PUBLIC ROADS

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

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THE PROBLEM PRESENTED BY RAILROAD GRADE CROSSINGS IS A SERIOUS ONE

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A STATISTICAL ANALYSIS OF HIGHWAY-RAILROAD GRADE-CROSSING ACCIDENTS IN 1926

Reported by A. B. FLETCHER, Consulting Highway Engineer, and WILLIAM G. ELIOT, 3d, Associate Highway Economist, United States Bureau of Public Roads

THE PROBLEM of the highway–railroad grade crossing, serious enough when the highways carried nothing faster than horse-drawn vehicles, and not very many of them, has become much more urgent since the advent of high-speed automotive traffic. Figures published by the Bureau of Statistics of the Interstate Commerce Commission show a rapid increase in grade-crossing fatalities in the United States, especially during the past 10 years. From a total of 1,652 deaths at steam railroad grade crossings in 1916 the annual toll increased to 2,491 in 1926.[1] While this increase is by no means in proportion to the increased use of the highways, grade crossings, nevertheless, remain one of the most important hazards to traffic.

CONCLUSIONS SUMMARIZED

In the belief that the most intelligent program for grade-crossing safety depends upon a thorough knowledge of the existing conditions, the United States Bureau of Public Roads has recently completed a careful analysis of nearly 6,000 grade-crossing accidents as reported to the Interstate Commerce Commission by the steam railroads of the country during 1926. These reports are public records and are open to examination without special arrangement with the commission, though it is only fitting to state that the officials of its Bureau of Statistics evinced great interest in the work and gave special facilities for the study.

Some of the more definite conclusions to which this study points may be summarized as follows:

There is a real need for a series of intensive studies of individual grade-crossing accidents, as well as for more complete and accurate reporting of grade-crossing accident data in general.

The hazard at grade crossings in rural areas is far more important than has heretofore been reported or understood. At least 16 per cent of all fatalities due to accidents on the rural highways of the country are attributable to the crossings of the railroads and highways at grade.

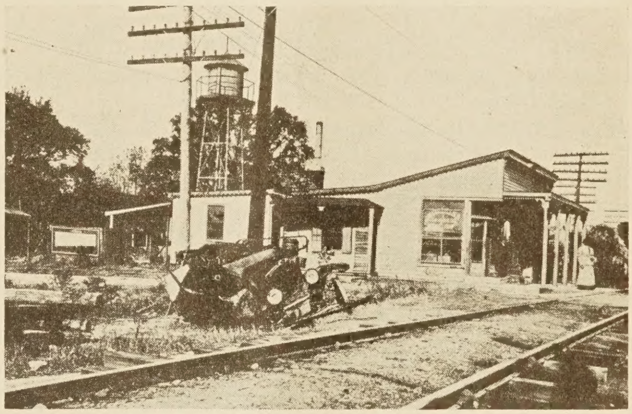
A serious effort should be made to hasten the change of thousands of crossings from the "unprotected" to the "protected" class by the installation of suitable warning devices and continued attention given to the improvement of existing protection.

Despite all external safeguards, it will be necessary by persistent and forceful publicity to keep in the minds of all highway users a realization of the hazards to which they are exposed as long as any considerable proportion of the 235,000 steam railroad grade crossings in the United States continue to exist.

THE SOURCE OF DATA

Under the act of Congress of May 6, 1910, each railroad is required to report monthly to the Interstate Commerce Commission all accidents "arising from the operation of such railroad under such rules and regulations as may be prescribed by the said commission." Under the rules of the commission effective January 1, 1922,—

> a reportable accident is an accident arising from the operation of a railway that results in one or more of the following circumstances:
>
> (*a*) Damage to railway property amounting to more than $150, including the expense of clearing wreck * * *.
>
> (*b*) Death of a person.
>
> (*c*) Injury to an employee sufficient to incapacitate him from performing his ordinary duties for more than three days in the aggregate during the 10 days immediately following the accident. This rule * * * does not apply to employees classed as passengers or trespassers.
>
> (*d*) Injury to a person other than an employee if the injury is sufficient, in the opinion of the reporting officer, to incapacitate the injured person from following his customary vocation or mode of life for a period of more than one day * * *.



THE RESULT OF A GRADE-CROSSING ACCIDENT

In general, the reports cover—

> accidents at public highway grade crossings due to trains, locomotives, or cars striking pedestrians or colliding with trolley cars, automobiles, or other vehicles, or objects other than hand cars or other railway tools or material * * *.

In the classification of accidents by the commission this has been extended to include such miscellaneous cases as injuries to crossing flagmen when struck by highway vehicles, injuries to persons who have jumped from vehicles in anticipation of collisions which do not occur, and injuries resulting from the wrecking of highway vehicles in averting collisions with trains, when such accidents occur on the railroad right of way.

Under the rules of the commission, "Any person killed in an accident at the time of its occurrence, or so seriously injured as to die within 24 hours thereafter, should be reported as killed." All other personal casualties are listed as injured, even though death follows after a period of more than 24 hours. No attempt was made in this study to tabulate these later deaths, but the Interstate Commerce Commission, as a result of a recent special analysis,[2] reports that in addition to its published totals of deaths, there was a total of 205 of these subsequent "fatalities" from grade-crossing accidents in the entire country during

[1] See Accident Bulletin No. 94, Interstate Commerce Commission, p. 113.

[2] Made for this study at the request of the Bureau of Public Roads

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1926. This amounts to an increase of 8 per cent over the commonly accepted and quoted figures. In the following study, however, the killed and injured are listed as reported by the railroads, without allowance for subsequent fatalities.

The railroads are instructed to—

state all material facts, including whether injured persons were pedestrians, occupants of trolley cars, automobiles, or other vehicles, riding bicycles or motor cycles, etc.; the nature of protection, if any, afforded at the crossing at the time of an accident; that is, whether crossing gates, watchman, audible or visual signals (not stationary signs), etc.; the kind of vehicle or object struck, and whether the view of crossing was obscured by buildings, trees, cars, or other objects.

GREAT VARIETY OF ACCIDENTS REPORTED

The reporting officers of the railroads differ widely in their interpretation of the phrase "material facts," and often fail to supply some of the details specifically enumerated above. This may be partly due to the fear of encouraging litigation, despite the legal provision that no accident report "shall be admitted as evidence or used for any purpose in any suit or action for damages growing out of any matter mentioned in said report." Many of the reports are merely perfunctory, but despite these limitations there is no comparable source for nation-wide grade-crossing accident facts.

The Interstate Commerce Commission, through its Bureau of Statistics, has tabulated a considerable volume of data from these reports, including the casualties at grade crossings and whether the victims were trespassers at the time; the type of accident, whether involving pedestrian, passenger automobile, truck, etc.; and the type of protection afforded at the crossings for each type of accident. These appear in quarterly reports and in the annual Accident Bulletin published by the commission. Certain of the analyses presented here are practically duplications of those previously made by the commission. For the most part, however, the study deals with what are believed to be new and hitherto unpublished data.

The method followed in the present analysis included copying off of pertinent data, codifying these data wherever that had not already been done by the Interstate Commerce Commission, transferring them to punch cards, and finally tabulating them by machine. No attempt was made to secure accurate correspondence of final results with the figures published by the commission. The total of 5,808 accidents analyzed in this study falls short of the 5,890 tabulated by the Interstate Commerce Commission. The deficiency is principally accounted for by the fact that some of the reports were misclassified by the railroads, were not in their proper place in the files, and escaped the present tabulation. On the other hand, a few of the accidents included in the commission's totals were found to be erroneously classified and were deliberately discarded. Various other differing judgments or minor errors in both tabulations make strict comparability impossible either as to number of accidents or as to details of those tabulated.

The greatest conceivable variety of grade-crossing mishaps was found in these reports. Interspersed in the monotonous sequence of pedestrians, automobiles, and teams blundering on to crossings and being struck by trains that could not turn aside nor stop quickly were frequent unique combinations of circumstances and, occasionally, a note of near-comedy. In one case a helpful neighbor and several members of his family met death when the friend whose car they were towing applied his brakes suddenly and stalled the first car in the path of a fast train. In another case, it was an excited woman passenger who grabbed the emergency brake and stalled the automobile on the track. One driver, after stopping on the track, backed off safely but continued backing in a semicircle until he was once more in front of the train.

A pedestrian standing close to the track was knocked down and injured when struck by the body of a switchman who was riding the side of a car. In yet another case a passenger on a train was thrown down and hurt when the engineman applied the emergency brakes as a truck ran into the side of his engine. An unlucky farmer lost his life while "endeavoring to urge cow over crossing." An intoxicated operator drove his car into the rear of another car waiting at the crossing and pushed it in front of an approaching train. Numerous cases were reported in which bystanders were struck by flying wreckage, sometimes with fatal results. Several persons lost their lives in futile attempts to push their stalled cars off the tracks.

RURAL AND URBAN ACCIDENTS COMPARED

One of the major questions in the minds of those responsible for this study was as to the distribution of accidents between rural and urban regions. It was believed that grade-crossing accidents would be found to constitute a much greater proportion of all traffic accidents on the country highways than on city streets, due to the differing traffic conditions. This conclusion was based on the assumptions, (1) that grade crossings in the cities are either eliminated or are better protected than in the country, while both rail and highway vehicles are moving at slower speeds; and (2) that because of the congestion of vehicles and pedestrians on city streets, a majority of all traffic accidents occur in the cities and larger villages.

According to the most recent estimate made by the National Safety Council, there were in 1926 approximately 25,000 fatalities due to street and highway accidents of all kinds. Railroad grade-crossing accidents, according to the Interstate Commerce Commission figures, account for 2,491 of these, or 10 per cent. Analysis of these statistics to show urban and rural accidents separately involves further estimates, which can be made, it is believed, with sufficient accuracy to be worth while.

The proportion of urban and rural grade-crossing accidents was determined from an analysis of the individual grade-crossing accident reports. According to the name of the "nearest station" as reported by the railroad and the "distance and direction from station named," with occasional assistance from other data given, the accidents were divided into two groups: (1), "Urban" occurring in incorporated places having a population (census of 1920) of 2,500 persons or more; and (2) "rural," all others. This classification is in accord with the definitions of urban and rural population as made by the Bureau of the Census. It also corresponds approximately with the provisions of Federal-aid legislation, which states that Federal aid shall not be extended to highways within incorporated places having a population of 2,500 or more, except on "that portion of any such highway or street along which, within a distance of 1 mile, the houses average more than 200 feet apart."

It was not always possible to determine whether an accident happened outside or within the corporate limits of the place named, even when the distance from the station was stated. When the distance was not given, as was frequently the case, it was necessary to assume the location as at the station or very near it. It is probable that a considerable number of rural accidents were tabulated as urban because the nearest station was urban. It is recognized that for certain purposes it would be much more helpful to know whether an accident occurred under rural conditions (light traffic, absence of buildings adjacent to the track, etc.) or under urban conditions, than to know where it occurred in relation to a certain boundary line. But such a refinement was clearly impossible without a great deal of unsatisfactory correspondence or a personal visit to the site of almost every accident, and would have raised difficult questions of definition.

The result of the rural and urban classification was not quite according to expectations. The total number of accidents was almost exactly equally divided, there being 2,897 rural accidents and 2,907 urban accidents.[3] On the other hand, the rural accidents were clearly of a more serious nature. They resulted in 1,570 fatalities while urban accidents caused but 895. The number of persons injured shows less discrepancy. These figures are tabulated by States in Table 1.

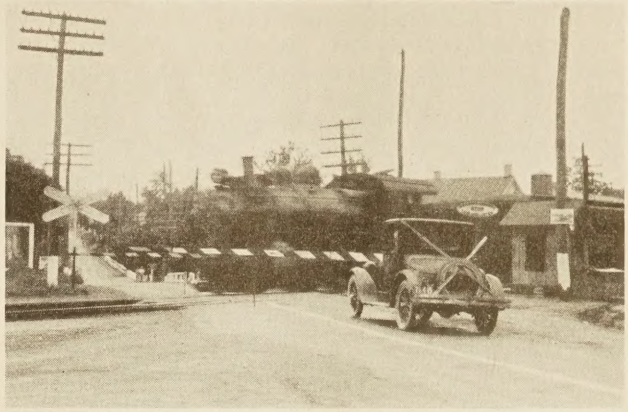
GRADE CROSSINGS RESPONSIBLE FOR 16 PER CENT OF RURAL HIGHWAY FATALITIES

Statistics for other types of street and highway accidents are scarce, but such evidence as we have seems to support the assumption that the majority of such accidents take place in urban regions. The Massachusetts motor vehicle department reports that out of 669 fatal motor-vehicle accidents during the fiscal year 1926, 394, or nearly 60 per cent, occurred in business districts or thickly settled residential districts. The New York State bureau of motor vehicles reports, for the months of June and July, 1927, but 1,440 motor-vehicle accidents, with 130 deaths, in localities of less than 2,500 population as compared with 12,937 accidents and 314 deaths in places of more than 2,500 persons. This places more than 70 per cent of these fatalities in urban areas.

It is possible that these highly urbanized States do not give a fair picture of the distribution of accidents in the country as a whole, but comparable statistics for the more rural States are not available. We do have, however, certain figures for the United States registration area,[4] published by the Bureau of the Census. According to this source, there were in 1925 (the latest figures available) a total of 19,335 motor-vehicle fatalities (including automobile collisions with street cars and railroad trains) in the registration area, of which 11,781, or 61 per cent, occurred in cities of over 10,000 population. The corresponding ratio for 1924 (not, however, including collisions with heavier vehicles) was nearly 63 per cent. Unfortunately for the complete usefulness of these authoritative statistics, they indicate only the place where death occurred, regardless of the place where the fatal injuries may have been received. It frequently happens that injured persons are brought to city hospitals after receiving injuries at points outside of the city—so frequently that the Bureau of the Census has felt it necessary to recognize the fact in its automobile accident-mortality reports for the larger cities, listing separately, so far as obtainable, the

[3] For four accidents the information given was inadequate for even a reasonable guess as to the place of occurrence.

[4] The registration area comprises those parts of the United States which meet certain standards in the reporting of mortality statistics. During 1925 it included 40 States and 25 cities outside those States (including the District of Columbia), representing 70.9 per cent of the area and 89.4 per cent of the population of the continental United States.



