	2.22
Blasters and powdermen	.31	.33	----------
Blasters	----------	----------	2.53
Painters	.12	.15	3.32
Chainmen and rodmen (surveying)	.09	.07	2.11
Electricians	.08	.12	3.84
Brick and stone masons, and tile setters	.07	.09	----------
Bricklayers	----------	----------	2.98
Stonemasons	----------	----------	3.32
Apprentices	.05	.05	----------
Carpenter apprentices	----------	----------	2.30
Ironworker apprentices	----------	----------	2.67
Plumbers	.04	.05	3.26
Other	.28	.23	----------
Subtotal	13.67	15.54	----------
Unskilled occupations	32.51	24.77	1.84
Total or average	100.00	100.00	2.42

[1] Based on reports received from 3,425 active Federal-aid projects, covering the 4-week period from July 13 to Aug. 9, 1958.
[2] Includes overtime.
[3] Includes rig operators, dredge levermen, and trenching machine and stabilizer operators.

a significant increase in the hourly wages of truckdrivers could raise the cost of bituminous construction considerably since they account for 25 percent of the hours worked, whereas a wage increase for truckdrivers might have comparatively little effect upon the overall cost of steel bridge construction, where truckdrivers account for only 3 percent of the hours worked. The same principle would apply to carpenters on concrete bridge construction as compared to bituminous surfacing projects.

Although bituminous projects, as mentioned previously, generated employment for more men per million dollars of contract amount than any of the other four types of work, grading projects generated a slightly larger weekly payroll, as shown in figure 1, since average hourly earnings on grading projects exceeded those on bituminous work.

Off-site employment

In addition to on-site employment, discussed in this article, highway construction generates considerable off-site employment. Exact figures were not available, but it is estimated that the off-site employment is at least as great as the on-site employment and may be slightly greater. Off-site employment consists primarily of workmen engaged in the production, processing, and distribution of construction materials and equipment, and also includes employees in construction contractors' central offices, supply depots, and repair shops.

New Publications

(Continued from page 161)

Federal-aid systems among vehicles of different dimensions, weights, and other specifications; and competition of highways with other modes of transportation.

Part VI of the report has been printed under the title *Economic and Social Effects of Highway Improvement*, as House Document No. 72, and is available at 25 cents per copy.

The purpose of the study was to make available to the Congress information on the basis of which it may determine what taxes should be imposed by the United States, and in what amounts, in order to assure an equitable distribution of the tax burden among the various classes of persons using Federal-aid highways or otherwise deriving benefits from them. The report does not contain any statements or recommendations regarding Federal fiscal policy relating to highways.

In considering the problem of cost allocation among various classes of vehicles, four different approaches were undertaken. One of these, relying upon data to be derived from the American Association of State Highway Officials Road Test, cannot be completed until the Road Test data analysis has progressed to a further stage. It is expected that this work will be completed in time to submit definitive findings on this phase of the study to the Congress by midsummer of 1961.

Maximum Desirable Dimensions and Weights of Vehicles

On January 3, 1961, an interim report on the *Maximum Desirable Dimensions and Weights of Vehicles Operated on the Federal-Aid Systems* was submitted to the Congress pursuant to section 108(k) of the Federal-Aid Highway Act of 1956.

As pointed out in the report, the compilation and analysis of data from the American Association of State Highway Officials Road Test had not been sufficiently advanced to serve as a basis for making specific recommendations, at the time of the report transmittal, as to maximum desirable dimensions and weights of vehicles operated on the Federal-aid highway systems. The report therefore suggested that no changes be made in the existing law on vehicle dimensions and weights (sec. 108(j) of the Federal-Aid Highway Act of 1956), pending submission of a final report containing recommendations. The final report will be made during the summer of 1961.

The report also contained a certain amount of background information on the subject, which presumably will be included in the final report. The interim report has not been printed as a Congressional document, and copies are therefore not available for general distribution.

U.S. GOVERNMENT PRINTING OFFICE: 1961

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REPORTS TO CONGRESS

Economic and Social Effects of Highway Improvement, House Document No. 72 (1961). 25 cents.

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

Federal Role in Highway Safety, House Document No. 93 (1959). 60 cents.

Final Report of the Highway Cost Allocation Study, House Document No. 54 (1961). 70 cents.

First Progress Report of the Highway Cost Allocation Study, House Document No. 106 (1957). 35 cents.

Progress and Feasibility of Toll Roads and Their Relation to the Federal-Aid Program, House Document No. 139 (1955). Out of print.

Public Utility Relocation Incident to Highway Improvement, House Document No. 127 (1955). Out of print.

The 1961 Interstate System Cost Estimate, House Document No. 49 (1961). 20 cents.

PUBLICATIONS

Catalog of Highway Bridge Plans (1959). $1.00.

Classification of Motor Vehicles, 1956–57. 75 cents.

Construction of Private Driveways, No. 272 MP (1937). 15 cents.

Design Capacity Charts for Signalized Street and Highway Intersections (reprint from PUBLIC ROADS, Feb. 1951). 25 cents.

Federal Laws, Regulations, and Other Material Relating to Highways (1960). $1.00.

Financing of Highways by Counties and Local Rural Governments: 1942–51. 75 cents.

General Location of the National System of Interstate Highways, Including All Additional Routes at Urban Areas Designated in September 1955. 55 cents.

Highway Bond Calculations (1936). 10 cents.

Highway Capacity Manual (1950). $1.00.

Highway Statistics (published annually since 1945):
1955, $1.00. 1956, $1.00. 1957, $1.25. 1958, $1.00.

Highway Statistics, Summary to 1955. $1.00.

Highway Transportation Criteria in Zoning Law (1960). 35 cents.

Highways of History (1939). 25 cents.

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Legal Aspects of Controlling Highway Access (1945). 15 cents.

Manual on Uniform Traffic Control Devices for Streets and Highways (1948) (*including 1954 revisions supplement*). $1.25.
Revisions to the Manual on Uniform Traffic Control Devices for Streets and Highways (1954). *Separate,* 15 cents.

Parking Guide for Cities (1956). 55 cents.

Public Control of Highway Access and Roadside Development (1947). 35 cents.

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Road-User and Property Taxes on Selected Motor Vehicles, 1960. 30 cents.

Results of Physical Tests of Road-Building Aggregate (1953). $1.00.

Selected Bibliography on Highway Finance (1951). 60 cents.

Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958: a reference guide outline. 75 cents.

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-57 (1957). $2.00.

Standard Plans for Highway Bridge Superstructures (1956). $1.75.

The Identification of Rock Types (revised edition, 1960). 20 cents.

The Role of Aerial Surveys in Highway Engineering (1960). 40 cents.

Transition Curves for Highways (1940). $1.75

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