A Crossing Protected By Lowered Gates

Table 1.—*Rural and urban grade-crossing accidents and personal casualties by States, 1926*

State	Total[1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
Ohio	541	260	600	220	130	227	320	130	372
Illinois	516	237	570	221	136	233	294	101	336
New York	412	204	448	210	115	231	202	89	217
Indiana	401	173	457	173	107	184	228	66	273
Pennsylvania	398	160	484	214	106	261	184	54	223
Michigan	350	133	425	141	69	157	209	64	268
California	280	125	301	130	82	139	150	43	162
Texas	238	84	313	117	61	132	121	23	181
Wisconsin	170	88	217	80	49	113	90	39	104
New Jersey	164	81	173	93	54	100	71	27	73
Florida	156	69	186	95	57	109	60	12	76
Iowa	141	54	154	73	36	80	68	18	74
Alabama	136	41	199	68	24	101	68	17	98
Kansas	131	44	196	68	33	93	63	11	103
Oklahoma	128	56	155	58	37	61	70	19	94
Georgia	127	50	163	55	30	61	72	20	102
Missouri	126	65	128	68	42	63	58	23	65
North Carolina	125	63	125	68	37	60	57	26	65
Minnesota	120	47	159	75	36	95	45	11	64
Kentucky	107	43	119	48	23	47	59	20	72
Tennessee	102	24	174	40	17	81	62	7	93
Arkansas	95	23	109	51	16	55	43	7	53
Mississippi	88	27	101	62	25	62	26	2	39
Louisiana	74	25	94	35	13	44	39	12	50
Washington	64	26	76	39	21	39	25	5	37
Colorado	62	25	83	26	15	32	36	10	51
South Carolina	56	15	73	36	11	42	20	4	31
Virginia	56	23	95	42	18	63	14	5	32
Nebraska	55	22	71	36	20	45	19	2	26
Maryland	50	24	57	31	20	36	19	4	21
Massachusetts	50	17	58	27	12	27	23	5	31
West Virginia	46	22	56	33	20	35	13	2	21
North Dakota	30	11	32	23	10	24	7	1	8
Oregon	29	15	28	15	11	15	14	4	13
Vermont	25	11	35	21	10	32	4	1	3
Connecticut	22	13	29	12	8	24	10	5	5
Montana	22	7	27	15	7	12	7	0	15
South Dakota	19	7	20	16	6	16	3	1	4
Delaware	15	21	16	11	20	12	4	1	4
Maine	15	3	15	14	3	14	1	0	1
Arizona	14	5	14	6	4	5	8	1	9
Utah	14	7	25	9	7	15	5	0	10
Idaho	11	4	10	6	4	5	5	0	5
New Hampshire	11	5	16	6	5	8	5	0	8
New Mexico	9	3	16	8	3	13	1	0	3
Rhode Island	3	1	2	1	0	2	2	1	0
District of Columbia	2	2	1	0	0	0	2	2	1
Nevada	1	0	1	0	0	0	1	0	1
Wyoming	1	0	1	1	0	1	0	0	0
Total	5,808	2,465	6,907	2,897	1,570	3,306	2,907	895	3.597

[1] Total includes four accidents unclassified as to rural or urban locality.

total accidental deaths for each city and the deaths resulting from accidents which happened within the city. For the 52 weeks ended November 5, 1927, out of 5,674 deaths reported from 61 of the larger cities, 751 were the result of accidents occurring elsewhere, though not necessarily in rural districts.

Offsetting in some degree this possible 13 per cent error in the statistics for urban fatalities is the fact that in its mortality statistics the Bureau of the Census treats all localities of less than 10,000 population as rural, whereas in its population studies, and in this discussion, the line is drawn at 2,500. Cities of 10,000 and over in the United States include but 42.3 per cent of the entire population, while cities and villages of between 2,500 and 10,000 include 9 per cent. If fatality figures were available separately for the smaller incorporated localities the urban total would be considerably increased.

It therefore appears justifiable to estimate that of all street and highway fatalities, approximately 40 per cent,

A Typical Rural Crossing

or 10,000,[5] in 1926 occurred in rural areas. As shown in Table 1, some 1,570 grade-crossing fatalities occurred in rural regions. On this basis, rural grade crossings are responsible for 16 per cent of all rural highway fatalities.

Two further considerations support the belief that this estimate of 16 per cent is conservative:

(1) As previously stated, the actual number of deaths from grade-crossing accidents includes approximately 8 per cent additional subsequent fatalities.

(2) The grade-crossing accident statistics quoted are only those for the steam railroads of the country. During 1926 there were also 237 persons killed at crossings by the electric railroads which report to the Interstate Commerce Commission. While it is probable that the proportion of urban accidents on these roads is higher than for the steam roads, a considerable number of these fatalities should properly be included in the rural grade-crossing total.

TYPES OF GRADE-CROSSING ACCIDENTS

Of the accidents analyzed in this study, by far the greater number involve passenger automobiles, as might be expected in view of the large predominance of such vehicles. Table 2 shows the number of accidents according to type, together with the number of personal casualties for each type:

[5] Based on estimate of National Safety Council of 25,000 in 1926.

Table 2.—*Grade-crossing accidents by type, and personal casualties, 1926*

Type of accident	Total[1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
Accident involving—									
Passenger automobile	4,035	1,742	5,290	2,122	1,206	2,621	1,910	536	2,666
Automobile truck	880	284	916	468	189	457	411	95	458
Pedestrian	535	301	251	157	104	59	378	197	192
Animal-drawn vehicle	152	48	124	86	34	61	66	14	63
Trolley car	35	1	149	4	0	20	31	1	129
Automobile bus	30	19	89	17	19	53	13	0	36
Motorcycle	17	10	12	6	3	4	11	7	8
Bicycle	10	8	2	1	1	0	9	7	2
Other vehicle	12	3	14	6	2	6	6	1	8
Miscellaneous	102	49	60	30	12	25	72	37	35
Total	5,808	2,465	6,907	2,897	1,570	3,306	2,907	895	3,597

[1] Total includes four accidents unclassified as to rural or urban locality.

The differing significance of rural and urban accidents becomes still more apparent when the accidents are thus classified by type, and the inadequacy of mere numbers of accidents as a measure of grade crossing danger is plain. Deaths for each important type of accident in rural localities are practically double those for urban localities, with the exception of those involving automobile buses, pedestrians and those classed as miscellaneous. In the first-named group all the fatalities occurred in rural accidents, while for the last two types urban accidents predominate. The number of nonfatal injuries is approximately the same for rural and urban accidents in each class except trolley-car and pedestrian accidents. The lower fatality rate in vehicular accidents in urban areas may be attributed, among other things, to the slower speed of both trains and highway vehicles.

The total number of persons killed and injured in practically every group exceeds the number of accidents in that group for the reason that many of the accidents result in plural casualties. Even among the pedestrian accidents there were frequent cases in which two or more persons went upon the track at the same time and were struck by the same train, the several casualties being included in a single accident report.

GRADE CROSSINGS PROTECTED BY VARIOUS DEVICES

A casual study of grade-crossing accidents makes it evident that no sort of crossing protection can guarantee safety to certain sorts of people, nor even, under particular combinations of circumstances, to careful users of the highways. Many grade crossings have been eliminated in recent years from the more important highways either by separation of grade or by relocation of one or both of the rights of way. This remedy is too expensive to be applied everywhere, and it is necessary to resort to various degrees of protection.

The most positive form consists of gates, operated by a watchman on the crossing or in a near-by tower, these gates closing the highway on both sides of the crossing when a train is about to pass. When the gates are down the railroad right of way is fenced off from the public, and highway travelers injured in crossing accidents at such times are classed by the railroads and by the Interstate Commerce Commission as trespassers. The gates may be operated at all times, or only during certain hours when it is believed that the volume of traffic requires them.

Next in order is the crossing flagman, who stands on the crossing with a sign or a lantern and stops traffic during train movements. He, like the gateman, may be on duty all or only a part of the 24 hours.

Audible and visual signals are those which, on the approach of a train, sound a bell or other audible signal and further attract attention by a flashing or swinging light or moving sign. They are commonly operated automatically by train movement, like railroad block signals, though, occasionally, manual operation is depended upon.

Crossing bells are also used without a supplementary visual signal (i. e., no lights or moving signal operated by train movement), while visual signals are similarly found without audible accompaniment.

Finally, there are fixed signs, which only call attention to the existence of the crossing, and give no special notice of the approach of trains. Crossings marked by fixed signs only are classed by the Interstate Commerce Commission as "unprotected," and have been so treated in the present study. The fixed sign may be the familiar cross arm or its equivalent, at the side of the road, or it may be some special device such as an overhead sign, a sign placed on an island in the middle of the road, an approach sign placed along the road some distance from the crossing, or a sign painted on the highway surface.

A Village Crossing Protected By Audible (Bell) Signal and Standard Sign

MAJORITY OF ACCIDENTS OCCUR AT UNPROTECTED CROSSINGS

In this study the analysis of type of protection is carried farther than in that of the Interstate Commerce Commission, since the kind of protection recorded for each crossing is the highest type normally to be found at that crossing, regardless of its temporary discontinuance for whatever cause. If, for example, an accident occurred at a certain crossing at 11.30 p. m., after the gate operator had gone off duty, that crossing is here tabulated as protected by gates, with the added notation that the gate operator was off duty at the time. Similar treatment is given where gates were reported as out of order, where a flagman was negligent though supposed to be on duty, or where an automatic signal failed to operate. All accidents occurring under such circumstances appear in the reports published by the Interstate Commerce Commission as having taken place at unprotected crossings. On the other hand, it frequently happens that under the rules of some railroads, irregular switching movements are protected by members of the switching crews at crossings otherwise unprotected at the time. In the tabulation here made, and in the reports of the Interstate Commerce Commission, such crossings are reported as protected by watchmen, even though the regular watchman may be off duty at the time or there may be normally some other type, or no type of protection.

Table 3 shows the frequency of accidents occurring under each type of protection for both rural and urban localities. The great majority of accidents take place at unprotected crossings and it is probable that most of those under the heading "Not stated" are also in this category.

A Crossing Watchman on the Job

Table 3.—*Type of protection at grade crossings where accidents occurred in 1926*

Type of protection	Total[1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
Gates	412	162	457	60	31	85	352	131	372
Watchman	735	236	914	155	69	183	580	167	731
Audible and visual signals	220	147	260	115	84	137	105	63	123
Audible signals	366	197	414	206	138	203	160	59	211
Visual signals	277	123	287	139	82	136	138	41	151
Unprotected	2,440	1,101	2,919	1,447	810	1,652	991	291	1,265
Not stated	1,358	499	1,656	775	356	910	581	143	744
Total	5,808	2,465	6,907	2,897	1,570	3,306	2,907	895	3,597

[1] Total includes four accidents not classified as to rural or urban locality.

Most of the higher types of protection, namely, the gates and watchmen, are in urban localities, while unprotected crossings greatly predominate in the rural accidents. According to figures supplied by the Interstate Commerce Commission, the 235,158 railroad grade crossings on Class I steam railroads[6] in the United States are protected as shown in Table 4.

NUMBER OF ACCIDENTS NOT A MEASURE OF EFFICIENCY OF PROTECTION

A comparison of Tables 3 and 4 reveals that while less than 3 per cent of the crossings are protected by gates for all or part of the day, 7 per cent of the accidents and almost the same proportion of the fatalities occurred at such crossings. Slightly more than 3 per cent of the crossings are protected by watchmen, but nearly 13 per cent of the accidents and nearly 10 per cent of the fatalities are found at these crossings. This disproportionate number of accidents and fatalities at crossings having the higher types of protection is not to be taken as an indication of the ineffectiveness

[6] These totals would be little changed by the inclusion of grade crossings on rail roads other than Class I carriers.

TABLE 4.—*Kind of protection at highway grade crossings on Class I steam railroads in the United States, 1926*

Kind of protection	Number at beginning of year	Number added during year	Number eliminated during year [1]	Number at end of year
Gates, with or without other protection, operated 24 hours per day	3,400	134	187	3,347
Gates, with or without other protection, operated less than 24 hours per day	2,986	69	232	2,823
Watchmen, alone or with protection other than gates, on duty 24 hours per day	1,263	130	90	1,303
Watchmen, alone or with protection other than gates, on duty less than 24 hours per day	6,672	198	408	6,462
Both audible and visual signals, without other protection	5,619	959	119	6,459
Audible signals only	5,732	80	485	5,327
Visual signals only	1,613	685	92	2,206
Special fixed signs or barriers, with or without standard fixed signs	26,247	3,634	515	29,366
Standard fixed signs only	176,101	3,358	6,205	173,254
Otherwise unprotected	4,068	949	406	4,611
Protected	27,285	2,255	1,613	27,927
Unprotected	206,416	7,941	7,126	207,231
Total	233,701	10,196	[1] 8,739	235,158

[1] Total includes 195 crossings eliminated by separation of grades.

of such protection. The hazard at any given crossing may be said to be measured roughly by the product of the total highway traffic by the total train movement, although numerous other variables such as topography, highway surface, and speed also play a part. The value of any safeguard must be judged by the number of accidents which are prevented rather than by the number which happen in spite of it. Data of a sufficiently general nature for use in drawing statistical conclusions as to the relative merits of types of crossing protection are as yet not available.

Of the 412 accidents and 162 fatalities which occurred at crossings protected by gates, 58 accidents, with 22 fatalities, occurred during hours when the gate operator was off duty. One hundred and six accidents, with 31 fatalities, occurred when the operator was on duty but failed for one reason or another to have the gates lowered at the proper time, while 220 accidents, with 98 fatalities, occurred in spite of properly lowered gates. These figures are shown in detail in Table 5.

TABLE 5.—*Operation of crossing gates at crossings where accidents occurred, 1926*

Operation of gates	Number of accidents	Persons killed	Persons injured
Gates functioning properly	220	98	169
Gateman off duty at hour of accident	58	22	86
Gateman on duty but failed to have gates lowered	95	29	144
Gates out of order	11	2	17
Insufficient information and miscellaneous	28	11	41
Total	412	162	457

Accidents occuring despite lowered crossing gates were due, with rare exceptions, to vehicles crashing into or through the gates, or pedestrians passing around or under them. Table 6 shows this group in detail.

It will be noted that over half the accidents and more than three-fourths of the fatalities involved pedestrians. Four accidents, with two fatalities, were the result of pedestrians trying to climb between or over cars. In view of the common assertions as to the frequency with which crossing gates are wrecked by motorists, it is of interest to discover that, according to these records, few reportable accidents result. Either the usual

TABLE 6.—*Types of accidents occurring at crossings protected by lowered gates, 1926*

Type of accident	Number of accidents	Persons killed	Persons injured
Collision with passenger automobile	67	15	92
Collision with automobile truck	7	3	6
Pedestrian accident	137	76	65
Miscellaneous	9	4	6
Total	220	98	169

statements are exaggerated or the resulting casualties are of too minor a nature to come under the reporting rules. Only 74 accidents and 18 fatalities are attributed to motor vehicles at crossings protected by lowered gates.

At crossings protected by watchmen there were 735 accidents and 236 fatalities, of which 130 accidents with 50 deaths occurred during hours when the watchman was off duty. Fifty-four accidents with 32 fatalities were attributable to negligence on the part of the watchman, including 5 cases in which the watchman himself was the victim of a train while on duty. In 504 accidents, taking a toll of 140 lives, the watchman was reported as properly at his post of duty on the highway. Apparently there is sometimes confusion as to the signals given by watchmen to highway travelers, as in a number of instances cars were driven on to the crossing under a mistaken impression that a proceed signal was given. This is especially apt to happen when the watchman is a member of a train crew and is giving signals to his engineman. On the other hand, the watchman is more often completely ignored. Instances were reported in which the watchman was struck by an automobile, or had the lantern knocked out of his hand. One watchman threw his lantern at an approaching car in a last futile effort to bring it to a safe stop.

INTERMITTENT CROSSING PROTECTION GIVES FALSE SENSE OF SECURITY

It should be stated that the absence of the gate operator or watchman does not in every case leave the crossing unprotected. Bells or visual signals are frequently in operation during such hours. Where a gateman or watchman is on duty only a portion of the day, it is customary to post a sign at the crossing indicating the hours during which he is not present. These signs are not always sufficiently conspicuous or legible, and even at best, the person who is familiar with a crossing does not stop to read them or to consult his watch each time he passes. Numerous accidents were noted which occurred within a few minutes after the gateman or watchman went off duty, or just before he arrived on duty. One instance was reported from Arizona in which the motor-vehicle driver was a Chinaman and unable to read the sign which stated that the crossing was unprotected at that hour.

Despite various safeguards, it appears that intermittent protection introduces certain dangers. In the report of the committee on grade-crossing design, protection, and elimination, of the American Railway Engineering Association, December, 1926, this statement is made:

> Where gates are in service for less than 24 hours and not in service when there is traffic on the railway, the protection is not satisfactory in that it conveys a false sense of security to those using the crossing and may result in serious injury.

The automatic signals of the audible or visual type appear to be highly dependable in their operation, and there seems to be no reason why they should not be as reliable as the block signals which control train operation. Only 12 cases were found in which they were reported as being out of order. A most serious criticism of such signals, however, is that they will continue to operate as long as there is a train inside the circuit. Where switching is being done in the vicinity it is not uncommon for the bell or other signal to operate continuously for long periods, despite the fact that no train moves over the crossing. At such crossings the stranger is perplexed and the local citizen soon begins to ignore the warnings.

SPEED OF TRAINS

The higher fatality rate in rural accidents appears to be correlated with the higher speed of trains in rural areas. The higher average speed and relatively greater damage done in rural accidents is clearly shown in Table 7.

TABLE 7.—*Speed of train, number of accidents, and casualties at grade crossings, 1926*

Speed of train (miles per hour)	Total [1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
0 (standing)	195	18	334	99	12	159	95	6	174
1 to 4	509	59	645	128	9	178	381	50	467
5 to 9	981	131	1,425	245	36	380	736	95	1,045
10 to 19	1,455	378	1,858	613	166	789	841	212	1,068
20 to 29	1,014	462	1,206	606	284	733	407	178	472
30 to 39	712	550	647	521	391	488	190	159	158
40 to 49	479	454	387	360	336	309	119	118	78
50 to 59	266	286	194	223	241	167	43	45	27
60 and over	84	101	65	65	87	55	19	14	10
Not reported	113	26	146	37	8	48	76	18	98
Total	5,808	2,465	6,907	2,897	1,570	3,306	2,907	895	3,597

[1] Total includes four accidents not classified as to rural or urban locality.

The 195 accidents occurring when trains were standing still are accounted for principally by collisions of motor vehicles with stationary trains or cars. There were six cases of persons climbing between or over standing cars, resulting in no fatalities but in injuries usually caused by unexpected motion of the cars when the train was coupled on to or started. Perhaps these should not be classed among standing-train accidents. One automobile bus and three trolley cars collided with standing trains, all in urban territory, with no fatalities but with 25 personal injuries. Collisions involving passenger automobiles alone and the casualties for each speed are shown in Table 8.

Chance of survival shows a steady decrease as the speed of the train increases above 10 miles an hour. The slightly higher mortality rate for the very slowest train movement is probably explained by the high proportion of automobiles running into trains in the low-speed groups. It is usually the reckless and high-speed driver who suffers from this type of accident, and what the train lacks in momentum, he supplies.

Pedestrian accidents usually occur near stations or in yards where switching is being done on multiple tracks. This is reflected in the speed of trains involved in such accidents. Excluding those accidents due to persons climbing between or over cars, the pedestrian accidents and speed of trains are shown in Table 9.

TABLE 8.—*Speed of train, accidents, and casualties for collisions involving passenger automobiles, 1926*

Speed of train (miles per hour)	Number of accidents	Persons killed		Persons injured	
		Total	Per accident	Total	Per accident
0 (standing)	172	17	0.10	284	1.65
1 to 4	334	29	.09	459	1.37
5 to 9	666	51	.08	1,070	1.61
10 to 19	985	234	.24	1,418	1.44
20 to 29	715	341	.48	942	1.32
30 to 39	510	422	.83	516	1.01
40 to 49	335	347	1.04	294	.88
50 to 59	188	219	1.16	146	.78
60 and over	58	70	1.21	54	.93
Not reported	72	12	.17	107	1.49
All speeds	4,035	1,742	.43	5,287	1.31

TABLE 9.—*Showing speed of train, accidents, and casualties involving pedestrians, 1926*

Speed of train (miles per hour)	Number of accidents	Persons killed	Persons injured
0 (standing)	[1] 1	0	1
1 to 4	56	16	42
5 to 9	117	49	73
10 to 19	150	80	72
20 to 29	69	46	24
30 to 39	41	38	5
40 to 49	41	39	4
50 to 59	19	17	5
60 and over	5	4	1
Not reported	13	7	6
All speeds	512	296	233

[1] 1 pedestrian injured himself by stumbling against a standing train.

A CROSSING WITH AN UNUSUALLY RESTRICTED VIEW, PROTECTED BY AUDIBLE AND VISUAL SIGNALS—BELL AND SWINGING DISK

GRADE-CROSSING ACCIDENTS VARY WITH SEASON OF YEAR

There is a marked seasonal variation in grade-crossing accidents as shown in Table 10 and Figure 1. Surveys made by the Bureau of Public Roads on the highways of several eastern States have shown August to be the month of maximum traffic. Nevertheless, rural grade-crossing accidents do not reach their peak until October, and urban accidents until November, with a marked peak in November for both combined. For fatalities the maximum is reached in October. The only reasonable explanation of this condition appears to be that people are slow in adjusting their walking and driving habits to meet the inclement winter weather. Slippery roads, side curtains or frosty windows, rainy windshields, early darkness, umbrellas—these and other factors doubtless play their part.

A relative increase in recent years in the number of grade-crossing casualties occurring during the late fall months is perhaps due to improved roads, the more general use of closed cars and the consequent increasing volume of winter traffic. The figures published by the

TABLE 10.—*Grade crossing accidents and personal casualties by months, 1926*

Month	Total[1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
January	444	178	511	208	98	248	236	80	263
February	436	163	519	195	105	216	241	58	303
March	435	170	517	219	118	230	216	52	287
April	409	152	473	208	101	208	200	51	264
May	432	186	532	205	113	240	227	73	292
June	436	204	502	229	131	264	206	73	237
July	414	222	527	225	135	306	189	87	221
August	441	187	516	236	128	247	204	59	268
September	463	214	557	257	146	314	206	68	243
October	624	287	736	318	185	363	305	102	372
November	666	255	813	312	154	370	354	101	443
December	608	247	704	285	156	300	323	91	404
Total	5,808	2,465	6,907	2,897	1,570	3,306	2,907	895	3,597

[1] Total includes four accidents not classified as to rural or urban locality.

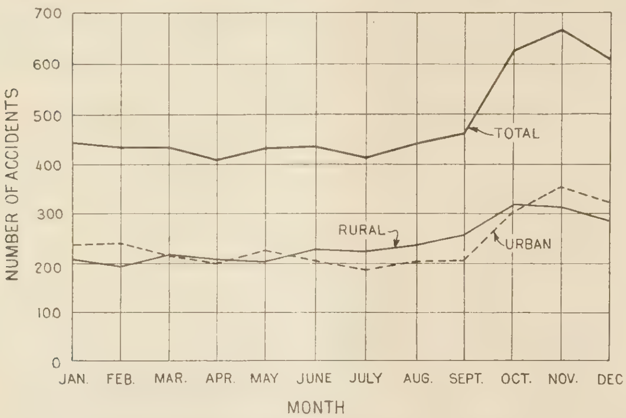


FIG. 1.—GRADE-CROSSING ACCIDENTS BY MONTHS IN 1926

Interstate Commerce Commission show August as the month of maximum fatalities in 1921, 1922, and 1923, November in 1924, and October in 1925 and 1926. For fatal and nonfatal injuries combined, the peak was reached during October in 1921 and 1922, during November in 1923, 1924, and 1926, and during December in 1925.[7]

GRADE-CROSSING ACCIDENTS BY DAYS OF THE WEEK

Most persons, if told that fewer grade-crossing accidents occur on Sunday than on any other day, would express considerable surprise. Such is the fact, however, as revealed by this study. In number of accidents Saturday is far ahead of any other day.[8] The statistics for grade-crossing fatalities, however, are considered more significant than those for number of accidents, and these tell a different story. In fatalities Sunday heads the list, with Saturday only a close second. The mortality per accident, therefore, reaches its peak on Sunday. This is the day when the whole family and some of the neighbors crowd into the car for a trip out into the country. The newspapers on Monday morning frequently report the deaths of entire families at grade crossings.

[7] See Accident Bulletin No. 94, Bureau of Statistics, Interstate Commerce Commission, p. 18.

[8] In New York State during 1926, according to the report of the State bureau of motor vehicles, the maximum number of all types of motor vehicle accidents and fatalities occurred on Saturday, with Sunday in second place.

The number of grade-crossing accidents and personal casualties by days of the week are shown in Table 11 and Figure 2.

TABLE 11.—*Grade-crossing accidents and personal casualties by days of the week, 1926*

Day	Total[1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
Sunday	713	454	1,029	379	314	506	334	140	523
Monday	825	325	919	409	205	452	415	120	466
Tuesday	842	309	948	408	181	437	433	128	510
Wednesday	833	295	964	415	194	471	418	101	493
Thursday	776	279	850	382	172	392	393	107	457
Friday	842	355	942	416	215	479	426	140	516
Saturday	976	448	1,200	487	289	568	488	159	632
Total[2]	5,807	2,465	6,852	2,896	1,570	3,305	2,907	895	3,597

[1] Total includes four accidents unclassified as to rural or urban locality.
[2] Does not include one rural accident for which exact date was not reported.

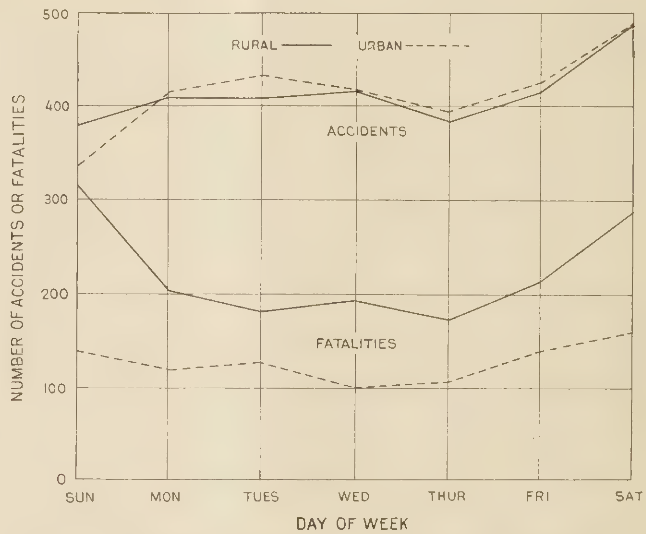


FIG. 2.—GRADE-CROSSING ACCIDENTS AND FATALITIES BY DAYS OF THE WEEK, 1926

The heavy toll on pleasure driving is shown even more emphatically in the figures for rural grade-crossing accidents involving passenger vehicles in the summer months, in Table 12 and Figure 3. During September and October there were twice as many fatalities on Sunday as on any other day.

TABLE 12.—*Rural grade-crossing accidents and fatalities for passenger automobiles by days of the week during the summer months, 1926*

Day	6 months, May to October, inclusive		2 months, September and October	
	Number of accidents	Persons killed	Number of accidents	Persons killed
Sunday	181	190	80	97
Monday	137	70	44	15
Tuesday	138	62	50	24
Wednesday	144	71	50	28
Thursday	137	69	57	31
Friday	146	73	60	26
Saturday	195	119	76	44
Total	1,078	654	417	265

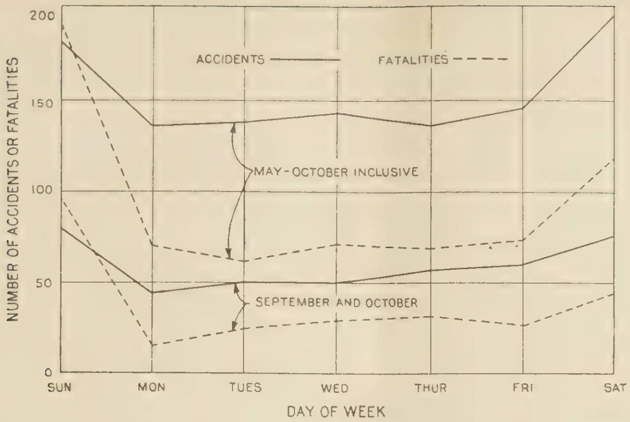


FIG. 3.—RURAL GRADE-CROSSING ACCIDENTS AND FATALITIES FOR PASSENGER AUTOMOBILES BY DAYS OF THE WEEK DURING THE SUMMER MONTHS, 1926

The severity of these Sunday accidents is apparent from the fact that the number of deaths exceeds the number of accidents. While these average more than one fatality per accident, passenger-automobile grade-crossing accidents throughout the year average less than 1 fatality for every two accidents.[9]

GRADE-CROSSING ACCIDENTS BY HOURS

Published accident statistics show that the dangerous hour in traffic comes in the late afternoon when a presumably fatigued populace is hastening home from work. Such figures, however, are predominantly from city reports or from the more urban States, rural accident reporting being as yet in a feeble but not unpromising infancy. It may, therefore, be significant that while grade-crossing accidents in general, and urban grade-crossing accidents in particular, reach a peak during the hour between 5 and 6 p. m., rural grade-crossing accidents reach their peak between 3 and 4 p. m. The figures are given in Table 13, and shown graphically in Figure 4.

TABLE 13.—*Grade-crossing accidents and personal casualties by hours, 1926*

Hour	Total [1]			Rural			Urban		
	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured	Number of accidents	Persons killed	Persons injured
12 to 1 a. m.	155	47	231	55	19	64	100	28	167
1 to 2 a. m.	112	25	174	44	16	65	68	9	109
2 to 3 a. m.	73	16	103	26	5	38	47	11	65
3 to 4 a. m.	61	12	84	21	4	27	40	8	57
4 to 5 a. m.	58	24	65	21	6	24	37	18	41
5 to 6 a m.	100	29	118	36	15	38	64	14	80
6 to 7 a. m.	211	70	254	81	37	92	130	33	162
7 to 8 a. m.	260	92	284	137	62	160	123	30	124
8 to 9 a. m.	271	119	287	152	81	167	119	38	120
9 to 10 a. m.	288	131	286	166	84	171	121	47	114
10 to 11 a. m.	329	139	335	192	102	181	137	37	154
11 to 12 a. m.	332	161	368	202	129	217	130	32	151
12 to 1 p. m.	318	152	367	177	106	192	141	46	175
1 to 2 p. m.	290	136	315	156	89	165	133	47	149
2 to 3 p. m.	326	179	341	195	138	202	131	41	139
3 to 4 p. m.	373	199	395	241	150	258	132	49	137
4 to 5 p. m.	349	187	385	192	134	202	157	53	183
5 to 6 p. m.	410	205	463	183	87	224	227	118	239
6 to 7 p. m.	341	141	396	161	90	191	180	51	205
7 to 8 p. m.	282	115	350	123	64	148	159	51	202
8 to 9 p. m.	231	70	354	89	35	121	142	35	233
9 to 10 p. m.	210	62	311	90	42	134	119	20	176
10 to 11 p. m.	223	74	316	72	42	94	150	32	221
11 to 12 p. m.	193	79	306	77	32	117	116	47	189
Hour not stated	12	1	19	8	1	14	4	0	5
Total	5,808	2,465	6,907	2,897	1,570	3,306	2,907	895	3,597

[1] Total includes four accidents not classified as to rural or urban locality.

[9] See Table 2.

The curves for hourly fatalities (not shown) closely correspond with those for numbers of accidents, though, of course, on a lower level.

Pedestrian accidents in urban localities show a very marked peak between 5 and 6 p. m., as will be seen in Figure 5 and Table 14. For passenger automobiles only in urban crossing accidents the peak is reached between 10 and 11 p. m., although the fatalities show a decided maximum between 5 and 6 p. m. (Fig. 6 and Table 14.)

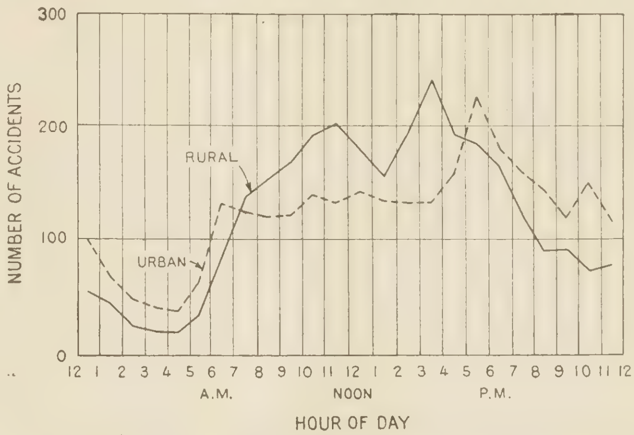


FIG. 4.—RURAL AND URBAN GRADE-CROSSING ACCIDENTS BY HOURS, 1926

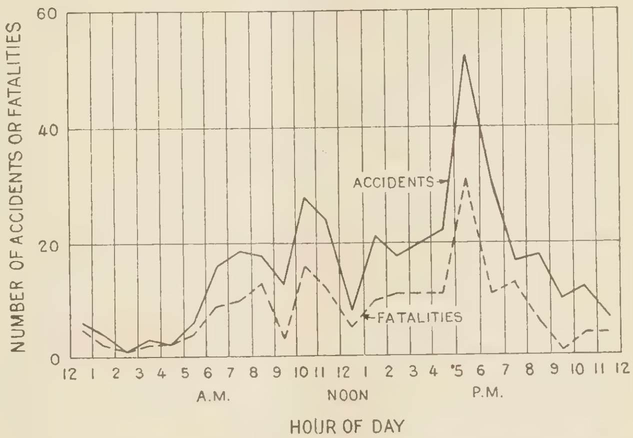


FIG. 5.—PEDESTRIAN ACCIDENTS AT URBAN CROSSINGS, BY HOURS, 1926

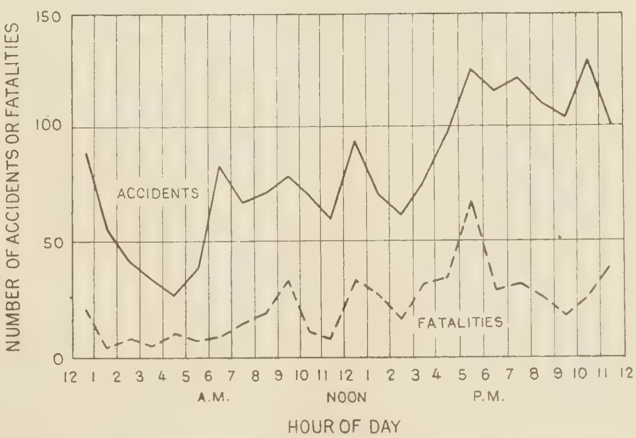


FIG. 6.—PASSENGER-AUTOMOBILE ACCIDENTS AT URBAN GRADE CROSSINGS, BY HOURS, 1926

Table 14.—*Pedestrian and passenger automobile accidents and fatalities at urban crossings, by hours, 1926*

Hours	Pedestrian accidents		Passenger auto accidents	
	Number of accidents	Persons killed	Number of accidents	Persons killed
12 to 1 a. m.	6	5	88	21
1 to 2 a. m.	4	2	54	5
2 to 3 a. m.	1	1	41	9
3 to 4 a. m.	3	2	33	6
4 to 5 a. m.	2	2	27	11
5 to 6 a. m.	6	4	38	8
6 to 7 a. m.	16	9	82	10
7 to 8 a. m.	19	10	66	16
8 to 9 a. m.	18	13	71	20
9 to 10 a. m.	13	3	78	33
10 to 11 a. m.	28	16	69	12
11 to 12 a. m.	24	12	59	8
12 to 1 p. m.	8	5	94	33
1 to 2 p. m.	21	10	70	27
2 to 3 p. m.	18	11	61	17
3 to 4 p. m.	20	11	75	31
4 to 5 p. m.	22	11	96	34
5 to 6 p. m.	52	31	126	66
6 to 7 p. m.	31	11	116	28
7 to 8 p. m.	17	13	122	32
8 to 9 p. m.	18	6	110	26
9 to 10 p. m.	10	1	103	18
10 to 11 p. m.	12	4	130	26
11 to 12 p. m.	7	4	100	39
Hour not stated	2	0	1	0
Total	378	197	1,910	536

VISIBILITY OF APPROACHING TRAINS DISCUSSED

A study was also made of the degree to which the approaching train was visible to the traveler on the highway. Accidents do happen under the most favorable conditions of visibility—almost incredible accidents for which the only reasonable explanation is sheer inattention. Nevertheless, it is equally certain that many of the mishaps reported would not have occurred had the vehicle operator been able to see the approaching train a moment sooner than he did. The average motorist slows down when he sees the railroad crossing sign ahead, but he is disinclined to stop until he sees the necessity for so doing. Stopping and starting a car causes a few moments of delay, and calls for a certain physical and nervous effort, especially when the highway leads upgrade to the crossing. Where the driver does not have a clear view up and down the track for some distance before he reaches the rails, he is apt to see the train too late for a safe stop in the distance left to him.

A recent decision of the United States Supreme Court [10] places the responsibility for caution at grade crossings squarely upon the motorist or other user of the highway. Under this decision the motorist is expected to take every care to learn whether the way is clear, even, when necessary, to the extent of getting out of his car for a look up and down the track. Even with the responsibility so definitely assigned, however, the improvement of visibility at grade crossings should be as much a part of a highway-safety program as any other measures designed to protect the careless driver and to expedite traffic generally.

The ideal grade crossing, as measured by the criterion of visibility of approaching trains, would be in the center of a wide open field. The traveler nearing it from either direction on the highway would have a clear view, beginning several hundred feet away and continuing until he reached the crossing, of any train within a distance of at least a thousand feet. Even a fast driver arriving as the limited express was due would have ample time and space in which to stop safely under such conditions. And yet accidents happened in 1926 at crossings answering practically to this description. As a rule, however, there are buildings or other obstructions to clear visibility located not far from the track. The illustration below shows an urban crossing where the view is definitely cut off up to a few yards from the rails. Approximately 35 trains pass this point daily, some of them fast expresses. Two women in an automobile were killed here during 1927.

There is no standard or generally accepted definition of what constitutes a reasonable and safe view at a crossing. This probably explains why the railroad reports were rarely specific in respect to the conditions of visibility. Where the view was mentioned at all (and there were only 3,224 such reports altogether) the information was usually limited to the statement that the view was "clear" or "good," or that it was obstructed in one way or another. Some of the reporting officers appeared to be using the term "unobstructed view" to mean that the traveler was able to see the crossing ahead, without regard to the visibility of any approaching train.

An Unprotected Urban Crossing. The Fixed Red Lanterns Give No Special Warning of Approaching Trains. This Was the Scene of a Recent Fatal Accident

Sometimes the view was described as "clear," with a following statement indicating that obstructions were located perhaps as near as 50 feet from the track. The difficulty of bringing such reports to a common basis is apparent. Some of the roads, however, carefully reported just how far from the crossing, measured along the highway, the train would be visible for a named distance as it approached on the rails. One of the smaller roads sent in with each of its reports a detailed blue print showing the exact relation of highway to railroad, including the grade of each, as well as the location of all buildings, trees, and other obstructions to a clear view. The exact distances at which the train might be seen from different points on the highway were also indicated.

Table 15 shows the result of the analysis of the conditions of visibility at crossings where accidents occurred involving motor vehicles. In relation to accidents involving slower vehicles or pedestrians, obstructions to view are of less importance or play no part. The category, "clear," in this table includes all those in-

[10] Baltimore and Ohio Railroad Co. v. Dora Goodman, October 31, 1927.

stances in which the view was reported as "clear" or "good," without further qualifications. It also includes those in which visibility was reported as clear to at least 100 feet from the rails. Those classed as having an obstructed view are all those at which some obstruction was reported within the 100-foot zone, as well as those for which the distance of the given obstruction was not specified. The 100-foot limit was chosen as the minimum which could be regarded as giving a safe view at modern highway speeds. In each case only the most important obstruction was tabulated.

Table 15.—*Visibility of approaching trains in motor-vehicle grade-crossing accidents, 1926*

Conditions of visibility	Number of accidents		
	Total [1]	Rural	Urban
Clear	1,818	1,054	763
Obstructed by building	395	182	213
Obstructed by vegetation or bank	160	128	31
Obstructed by train or railroad car	195	82	113
Obstruction not stated	307	154	153
Conditions not stated	2,087	1,013	1,072
Total	4,962	2,613	2,345

[1] Total includes four accidents not classified as to rural or urban locality.

For but 117 rural accidents and 65 urban accidents was it definitely stated that there was a clear view of the approaching train at all points within 100 feet of the crossing in the direction from which the vehicle approached. There were doubtless numerous other crossings where this condition also existed but was not specifically reported. Often, too, the obstruction to view caused by a building or railroad car, for example, was only partial, the vehicle operator having his view cut off for only a short while after having had a clear view at a safe distance previously.

Most of the instances of obstruction to view caused by trains or railroad cars are chargeable to standing freight cars on parallel tracks, though in occasional cases the victims were reported to have passed behind one moving train into the path of another. Often, especially at urban crossings, the cars are only one factor of several which combine to cut off the view, but the most serious because nearest to the track of the oncoming train. Almost every motorist can recall with uneasiness driving over some utterly blind crossing where a string of box cars was standing on a track immediately adjacent to that on which another train might be approaching. Even when the cars are some distance from the highway crossing they may constitute a serious obstruction to any adequate view.

TRAIN VERSUS AUTOMOBILE

In its published accident bulletins, the Interstate Commerce Commission presents an analysis showing separately those cases in which persons or vehicles were struck by trains at crossings and those in which they ran into the side of trains which were already on the crossing. These figures are frequently quoted, usually as an impressive illustration of the carelessness of highway users. While it is true that a train already occupying a crossing is not easily overlooked, is equally true that some trains arrive on the scene rather suddenly. At a mile a minute, a train travels 88 feet in a second. At even moderate speeds, the difference of a very small fraction of a second may determine whether an automobile is struck by the engine or whether it strikes the side of the engine at the pilot beam, the cylinder, or the drivers. The degree of responsibility for a collision can hardly be significantly affected by a distinction measured in such brief intervals of time. On the other hand, when a motorist strikes somewhere far back on a long train, or collides with a standing or slowly moving car or train, there is reason to suspect excessive speed, inattention, or other fault on the part of the driver.

Of the 4,962 accidents involving motor vehicles here tabulated, 1,110 were reported as cases in which the

The Safe Successor to a Dangerous Grade Crossing on an Important Highway

vehicle ran into the side of the train. Further analysis reveals the fact that at least 513 of these collisions occurred when the motor vehicle struck the engine, or the leading car of a train not preceded by an engine. In only 289 cases was it definitely reported that the train was struck somewhere behind the engine or leading car. While this crude analysis takes no account of the speed of the train, it will be apparent that too sweeping conclusions should not be drawn from the fact that highway vehicles—and pedestrians—[11] frequently collide with the sides of trains.

DATA AS TO VEHICLE OPERATORS INADEQUATE

While some of the reporting railroads were careful to give the age and other personal facts concerning vehicle operators and pedestrians involved in crossing accidents, the data are far from complete. Even with the best of intentions it is not always possible after a serious automobile accident to learn which of several occupants was driving at the time. In the analysis here made, victims were presumed to be adults unless there was definite evidence to the contrary or ground for reasonable doubt. Children are those reported as such or those whose ages were given as under 18 years.

Without comparable data as to the ratios of men, women, and children operating motor vehicles on the streets and highways, this table can not be used as the basis for any conclusions as to the relative safety of the different classes of operators. It may be suggested, however, that the 50 motor-vehicle accidents occurring to child operators out of a total of 4,962 seems disproportionately high. The larger proportion of child operators in the rural accidents, too, is noticeable, and

[11] In 25 cases during 1926.

TABLE 16.—*Operators of motor vehicles and pedestrians involved in grade-crossing accidents, 1926*

Class	Total [1]		Rural		Urban	
	Motor-vehicle operators	Pedestrians	Motor-vehicle operators	Pedestrians	Motor-vehicle operators	Pedestrians
Adult—male	2,914	330	1,543	90	1,368	240
Adult—female	251	128	134	38	117	90
Child	50	59	35	22	15	37
Not stated	1,747	18	901	7	845	11
Total	4,962	535	2,613	157	2,345	378

[1] Total includes four accidents not classified as to rural or urban locality.

is probably to be attributed to the absence of regulations, or the more liberal regulations regarding the licensing of operators in the less urbanized States, together with the laxity of enforcement of such regulations in the rural areas even where they do exist.

One hundred and three intoxicated motor-vehicle operators were reported and 25 intoxicated pedestrians. It is not surprising to discover that of the 103 drivers, 64 were listed as having run into the train and only 39 as having been struck by the train. The high proportion of the former may be due to the desire of the reporting officers to explain certain otherwise inexplicable accidents, whereas in more ordinary cases intoxication might be passed over without special mention.

Twenty-four motor-vehicle operators, seven drivers of animals, and forty-seven pedestrians were reported as partially or totally deaf. Of the pedestrians a very considerable proportion were quite aged and sometimes of failing mentality.

INFLUENCE OF WEATHER AND LIGHT DISCUSSED

The importance of climatic conditions and light as factors in the grade-crossing accident rate can not be determined without a knowledge of the relative prevalence of the different sorts of weather and the volume of highway traffic under each. That unfavorable weather does bring more than its share of accidents, however, seems to be indicated by the figures shown in Table 17.

TABLE 17.—*Weather and light conditions at time of grade-crossing accidents, 1926*

Weather and light	Number of accidents		
	Total [1]	Rural	Urban
Clear, daylight	3,056	1,696	1,360
Cloudy, daylight	498	281	215
Foggy, daylight	44	32	12
Raining, daylight	173	102	71
Snowing, daylight	69	36	33
Clear, dark	1,392	520	870
Cloudy, dark	283	114	169
Foggy, dark	70	36	34
Raining, dark	158	53	105
Snowing, dark	65	27	38
Total	[1] 5,808	2,897	2,907

[1] Total includes four accidents not classified as to rural or urban locality.

OTHER CIRCUMSTANCES

Various other details were noted and recorded in the course of this inquiry, some of which in the final analysis proved to be either insignificant, incomplete, or of doubtful accuracy. A study of the angle of intersection and the highway grade at the crossings, for example, was abandoned for lack of adequate information in a very large majority of the reports. In view of the nature of grade-crossing accidents, too, accurate statements as to the equipment and condition of vehicles and the mental processes of their operators are sometimes unobtainable.

Defective brakes were mentioned as contributing factors in only 51 motor-vehicle accidents. Inadequate automobile headlights were reported in only 14 instances.

Attempts to beat the train were occasionally reported, but usually only as the opinion of the reporting officer. The reasons for many of the nearly 250 cases in which the drivers apparently stalled on the crossings can never be known. In no case was a motor-vehicle operator said to have been asleep at his wheel.

A question of definition is raised by the fact that electric or gasoline rail cars or trains (not including section motor cars) operated by the steam railroads figured in 157 of the accidents. From one viewpoint it can be argued that these should be segregated from the other accidents on steam roads.

HIGHWAY RESEARCH BOARD HOLDS ITS SEVENTH ANNUAL MEETING

Reported by A. C. ROSE, Associate Highway Engineer, United States Bureau of Public Roads

REPORTS on the year's progress in highway research were presented to a group of investigators prominent in the field of research at the seventh annual meeting of the Highway Research Board of the National Research Council. The meeting was opened by the presiding officer, T. R. Agg, of Iowa State College, on December 1, at the National Academy of Sciences Building, Washington, D. C., and Vernon Kellogg, permanent secretary of the National Research Council, delivered a brief address of welcome to the visiting delegates from the several State highway departments, universities, and colleges, and the industries.

VALUE OF RESEARCH DISCUSSED

Frank B. Jewett, the retiring chairman of the division of engineering and industrial research, discussed the value of scientific investigation to industry from a retrospective and prospective point of view. Referring to the necessity for a rigid control of the variables as a fundamental of all scientific research, the speaker stated that there is a tendency to draw conclusions in regard to one factor without giving proper consideration to the other controlling factors. In order to reduce this error to a minimum, the work should be controlled so that only one factor in the problem is a variable. With two variables the interpretation of the data becomes very difficult and with three or more variables it is practically impossible to reach accurate conclusions.

Research workers, continued Mr. Jewett, are prone to try initial experiments on too large a scale before the feasibility of the project has been established in a small way. When the large-scale projects are carried out without the necessary preliminary test tube and other work in the laboratory, it is often difficult to determine the exact reason why satisfactory results are not obtained. For satisfactory progress in research the following routine procedure was advanced as necessary to the solution of each individual problem:

1. Make a decision as to the essentials of the problem.
2. Try out the experiment on a laboratory scale, with the work carefully controlled so as to eliminate all but a single factor in any given experiment.
3. If experimentally successful in the laboratory, then due consideration should be given to the transfer of the research to a larger scale.
4. The large-scale test usually indicates that some modifications are necessary before the apparatus may be used commercially.
5. The next step is to manufacture the tool-made apparatus so as to determine whether large-scale production may be economically feasible.

It is only after these five routine operations have been carried out that research workers are able to broadcast with assurance the successful conclusion of an experiment. This method has been in use in the telephone industry for the past 20 years.

Another lesson that research workers are learning, said Mr. Jewett, is that an infinitesimally small amount of a given chemical substance may produce stupendous changes in the character of the aggregate material. As an illustration of this fact, he cited the successful search some years ago for an alloy that would exhibit greater magnetic properties than any substance then in existence. This was found by research to be an alloy now known as "permalloy," consisting of iron and nickel, which showed magnetic characteristics 100 times greater than any other known material. It was later discovered that one-thousandth to one-hundredth of 1 per cent of a certain so-called "poisonous" material would reduce the magnetic properties to 10 per cent of what they were in the pure alloy.

It has also been found, in connection with studies of the ravages of teredos on wooden piles, that the life of concrete in sea water varies considerably. This variation does not seem to be due to the character of the concrete mixture but rather to the chemical composition of the aggregate. Such experiences as these, Mr. Jewett said, have led him to the conclusion that in making combinations of various materials, as is necessary in road-building operations, due consideration should be given to the chemical reactions of the aggregate.

In summing up his comments with regard to research in retrospect, Mr. Jewett emphasized the necessity of basing conclusions:

1. On good engineering practice with the experiments controlled so as to confine the data to one variable.
2. On the constituents of which engineering articles are constructed. Information should be gathered concerning different proportions of the individual components of the aggregate material.

With regard to prospective research, viewing the situation as a whole, Mr. Jewett pointed out that pure and applied science is producing a rapidly accumulating supply of knowledge. The universities are turning out more and more fundamental information and this is one of their two primary jobs. The other vital work of the higher institutions of learning—as important as delving for facts—is that of supplying highly trained individuals. The research branches of commercial organizations are applying the new store of data to the solution of practical problems. For this reason more rapid progress may be expected in the decades to come than has been possible in the past.

REPORT OF THE DIRECTOR

Charles M. Upham, director of the Highway Research Board, presented a report of activities during the past year. After giving a historical review of the National Research Council, beginning with its creation in 1916 by an Executive order of President Wilson, Mr. Upham stated that the Highway Research Board was organized as a branch of the national body in 1920, with officers and six research committees.

Examples where industry has profited by discoveries in pure science were presented and in these discoveries the chemist was an important factor. Analogy was made between these problems and the needed research on subgrade clay.

At present there are eight committees, which the director reported are making excellent progress, but more could be done if more ample funds were available. He also suggests as desirable the appointment of paid secretaries for each committee who could devote their entire time to the work. This suggestion was advanced, not to minimize the excellent work already accomplished by the chairmen of the existing committees, but as a means of obtaining greater results.

MOTOR-VEHICLE ACCIDENTS STUDIED

Austin B. Fletcher, chairman of the committee on causes and prevention of highway accidents, in his introductory remarks, preliminary to the reading of the detailed papers by the six members of his committee, stated that motor-vehicle accidents were increasing at the rate of 5 per cent a year, and for this reason it did not seem necessary to emphasize the need of highway-safety precautions. In order to make the investigations of the committee as comprehensive as possible, there were included in its membership not only highway engineers but also a psychologist, a physicist, and an automobile manufacturer.

S. J. Williams, director of the public-safety division of the National Safety Council, a member of the committee, estimated motor-vehicle fatalities in 1926 at 23,000, and stated that they are growing at the rate of 1,000 a year. In the cities two-thirds or more of the accidents involve pedestrians, while on the rural roads the corresponding proportion is one-half. The speaker stressed the need for more accurate information concerning the causes of accidents since, unfortunately, only about six States require systematic accident reports and statistics. To supply this deficiency, Mr. Williams advocated the adoption of a standard reporting system that would consist of: (1) An individual report card, and (2) a tabulation form for summarizing the cards monthly and annually. For small municipalities, tally sheets would be used, and for large States the punch-card system would be more economical.

In trying to arrive at the causes of accidents Mr. Williams believes it is a mistake to try primarily to fix the personal responsibility. He thinks it a much better plan to collect data as to the circumstances or facts in each case in order to eliminate the element of personal judgment. He concludes, however, that the most refined accident statistics are at best only the first step in solving the problem, the final solution of which depends upon the application of remedial measures, based upon a scientific study of the accident statistics.

M. G. Lloyd, chief of the safety section of the United States Bureau of Standards, delivered a paper on the standardization of motor-vehicle equipment as a means of reducing the accident risk. He believes that headlight devices should be regulated by the States and not by Federal or municipal authorities.

The general specifications now in use are those adopted by the Illuminating Engineering Society in 1920, and revised in 1922. These have also been adopted by the engineering standards committee. There are two basic ideas included in these specifications:

1. An attempt to avoid throwing excessive light into the eyes of the driver of an approaching automobile.
2. An attempt to throw the maximum amount of light upon the highway.

The defect in the present regulations is that while they require adequate equipment they do not include sufficiently drastic regulations concerning the maintenance of the apparatus in proper adjustment. This deficiency, said Doctor Lloyd, should be remedied. The depressible beams of light, now being developed commercially, involve legal complications because they are in conflict with the existing laws based upon fixed-beam lights. The adjustment of headlights involves two factors: (1) Proper aiming, and (2) proper focusing.

The speaker continued with a discussion of tail lights and rear signaling lamps and concluded with a reference to the new code which had been prepared for testing and regulating brakes. With the four-wheel brakes in use, Doctor Lloyd believes the requirements relative to stopping distance could be made more severe.

PSYCHOLOGY A FACTOR IN ACCIDENT PREVENTION

In delivering the third section of the accident report, Knight Dunlap, professor of experimental psychology at Johns Hopkins University, said that psychologists were interested in the sense of perception and the formation of habits. It is important in reducing accidents to develop safety habits which become instinctive. The time lost in thinking of the action required is often critical. Unnecessary and misplaced signs cause accidents not only at the point at which they are situated but also at other locations, because they breed a contempt of warning signs which leads to the development of unsafe driving habits.

In commenting upon the proper colors for luminous signals and fixed signs, Doctor Dunlap stated that the entire retina of the eye is not equally susceptible to color. For all practical purposes, the rapid discernment of color is limited to the central vision. Yellow and blue are excellent colors for this purpose, but the generally used red and green are tolerably satisfactory. In order to improve the colors now generally accepted, the green should be made as blue as possible, and then, if the cautionary yellow color could be abandoned, it would be better to shade the present red into an orange-red color.

With regard to refusing licenses to color-blind people, the speaker said it is impracticable to solve the problem by refusing to issue licenses. Color-blind persons with some preliminary training can pass a casual examination and only a thorough investigation by a highly trained physician or psychologist can detect vision defective in regard to color. Furthermore, normal persons, when under the strain of an examination, have their color sense sometimes temporarily disturbed.

John C. Long, secretary of the street-traffic committee of the National Automobile Chamber of Commerce, gave a report of a study limited to motor-truck accidents in Hartford, Conn., during the period of January 1 to 30, 1927. All accidents involving property damage of $10 or more were included. The conclusions show that drivers were at fault in 57 per cent of the cases. Difficulty was experienced in obtaining information because of the fear of unfavorable publicity on the part of the motor-truck owners. This difficulty was removed when it was explained that the aim was not to fix personal responsibility but to determine the causes of accidents and to reduce these by adequate instruction in a motor-truck drivers' school.

A. N. Johnson, dean of the University of Maryland, showed lantern slides giving the results of a method used for measuring the relative efficiency of traffic flow through street intersections under various conditions of control, such as traffic lights and police officers. The speaker believed that the flow of traffic through street intersections is a fundamental consideration both with respect to safety and to the speeding up of traffic.

W. G. Eliot, 3d, of the Bureau of Public Roads, concluded the accident reports with a statistical study of the number of grade-crossing accidents in the United States. The data indicated that grade crossings are responsible for 10 per cent of all motor-vehicle fatalities, but only 1 per cent of the total injuries. The number of rural and urban grade-crossing accidents are almost equal, but 65 per cent of the fatalities are rural. One explanation of this is the slower speed of trains in cities. Mr. Eliot estimates that only 40 per cent of traffic accidents of all kinds occur on rural highways, and that grade-crossing accidents represent 16 per cent of the total on rural roads.

PROGRESS MADE IN VARIOUS STUDIES RELATING TO VEHICLE OPERATION

Professor Agg, the chairman of the committee on economic theory of highway improvement, in summarizing the reports of individual members of the committee, stated that the paper on the measurement of tractive resistance, although not perhaps a final report, may be considered to represent the completion of the project. Roughly, the report dealt with four factors: (1) Rolling resistance, influenced by the condition and kind of tire; (2) impact, as affected by the distortion or character of the road surface; (3) air resistance; and (4) the coefficient of friction between the tire and the roadway surface.

Relative to the progress report on the cost of operation of automobiles, Professor Agg stated that the records show lower costs per mile as compared with figures obtained four or five years ago. This was believed to be caused by the greater distance traveled annually by the average driver and also to the improved character of motor vehicles.

It was announced that the report on the effect of roadway surface on tire wear was not ready for presentation but that it was expected to be completed in time to be made a part of the printed proceedings.

Professor Agg referred to studies his committee has made on the contribution of common-carrier busses to State-road funds. The information so far tabulated had been obtained from the records of the public service commissions of Michigan and Iowa. In Iowa the contribution of the motor bus per ton-mile is decidedly greater than that of privately-owned automobiles. In Michigan the reverse is true. The committee will attempt to determine the proper contribution.

L. E. Conrad of Kansas State Agricultural College delivered his report on wind resistance to motor vehicles. In summarizing available information on the subject, he pointed out that only three investigations are known to have been made in the United States, those of: (1) The United States Bureau of Standards; (2) the engineering experiment station of Kansas Agricultural College; and (3) the engineering experiment station of Iowa State College. Some work has also been done along similar lines in Germany.

Professor Conrad concludes that for a straight head wind the resistance for ordinary passenger cars may be considered as $0.0025V^2$ pounds per square foot of projected area. In this formula V is equal to the velocity of the automobile in miles per hour. He believes that an even exponent of V will serve as well as a fractional one for all practical purposes. Studies are to be continued on the effect of side and quartering wind.

H. B. Shaw, of North Carolina State College, gave a résumé of research on tractive resistance. An attempt is being made to formulate a practical theory based upon the results of outstanding studies. As an interesting side light he recalled that Sir Isaac Newton, years ago, developed theoretically a value for air resistance that has since been confirmed experimentally. The present experiments indicate that tire displacement resistance decreases with increased air pressure in the tire which results from the heating which takes place when a vehicle is in motion. Tire displacement has been found to increase at a greater rate than the increase of the weight on the tire.

MANY PHASES OF STRUCTURAL DESIGN OF ROADS STUDIED

A. T. Goldbeck, of the National Crushed Stone Association, chairman of the committee on structural design of roads, because of the limited time, summarized the reports of the members of his committee. These papers covered 19 subjects. With regard to the loads on highways the speaker stated that with the same total load the rear wheels of four-wheel trucks transmit twice as much load to the pavement as either pair of rear wheels of the six-wheel truck.

The report on subgrade studies outlined methods of soil identification from known proportions of the separates of sand, silt, and clay. The slaking value test was mentioned as indicating the susceptibility of soil to erosion. A simple percolation test was considered to be adequate to determine those soils which might be drained with tile. The report continued with a discussion of the behavior of subgrade soils when subjected to various moisture conditions. Granular subbases were mentioned as an efficacious method of compensating undesirable subgrades. The studies of landslides, and the sand-clay, gravel, and top soil surfaces of the Southern States were outlined.

A rough practical rule given for the construction of bituminous macadam surfaces was that the depth of the surface course in inches should be equal to the maximum size of stone in the surface course, and the number of gallons of bitumen per square yard of surface might be estimated at the same numerical figure. Thus for a 1½-inch surface course, the maximum size of stone would be 1½ inches, and there would be required 1½ gallons of bitumen per square yard.

With respect to the design of concrete pavements, the speaker stated that this is affected by the character and condition of the subgrade, and that the latter must be evaluated in order to make possible a more accurate cross section. The maximum wheel load is now recognized as causing the stress for which the pavement must be designed. There is a noticeable tendency on the part of highway engineers to reduce the size of concrete pavement slabs with longitudinal and transverse joints.

Mr. Goldbeck concluded his summary with comments concerning reinforcing and curing of concrete pavements, and methods of constructing brick pavements.

In a general discussion of the report of the committee on structural design of roads, C. H. Moorefield, State highway engineer of South Carolina, stressed the importance of considering the subgrade and emphasized the need of further knowledge of subgrade soils and their behavior as a prerequisite to adequate pavement design.

REPORT OF COMMITTEE ON CHARACTER AND USE OF ROAD MATERIALS

The report of the committee on character and use of road materials was presented by the chairman—H. S. Mattimore of the Pennsylvania State highway department. The paper discussed six factors in the control of the construction of concrete pavements: (1) Retesting of cement stored over three months; (2) fine aggregate; (3) coarse aggregate; (4) proportioning of materials; (5) curing the finished pavement; and (6) tests of the finished pavement.

The quantity of Portland cement used, said the speaker, should be carefully checked at the plant, on the job, and by counting the empty sacks. With regard to fine aggregates, uniformity, durability, and a uniform degree of hardness and toughness, are desirable. Stone screenings contain too much dust for satisfactory use as concrete aggregate. They also make it more difficult to finish the pavement. Seven theories of designing concrete mixtures were discussed.

In commenting on the recently developed methods for curing concrete pavements, using such materials as calcium chloride, sodium silicate, and bitumen as a seal coat, Mr. Mattimore stated that all of these, from an economic standpoint, are superior to the customary water-curing method. The new methods, however, have a number of disadvantages in their practical application. Reports indicate that calcium chloride may not be desirable for surface curing because of excessive scaling of the pavement surface. As an admixture the success of calcium chloride depends on atmospheric conditions. In the Northern States, under average conditions of temperature and humidity, it is possible to obtain good average concrete with a calcium chloride admixture. In the successful use of seal coats, the character of the subgrade, whether porous or impervious is an important factor.

Discussing tests of finished pavements, Mr. Mattimore stated that three methods are in general use: (1) A compression test on specimens made and partially cured in the field; (2) a compression test on cores drilled from the finished pavement; and (3) a transverse beam test on specimens made and cured in the field. Although the prevailing practice has been to keep concrete pavements closed for three weeks, the indications are that it is better practice to vary the time according to the results of tests. Up to the present time the procedure for making the field transverse test has never been standardized so as to produce comparable results by different observers.

P. J. Freeman of the Allegheny County department of public works, in Pennsylvania, discussed the practical aspects of Mr. Mattimore's report. He believed that not enough attention has been paid to the weight of the bagged cement at the mill. In some cases observations show a difference of 13 per cent between the high and low weight. Careful consideration should be given the proposed plan of proportioning the cement by weight. With regard to the bulking of sand, it is not a difficult matter to determine the percentage of moisture in the field. The weighing and inundation methods seemed to be the simplest yet devised.

Referring to the committee's recommendations relative to the sampling of coarse aggregate, he differentiated between the purposes of the sampling. If it is desired to determine the average quality of coarse aggregate, say on a barge, then the suggested method is satisfactory, but where it is desired to determine whether one end of a pile is badly segregated, then a method other than that proposed by the committee would have to be used.

With reference to sampling, proportioning and design of concrete mixtures, Mr. Freeman believes that more attention should be given to prevention of segregation of aggregate. To accomplish this, flat rather than conical piles should be used.

Referring to the proposed method of proportioning concrete by combining definite weights of the several constituent materials, the speaker believes that nothing more elaborate is being advocated than what has been in use for years in the construction of bituminous pavements.

Mr. Freeman emphasized the urgency of placing wet burlap on the concrete as soon as possible for curing. He fears that too much time is being spent on finishing. Stating also that excessive checking is caused by too early belting, he believes there is a happy medium of time and that more research is needed concerning this factor.

Calling attention to the present methods of testing the finished pavement, he stated his belief that it is illogical to close pavements for a standard time of three weeks in July and November, because of the widely different weather conditions. Some of the concrete pavements in Allegheny County, laid in the summer, have been opened successfully in three days, while other projects, built late in the fall, have not been opened until the following spring. For the traffic in Allegheny County Mr. Freeman believes that a modulus of rupture of 500 pounds per square inch, as determined by the beam test, gives an ample factor of safety.

D. A. Abrams, acting as presiding officer at the morning session on December 2, introduced A. J. Brosseau, who spoke on highway finance. The speaker analyzed the aggregate Federal expenditures and showed the relation thereto of the Federal highway disbursements. The Federal road expenditures were shown to be less than 8 per cent of the entire rural highway bill. Mr. Brosseau believes that our national highway finance structure is sound, necessary, and profitable.

In discussing Mr. Brosseau's paper, Professor Agg called attention to a new problem that is arising in highway finance. His studies indicate that, in some instances, municipalities are requesting that a portion of the gasoline tax be prorated to them for the construction and maintenance of the city streets. The city argument is that their motor-vehicle users are paying for a large part of the cost of rural roads, for which they are not receiving an equitable return. Professor Agg pointed out that if the gasoline taxes are returned to the cities the tendency will be to dissipate the funds which are now being used through a central State agency to secure maximum results on the rural roads. In discussing this point, J. G. McKay, of the Bureau of Public Roads, presented some conclusive arguments. He stated that traffic surveys of the bureau indicate that 80 to 90 per cent of the rural-road traffic and the bulk of the heavy-truck traffic originate within city limits. It is, therefore, logical that the city motor-vehicle owners should bear the bulk of the cost of the rural roads. He also added that there is no reason why the rural land owner should pay for any considerable portion of the through trunk roads because land values in the strictly rural areas are not increased to a large extent by this kind of road development.

REPORT OF COMMITTEE ON HIGHWAY TRAFFIC

G. E. Hamlin, of the Connecticut State Highway Commission, as chairman, introduced the individual reports of the committee on highway traffic. He stated that highways should be classified with respect to their weight-carrying capacity, and that there is an urgent need for establishing adequate rights of way in congested rural areas. Computations were presented showing that the maximum capacity of a single-lane road amounting to 1,969 motor vehicles per hour occurs at a speed of 22 miles. The maximum capacity of a two-lane road with mixed speeds is somewhat less than twice that of the single-lane road. He outlined the effect of overcrowding a two-lane road and showed the magnitude of the time losses at grade crossings and in small villages. The precautionary stop of a motor vehicle at a grade crossing was said to average seven and one-half to eight seconds. A comparison was made of the time consumed on by-pass or belt routes around centers of population, as contrasted with through roads. Forecasting the future development of traffic the speaker saw an increase in the use of six-wheel trucks.

J. G. McKay, of the Bureau of Public Roads, as a member of the committee, gave a description of the new traffic-flow recording device now being used by the bureau in the traffic studies in the Cleveland metropolitan area. An attempt is being made to determine the traffic capacity of various widths of roads as well as the preferential speed for various densities of traffic.

A. N. Johnson showed lantern slides of the airplane pictures taken during the traffic study on the Washington-Baltimore boulevard. The pictures were taken at an elevation of 3,600 feet and showed a strip of land 2,000 feet on each side of the road.

H. J. Kirk of the Ohio State Highway Department gave a description of a traffic speed recorder which had recently been manufactured by a firm in Dayton, Ohio. The variations in speed of a motor vehicle are shown by variation in the slope of a graph made upon paper mounted upon revolving cylinders. The device has been used on delivery wagons to determine if drivers are making the rounds on a regular schedule and may be useful in traffic flow studies.

Discussing the report of the committee on highway traffic, W. G. Sloan, State highway engineer of New Jersey, stated that traffic studies are vital to the solution of the highway transportation problem. Basing his remarks upon traffic surveys made in New Jersey, he estimates a 200 per cent increase in traffic in 1932, as compared with 1923. Traffic surveys and gasoline consumed indicate that the annual mileage traveled by automobiles is increasing more rapidly than the motor-vehicle registration. A graph prepared by the New Jersey department shows 1,600 vehicles as the maximum capacity of a single-traffic lane at 22 miles per hour, while the curve of the committee indicates 1,969 vehicles. The speaker emphasized the economic loss caused by the interruption to the flow of traffic at grade crossings in addition to the loss due to accidents and fatalities.

SELLING RESEARCH TO THE PUBLIC

Maurice Holland, director of the division of engineering and industrial research, gave an address on the subject of selling research to the public, or, as he expressed it, making the public research conscious. There are at present 1,000 research laboratories in the country and this is an increase of almost 100 per cent in six years. Stating that a man's success in business is in direct proportion to his ability to sell his services, he believes that until research can be translated into the language of the man on the street, we can not expect to obtain general attention. Lindbergh's flight was an example of the popularization of science, and to-day, as a result, 117 airplane factories in this country are running behind their production schedule.

The speaker said that the results of research must be made apparent and that proper showmanship is necessary to popularize the message. He referred to Pasteur as a master showman in reporting his studies to the French Academy, before whom he demonstrated the effects of living anthrax germs.

Speaking of the four mediums for reaching the public, he said that with the spoken word, in lecture form, only the attention of a few hundred people at best could be held. With articles written in trade journals 6,000 to 60,000 people could be reached. He mentioned the motion picture as an untried medium from a research standpoint, and added that one weekly news reel reaches 12,000,000. The speaker believes the radio the least expensive and most effective means of disseminating public information. One broadcasting station in New York City reaches four or five million people nightly.

CULVERT INVESTIGATION REPORTED

R. W. Crum, of Iowa State College, as chairman, presented the report of the committee on culvert investigations. Little additional field work had been done during the past year, but study had been made of previously collected data. Two general classes of culverts were considered: The rigid, such as concrete, vitrified tile, and cast iron; and the flexible, such as corrugated metal. It is difficult to rate the relative condition of rigid-type culverts since progressive deterioration is not indicated. With corrugated metal, however, the progressive deterioration could be determined. The committee, therefore, suggests a rating method for corrugated-iron culverts. In this rating, three stages of deterioration in the ordinary life of culverts are recognized: (1) Invisible, (2) visible, and (3) unsafe. The end point of the life of the culvert is used for comparison, and this is based upon the deterioration of the metal in the culvert.

W. H. Root, of the Iowa State Highway Commission, chairman of the committee on maintenance, presented a summary of the studies made of recent developments in road maintenance. C. P. Owens, of the Missouri State Highway Commission, led the general discussion of the paper which closed the morning session.

PROGRESS MADE IN LOW-COST ROAD INVESTIGATION

At the afternoon session C. N. Conner, chairman of the committee on low-cost road improvement, gave a detailed study of the construction practices determined by field inspections in 23 States. The work of the committee has been financed by the American Road Builders' Association and T. Coleman du Pont. The purpose of the study is to assist those engaged in the construction of this type of road. Studies of typical cross-sections in 26 States were shown with lantern slides. The low-cost roads studied have an average traffic of 600 and a maximum of 1,500 per day. The survey has been limited to untreated surfaces costing less than $10,000 a mile and surface treatments costing less than $6,000 a mile. The report presented was a digest of the full report which contains 60,000 words.

H. J. Kirk, of the Ohio State Highway Department, followed with a discussion of untreated traffic-bound types of low-cost roads.

C. A. Hogentogler, of the Bureau of Public Roads, presented a report on subgrades and soils, indicating their relation to the low-cost road problem. The subgrade soil observer attempts to determine where rigid or flexible road surfaces may be laid. The surest subgrade treatment was believed to consist of a granular subbase compacted under traffic.

N. S. Anderson, of the South Carolina State Highway Department, described the surface treatment of main highways with topsoil and selected earth. For bituminous surface treatment, the base should be sufficiently porous to permit the tar prime coat to penetrate one-fourth inch. Excessive mica in the material makes the base unstable.

W. R. Neel, of the Georgia State Highway Department, described untreated surfaces of sand-clay, chert, and gravel. He discussed the materials, methods of construction, cost of construction and maintenance, serviceability and salvage value. The average cost of sand-clay roads in Georgia is $1,650 a mile and the average annual maintenance costs $170 per mile. These roads are serviceable for 400 vehicles a day or less. For this amount of traffic the annual loss of surfacing material is one inch of depth. The sand-clay road is of great value as the first step in stage construction for stabilizing subgrades.

Chert construction costs up to $7,000 a mile and carries up to 1,000 vehicles a day. The average annual loss in depth is one-half inch.

On gravel roads, the traffic should not exceed 1,000 vehicles a day. The average annual maintenance cost is $200 a mile. The average annual loss in depth is three-fourths of an inch.

The Georgia State Highway Department has cooperated with Doctor Strahan, of the University of Georgia, in an extensive study of low-cost roads which has recently been completed.

J. T. Pauls, of the Bureau of Public Roads, presented a report on mixed-in-place surfaces, using local topsoil and gravel aggregates and tar or asphalt. The maintenence costs of untreated roads are excessive for a traffic greater than four to five hundred vehicles a day and resort is being had to various bituminous materials. Preliminary studies have been carried on in several States. To obtain good results with this type, correct maintenance is as necessary as first-class construction.

V. R. Burton, of Michigan, presented a paper on mixed-in-place surfaces of stone or gravel and fuel oil, prepared by C. L. McKesson, of the California State Highway Commission. This paper was in the nature of a discussion of Mr. Conner's paper. Mr. McKesson believes that untreated rock and gravel surfaces can not be justifiably termed low-cost roads when all the dependent costs are considered, such as maintenance, replacement, interest on first cost, excessive tire wear, motor-vehicle depreciation, and gasoline expenditures. Bituminous treatments according to recent California and Oregon practice are believed to so reduce these costs that the resulting surface might be classed as a low-cost road. Mr. McKesson had just returned from a trip abroad and it is his impression that European highway engineers agree that untreated gravel or stone roads are no longer economical.

B. E. Gray, of the West Virginia State Road Commission, illustrated his paper on the use of soft stone in the construction of puddle macadam with a number of lantern slides. The construction of the soft sandstone surfaces was said to range in cost between waterbound and penetration macadam. The annual maintenance costs, for traffic not exceeding 800 vehicles per day, does not exceed $200 to $300 per mile.

W. A. Van Duzer, of the Pennsylvania State Highway Department, discussed maintenance methods and equipment, referring to the maintenance organization of his State.

J. G. McKay, chief of the division of highway transportation and economics of the Bureau of Public Roads, presented a paper on traffic capacity and service of low-cost roads. He stated that the life costs of low, middle, and high-class surfaces must be determined before an intelligent selection of types may be made. Referring to the large mileages of low-type roads in the country, he stated that traffic studies of the bureau indicate that even in the densely populated State of Ohio, 70 per cent of the State highway system carries less than 600 vehicles a day. In both Pennsylvania and Vermont, 70 per cent of the primary road systems show an average daily traffic of 600 vehicles or less. With regard to the maximum wheel loads of trucks, the speaker believes that a 7,500-pound load per wheel will cover the maximum loading on 75 per cent of the State systems. Less than 1 per cent of the Pennsylvania State highway system carries wheel loads in excess of 9,000 pounds.

EFFECT OF SALTS IN MIXING WATER ON COMPRESSIVE STRENGTH OF MORTAR

An investigation has recently been completed at the University of Texas on the effect of various salts in the mixing water on the compressive strength of mortars.[1] In many parts of Texas, the only waters available for use in mixing concrete contain relatively large percentages of soluble salts, the so-called "gyp" and "alkali" waters being frequently encountered. It has generally been considered that the sulphates are the most injurious salts, and tests of such waters usually have consisted in a determination of the effect of the water on mortar strength in comparison with a water of acceptable quality, with occasional tests of total solids and percentage of sulphate ion. However, since it was not known definitely what percentage of sulphates might be expected to be injurious, a chemical analysis furnished little information of value.

To obtain definite quantitative results on the effect of some salts which might be present in mixing waters, a preliminary series of tests was started in 1922. These tests consisted of the determination of the compressive strength of 480 2-by-4-inch cylinders of neat cement mixed to normal consistency, using distilled water with the addition of various percentages of sodium chloride, sodium sulphate, sodium carbonate, magnesium chloride, and magnesium sulphate. These tests were made at ages of 28 days, 3 months, 1 year, and 3 years.

After these tests were started it was thought advisable to make similar tests on 1:3 (by weight) sand mortars, and to include some salts not used in the preliminary tests. In this series of mortars the following salts were used: Sodium chloride, sodium sulphate,

[1] University of Texas Bulletin No. 2730, Effect of Various Salts in the Mixing Water on Compressive Strength of Mortars, by F. E. Giesecke, H. R. Thomas, and G. A. Parkinson.

sodium carbonate, magnesium chloride, magnesium sulphate, calcium chloride, and ferrous sulphate. These tests were made on 2-by-4-inch cylinders, which were tested at the same ages as the neat cement.

In each case the amount of salts used was based on desired percentage of negative ion in the mixing water, the concentrations being 0, ½, 1, 2, and 4 per cent.

In the main group of 1:3 mortars consisting of 700 cylinders, the sand used was from the Colorado River at Austin. In another smaller group consisting of 500 cylinders, a natural limestone sand from Burnet County, Tex., having practically the same grading as the Colorado River sand, was used. In this latter group the calcium chloride and ferrous sulphate were omitted.

Materials.—(1) Cement: The cement used was a laboratory blend, made up of a mixture of two brands of Texas Portland cement. This blend met all of the requirements of the specifications and tests of Portland cement of the American Society for Testing Materials. (2) Sand: The Colorado River sand consists essentially of quartz and feldspar grains, with a small percentage of limestone grains. The natural limestone sand consists of clean grains of a good quality of limestone, having practically the same grading as the Colorado River sand. (3) Water: In all of the mixes distilled water was used, with the amounts of salts added as required for the several groups. The chemical formulas on which were based the quantities of salts required to give the desired percentages of the various negative ions are as follows:

Material	Formula	Molecular weight	
		Total salt	Negative ion
Sodium chloride	$NaCl$	58.5	35.5
Sodium sulphate	Na_2SO_4, $10H_2O$	322.2	96.1
Sodium carbonate	Na_2CO_3	106.0	60.0
Magnesium chloride	$MgCl_2$, $6H_2O$	203.3	71.0
Magnesium sulphate	$MgSO_4$, $7H_2O$	246.5	96.1
Calcium chloride	$CaCl_2$	111.1	71.0
Ferrous sulphate	$FeSO_4$, $7H_2O$	277.9	96.1

Fabrication of specimens.—For each group of cylinders having the same percentage of added salt, five mixes were made on five different days in order to minimize accidental variations. Each mix was sufficient to make four 2-by-4-inch cylinders, which were tested at the four ages. The materials for each mix were accurately weighed in the proportion of 1 part cement to 3 parts dry sand. The amount of water for use with each batch was measured and the calculated weight of salt thoroughly dissolved in it, when it was used in the mix. The consistency of the mortars was as nearly as possible the same as the standard consistency used in cement testing. The mixing and molding of the specimens were carried out as recommended by Committee C9-16T of the A. S. T. M., except for finish of ends.

Storage.—After molding, the cylinders were placed in the damp closet for approximately 24 hours, after which they were removed from the molds, marked for identification, and placed in running water in a storage tank where they were kept until time for testing.

Capping and testing.—A few hours before testing the cylinders were removed from water and capped with plaster of Paris. The specimens were tested in a 100,000-pound capacity, screw-type testing machine, a 2-inch spherical bearing being placed on top.

The results of the various series of tests are given in the report on the investigation and comparisons made on the basis of the ratio of the unit strength at a given age for a given percentage of added salt to the strength for no added salt. They show that all of the sodium salts used are injurious to Portland-cement mortars, the chloride, sulphate, and carbonate showing progressively greater reduction in strength for a given percentage of negative ion. The two magnesium salts used have only slight effect. Calcium chloride and ferrous sulphate are beneficial.

It is quite evident from the results that, so far as mixing water is concerned, the sulphate ion is not necessarily injurious to the strength of Portland-cement mortars. Of the three sulphates used, the sodium salt is injurious, the magnesium salt shows slight effect, and the ferrous sulphate increases the strength materially.

Compared to the percentages of salts used in these tests, the waters from springs, streams, and wells will, in general, contain relatively small percentages of dissolved salts. From a study of the chemical analysis of waters from many parts of the State, it is noted that in the great majority of cases the total solids are less than 5,000 parts per 1,000,000, or about one-half of 1 per cent. Even if all of this amount of salt were sodium carbonate (which was the most injurious of the salts tested) this would correspond to about 0.3 per cent of carbonate ion, which probably would not reduce the mortar strength more than about 5 per cent.

In presenting conclusions as to the results of the tests, attention is called to the fact that the results given apply only to salts present in the mixing water and that all brands of cement may not be affected in the same way. The following conclusions are presented as a general summary of the results obtained.

(1) Sodium salts (chloride, sulphate, and carbonate) are injurious to Portland-cement mortars.

(2) Magnesium chloride and sulphate have very little effect on mortar strength.

(3) In general, the strength ratios tend to increase with age—that is, for a salt that reduces the strength, the reduction is less for greater ages, and for salt that increases the strength the percentage increase at 3 years is usually greater than at 28 days.

(4) Sulphates are not necessarily injurious to mortar strength.

(5) Two per cent of sulphate ion in the form of ferrous sulphate—that is, about 6 per cent of the salt—increases the mortar strength approximately 20 per cent.

(6) Relatively few natural waters contain high enough percentages of total solids to make them unsafe for use in concrete.

While it is probable that ferrous sulphate will not be present in natural water, it was included in this series in order to determine the effect of an iron salt on the strength of Portland-cement mortar. For some years it has been noted by members of the laboratory staff that natural sands containing finely divided iron oxide seemed to show abnormally high strengths, and it has been the opinion that the iron present might have some chemical reaction with the cement, thus increasing the mortar strength. The results obtained with this salt seem to confirm the opinion. It would be interesting to know the effect of some other iron salts, and it is believed that it would be worth while to extend this part of the investigation to include the effect of various commercially available iron salts on the strength and other properties of Portland-cement mortars and concrete.

ELEMENTARY PROOF OF SHALE-LIKENESS OF CLAY PARTICLES

By DMITRY P. KRYNINE, Professor of Highway Engineering, Moscow Superior Technical School, and Moscow Institute of Transportation Engineering

AS IS well known, one of the essential differences between sand and clay lies in the dimensions and shape of particles of both soils. Sand particles have the shape of more or less large seed, and fine clay particles are shaped like shale or plates. This difference may not be established directly because of the small dimensions of clay particles which can not be isolated by any of our laboratory instruments for the purpose of studying them by the aid of a microscope, and in many cases the microscope is useless as our eye is unable to discern very small particles.

A proof of the shale-likeness of clay particles is given in Doctor Terzaghi's well-known book Erdbaumechanik.[1] In the experiment described by Doctor Terzaghi, water containing suspended clay particles 2 μ in size (1 $\mu = 0.001$ millimeter) remained between two

Demonstration of Rise of Capillary Water in Clay

watch-glasses located at a distance of 0.1 μ from each other, this distance being established by the color of Newton rings surrounding the water spots between the glasses. The phenomenon may only take place if clay particles are shalelike.

A practical highway engineer is not able to reproduce this experiment owing to lack of necessary laboratory equipment. An elementary proof of the shale-likeness of clay particles is given below and the suggested experiment can be easily repeated by anyone.

Everybody knows that if the lower end of a tube filled with dry soil is immersed in water the rise of water due to capillary action begins. If the tube is held vertically it is quite natural for the level of the water rising uniformly in the capillary pores of the soil to be normal to the axis of the tube. Logically it must be so. If the tube is inclined the case is different. In this case the experiment shows that the rise of capillary water does not take place in the same way in the clay as in the sand. With sand the level of the rising water is parallel to the surface of the water in the basin; i. e., it is horizontal. The pores of the sand seem to be disposed in disorder, the way of the water movement is relatively straight, and the capillary water rising to the surface passes approximately in the same direction through all the pores.

Now take a tube filled with dry clay powder; naturally the bottom end of the tube must be previously covered with cheesecloth. Before beginning the experiment clay particles and balls must be carefully broken into powder, and the powder strewn into the glass tube slowly and with great accuracy (for instance, from a constant height of 1 meter and through a rubber tube, as it was done in the laboratory mentioned below). This phenomenon is similar to that which took place in nature many centuries ago when the sedimentation of many contemporary clays was effected in the water. During the latter proceeding the clay particles probably disposed their broad side approximately horizontally on the lower layers, one layer being separated from another by a thin horizontal cleft. The tube is jarred until the soil reaches a certain height and no further settlement takes place. Then the glass tube is put into an inclined position and its lower end immersed in the water. The surface of contact between the soil and the water may be inclined or horizontal. In both cases the water rises as shown in the photograph; i. e., its surface is not parallel to the surface of the water in the basin but normal to the axis of the tube. This can only be explained by the shalelike shape of the clay particles. When the tube is placed in an inclined position the clefts between the layers also become inclined. The water rises through them and seeks a passage upward. This passage is found between the particles of the lower layer, then the water fills the following cleft, and so on.

The device at the right of the photograph has no special influence on the results of the experiment. It is merely an overturned cucurbit with water to maintain the water in the basin at a permanent level. A thin glass tube passes through its cork, the bottom end of the tube having a sloping cut. At the lowering of the level in the basin the air enters the cucurbit and releases a correspondent quantity of water to replace the loss.

The simple fact above described seems to be an undoubted proof of the shale-likeness of clay particles. It was observed in the highway laboratory of the Moscow Superior Technical School. (Prof. D. P. Krynine; Miss Mary V. Ivanova and Mr. T. A. Ovssiannikoff, both graduates in civil engineering, coworkers.)

[1] Published in Vienna, 1925.

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ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
Report of the Chief of the Bureau of Public Roads, 1927.

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Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 24, D- 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced-Concrete Slabs Under Concentrated Loading.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

*Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

DECEMBER 31, 1927

STATES	FISCAL YEARS 1917-1927			FISCAL YEAR 1928									BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS	STATES
	PROJECTS COMPLETED PRIOR TO JULY 1, 1927			PROJECTS COMPLETED SINCE JUNE 30, 1927			*PROJECTS UNDER CONSTRUCTION			PROJECTS APPROVED FOR CONSTRUCTION				
	TOTAL COST	FEDERAL AID	MILES	TOTAL COST	FEDERAL AID	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES		
Alabama	$ 20,061,371.68	$ 9,615,099.94	1,400.2	$ 457,143.22	$ 224,561.70	13.5	$ 8,668,566.66	$ 4,178,918.40	507.2	$ 511,688.94	$ 255,844.44	39.5	3,169,733.52	Alabama
Arizona	11,809,950.70	6,447,169.27	800.8	624,598.32	451,055.92	15.7	1,087,792.63	827,674.26	66.1	34,528.88	17,264.44	0.2	3,990,160.11	Arizona
Arkansas	22,337,014.63	9,525,192.75	1,560.6	52,245.29	26,122.64	0.2	4,637,217.27	2,063,459.92	231.3				2,550,709.69	Arkansas
California	35,128,269.04	16,967,026.82	1,306.3	2,928,130.87	1,329,916.26	77 9	7,808,471.71	3,534,759.02	150.5	230,101.00	134,662.03	9.4	5,076,302.87	California
Colorado	15,497,121.91	7,934,298.91	829.0	91,935.74	48,486.64	0.9	7,073,467.03	3,467,204.51	285.1	35,740.10	20,057.34	2.9	3,615,685.60	Colorado
Connecticut	6,397,392.29	2,444,000.54	137.3	1,352,857.40	367,626.33	17.7	5,712,748.89	1,597,373.38	69.6	484,816.75	82,320.00	5.5	789,258.75	Connecticut
Delaware	6,237,026.55	2,345,572.42	159.5	486,740.02	232,041.85	29.4	934,367 77	262,068.47	16.3				365,625.26	Delaware
Florida	7,476,856.31	3,627,912.60	245.1	2,871,749.92	1,387,492.49	38.8	6,639,551.70	2,849,989.14	170.2	777,845.42	269,730.00	18.0	1,750,591.77	Florida
Georgia	31,951,436.50	15,101,232.40	2,173.6	5,409,764.06	2,567,925.43	217.7	5,402,847.15	2,657,948.76	175.3				2,064,070.41	Georgia
Idaho	13,225,515.45	7,075,527.16	835.5	1,428,731.21	903,206.66	108.3	2,244,300.92	1,352,743.54	145.0	90,000.00	50,000.00	10.7	1,046,304.64	Idaho
Illinois	48,538,992.16	22,781,516.60	1,530.8	408,484.92	191,977.92	15.0	15,971,094.91	7,589,982.62	534.2	2,146,204.62	1,073,102.31	76.4	4,485,272.55	Illinois
Indiana	23,372,717.74	11,238,568.20	732.5	449,555.13	211,986.95	13.3	17,491,140.39	8,386,213.54	534.0	919,700.00	264,800.00	33.4	1,951,021.31	Indiana
Iowa	34,306,138.86	14,395,603.75	2,484.4	3,733,782.70	1,831,248.49	259.7	12,459,851.69	5,302,748.63	356.6	810,656.72	153,473.66	11.0	1,892,778.47	Iowa
Kansas	37,442,061.61	14,730,829.48	1,495.2	2,196,799.67	1,014,136.90	129.1	14,122,302.42	5,556,148.33	747.7	323,052.38	122,594.95	20.4	2,171,429.34	Kansas
Kentucky	23,216,600.53	9,510,694.75	874.9	977,715.26	458,941.60	51.2	9,808,976.42	4,625,251.11	420.9	70,743.47	35,371.73	5.4	1,421,525.81	Kentucky
Louisiana	15,877,552.20	7,093,892.21	1,178.7	1,187,081.99	552,031.69	44.9	3,879,450.37	1,761,995.28	140.0	1,664,341.16	832,170.56	53.6	1,064,908.26	Louisiana
Maine	10,564,800.06	4,858,452.67	357.6	1,088,204.92	443,485.16	40.5	2,197,577.44	745,846.35	55.3	87,912.01	43,956.00	5.6	1,735,312.82	Maine
Maryland	11,790,203.93	5,524,938.27	477.8	346,372.59	152,740.38	15.4	1,875,926.56	913,211.29	89.1				604,192.06	Maryland
Massachusetts	20,670,246.02	7,425,928 15	410.4	773,728.83	158,264.74	9.6	6,742,463.44	1,865,290.01	115.4	218,312.82	88,695.00	5.9	2,748,456.10	Massachusetts
Michigan	31,977,248.37	14,328,484.99	1,084.2	2,079,989.03	952,544.55	83.6	14,424,766.17	6,435,360.93	374.8	1,303,644.10	495,367.00	34.1	2,554,894.53	Michigan
Minnesota	45,099,648.47	19,046,145.67	3,643.5	5,722,267.64	1,976,398.90	237.8	3,185,223.92	609,100.00	210.7	391,800.98	6,000.00	13.6	2,187,471 43	Minnesota
Mississippi	18,331,230.75	9,004,294.62	1,314.1	1,736,175.48	861,108.12	93.4	6,071,864.19	2,936,907.80	319.9	292,417.68	146,208.83	29.9	1,797,106 63	Mississippi
Missouri	42,389,290.41	19,681,026.48	1,944.8	2,931,926.13	1,234,973.65	99.0	8,170,653.64	3,592,019.13	264.1	365,687.27	182,843.62	24.0	2,905,095.12	Missouri
Montana	12,854,995.72	7,287,288.69	1,151.6	378,421.33	288,968.05	50.5	3,833,147.52	2,633,163.05	302.3	1,240,701.11	689,437.11	132.5	5,630,103.10	Montana
Nebraska	16,157,040.25	7,739,386.39	2,246.6	1,643,659.00	1,750,774.35	347.7	12,447,725.18	6,140,663.68	1,221.9	541,653.02	268,479.27	50.5	1,906,050.31	Nebraska
Nevada	10,421,349.31	7,589,168.68	853.6	576,886.41	495,568.11	67.8	1,722,790.10	1,500,148.64	185.9	46,844.45	41,091.94	8.7	1,075,742 63	Nevada
New Hampshire	5,868,897.76	2,778,928.05	264.8	306,899.24	145,082.46	10.4	1,345,876.59	582,954.04	39.4	60 872.73	23,295.00	1.5	370,482.45	New Hampshire
New Jersey	22,228,240.08	7,495,364.48	316.3	3,695,432.42	976,965.00	65.1	4,075,841.72	852,364.17	55.6	236,240.80	77,337.35	5.5	935,122.00	New Jersey
New Mexico	13,336,250.94	7,937,598.06	1,505.2	640,889.03	430,188.26	52.8	3,294,953.42	2,519,773.46	214.8				2,460,950.22	New Mexico
New York	54,183,085.44	21,693,955.65	1,439.3	3,560,067.92	1,203,313.37	81.8	44,346,936.00	10,784,928.95	670.6	3,688,600.00	720,802.50	45.6	6,907,290.53	New York
North Carolina	35,295,849.21	14,518,903.16	1,460.1	1,568,316.60	729,783.35	63.3	3,267,375.11	1,563,015.52	92.0	185,355.00	90,500.00	7.3	2,244,269.97	North Carolina
North Dakota	15,881,558.55	7,746,293.68	2,715.6	2,658,673.73	1,531,977.04	317.0	4,667,745.57	2,300,831.14	718.4	530,495.95	238,146.14	112.6	1,319,802.00	North Dakota
Ohio	52,621,391.49	19,331,376.76	1,515.0	3,128,725.23	1,387,349.12	105.0	11,663,486.29	4,491,844.99	303.2	2,722,992.00	1,064,095.00	61.2	4,977,303.13	Ohio
Oklahoma	30,381,957.08	14,117,589.21	1,268.1	789,742.25	379,754.99	9.6	5,385,782.95	2,348,245.64	340.5	2,139,641.06	1,077,632.10	123.5	1,637,522.06	Oklahoma
Oregon	19,583,584.76	10,041,452.94	1,055.0	224,521.65	121,684.57	1.8	2,625,611.13	1,374,937.18	77.3	119,410.50	71,646.30	7.5	1,641,535.01	Oregon
Pennsylvania	77,726,174.22	26,317,620.32	1,534.3	3,196,065.72	957,970.87	69.6	19,066,646.79	5,768,610.23	361.5	2,040,621.03	606,016.34	40.0	4,358,084.24	Pennsylvania
Rhode Island	5,233,413.38	1,998,479.06	116.0	700,482.52	227,205.00	15.1	1,250,258.47	336,638.74	20.8	555,617.19	152,773.67	9.2	683,722.53	Rhode Island
South Carolina	17,002,039.93	7,526,988.80	1,568.4	2,024,769.53	963,609.27	56.7	8,345,687.34	2,219,652.91	240.4	978,618.81	26,000.00	17 9	1,179,794.02	South Carolina
South Dakota	19,262,063.24	9,507,525.54	2,502.9	295,102.62	158,099.84	56.2	4,964,866.65	2,625,742.50	772.7	374,232.18	143,290.49	55.1	1,176,176.63	South Dakota
Tennessee	24,283,035.03	11,551,457.55	868.7	1,931,012.79	872,400.80	40.3	9,109,483.84	3,785,390.33	240.7	1,182,909.13	516,274.89	54.0	1,781,845.43	Tennessee
Texas	78,190,246.37	31,566,960.45	5,466.4	7,174,057.07	3,256,590.84	267.7	12,214,998.68	5,440,251.66	374.0	5,207,690.76	2,075,125.67	181.1	7,267,350.38	Texas
Utah	9,154,377.33	5,767,079.95	628.9	854,916.56	628,347.38	80.5	2,735,358.04	2,035,223.37	169.9	224,936.28	34,628.72	4 0	1,048,498.58	Utah
Vermont	5,037,118.23	2,348,856.01	152.7	1,442,701.40	571,822.67	27.9	1,939,714.80	683,331.78	43.6				395,746.54	Vermont
Virginia	26,844,025.24	12,537,143.25	1,168.9	455,975.42	302,124.28	14.0	5,378,389.26	2,175,489.34	116.2	26,248.75	8,390.23	0.2	1,458,628.90	Virginia
Washington	18,184,505.97	8,246,551.95	711.1	847,151.85	415,736.32	5.3	3,093,196.86	1,400,600.00	71.8	1,557,271.50	543,000.00	66.5	1,814,645.73	Washington
West Virginia	10,424,847.32	4,573,748.01	419.4	1,754,151.83	698,546.52	46.5	6,613,323.55	2,758,168.42	233.7	129,443.32	64,721.66	6.7	844,758.39	West Virginia
Wisconsin	27,891,502.16	11,847,858.90	1,729.5	3,032,631.39	1,490,577.81	48.6	9,434,761.67	4,146,874.97	318.3	140,226.08	49,200.00	2.8	3,638,970.32	Wisconsin
Wyoming	12,650,712.15	7,139,267.05	1,315.9	1,183,201.35	757,873.29	44.1	2,438,769.37	1,554,451.69	243.3	61,005.56	39,165.56	19.8	949,432.41	Wyoming
Hawaii	343,664.15	97,440.00	6.5	160,636.91	70,440.00	4.7	1,624,080.08	491,922.64	25.0				1,171,600.36	Hawaii
TOTALS	1,154,740,601.48	510,007,691.24	60,957.6	85,561,072.11	38,291,028.53	3,662.6	353,497,430.27	145,627,433.46	13,433.1	34,750,821.51	12,895,511.85	1,413.2	110,803,334.92	TOTALS

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 126,480,829.63 Federal aid $ 53,473,669.30 Miles 4,916.2