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Proceedings of the 1960 Northwest Highway Engineering Conference

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(1) To stimulate and elevate engineering education by developing the research spirit in faculty and students.

(2) To serve the industries, utilities, professional engineers, public departments, and engineering teachers by making investigations of interest to them.

(3) To publish and distribute by bulletins, circulars, and technical articles in periodicals the results of such studies, surveys, tests, investigations, and research as will be of greatest benefit to the people of Oregon, and particularly to the state's industries, utilities, and professional engineers.

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CORVALLIS, OREGON

Proceedings of the
1960 NORTHWEST HIGHWAY ENGINEERING
CONFERENCE

Corvallis, Oregon
March 23-25, 1960

CIRCULAR NO. 27
DECEMBER 1960

Engineering Experiment Station
Oregon State College
Corvallis, Oregon

PREFACE

The 13th Annual Northwest Traffic Engineering Conference and the 1960 Annual Northwest Road Building Conference this year have been combined to give a broader concept of the field of highway engineering to persons interested in both phases. Future conferences will alternate as before between the States of Washington and Oregon. There will be a conference in Oregon every other year.

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Proceedings of the
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CONFERENCE

PROGRAM
WEDNESDAY, MARCH 23

Forenoon

G. W. HOLCOMB
Head, Civil Engineering Department
Oregon State College
Presiding

9:30 Opening Session.
WELCOME AND OBJECTIVES. M. Popovich, Dean of Administration, Oregon State College.

10:00 STABILIZATION OF BASES FOR COUNTY ROADS. Panel: John McInerny, Whitman County Road Engineer, Washington; A. S. Koch, Orange County Road Commissioner, Santa Ana, California; Vaughn Marker, Paving Engineer, The Asphalt Institute, Berkeley, California; Len Norlyng, Soils-Cement Engineer, Portland Cement Association, Paving Bureau, Chicago.

Afternoon

FORREST COOPER
Deputy State Highway Engineer, Oregon
Presiding

1:30 SOILS AND THEIR RELATION TO BASE DESIGN. G. L. Decker, Soils & Geology Engineer, Oregon State Highway Department.

2:15 PAVEMENT SMOOTHNESS. R. W. Beaty, Assistant Construction & Bituminous Engineer, Washington Department of Highways.

3:30 WHAT PAVEMENT CAN YOU AFFORD? V. L. Goodnight, City Engineer, Corvallis, Oregon.

4:15 BRUSH CONTROL. W. E. Green, Oregon Agricultural Chemicals, Tule Lake, Oregon.

THURSDAY, MARCH 24

Forenoon

ELLIS MATHES
Traffic and Planning Engineer
Idaho Department of Highways
Presiding

9:00 BRIDGE INSPECTION AND REPLACEMENT. Harold R. Sweet, Yakima County Engineer, Washington; Joseph Andiotti, Yakima County Bridge Engineer, Washington.

10:30 WORK BY CONTRACT AND PUBLIC FORCES. Panel: Donald Allen, Director of Public Works, Eugene, Oregon; Harold Davis, City Engineer, Salem, Oregon; H. O. Walberg, Highway Coordinator, Lane County, Oregon; Paul Rynning, Ex-County Engineer, Jackson County, Oregon.

Afternoon

REX G. STILL
Traffic Engineer
Washington Department of Highways
Presiding

1:30 THE PRESS VIEWS HIGHWAY TRANSPORTATION. Panel: Marshall Dana, Assistant to President, U. S. National Bank, Portland; Elmo Smith, Publisher, Albany Democrat-Herald; Donald J. Sterling, Jr, Oregon Journal, Portland.

3:30 WHY TRAFFIC ENGINEERING? J. Al Head, Assistant Traffic Engineer, Oregon State Highway Department.

4:15 HUMAN RELATIONS OF SUPERVISION. Roy Jorgensen, Engineering Counsel, National Highway Users Conference, Washington, D. C.

Evening

B. M. FRENCH
Regional Engineer
U. S. Bureau of Public Roads
Presiding

7:30 LOOKING AHEAD AS TO TRAFFIC OPERATIONS AND SAFETY. Burton W. Marsh, Director Traffic Engineering & Safety, American Automobile Assn, Washington, D. C.

FRIDAY, MARCH 25

Forenoon

WILLIAM A. BOWES
Commissioner of Public Works, Portland
Presiding

9:00 PLANNING AND THE HIGHWAY AT COUNTY AND CITY LEVEL. James Bell, Planning Consultant, Bureau of Municipal Research, Eugene, Oregon.

9:30 REVIEW OF DIMENSIONS AND PERFORMANCE CHARACTERISTICS. K. A. Stonex, Assistant Director, GM Proving Grounds, Milford, Michigan.

10:20 ROADSIDE DESIGN FOR SAFETY. K. A. Stonex.

11:05 SIGNING AND UNIFORMITY. Robert D. Conklin, Traffic Investigations Engineer, Oregon State Highway Department.

Afternoon

ROBERT DUNN
Assistant Planning Engineer
Washington Department of Highways
Presiding

1:30 WHAT'S NEW IN THE NORTHWEST. A series of 15-minute presentations.

MONTANA'S CHANGEABLE COPY SIGN. Maurice Richey, Traffic Engineer.

1:45 CANADA'S UNIFORM MANUAL - SIGN VARIATIONS. Robert Boyes, Assistant Director, Traffic Engineering, Vancouver, B.C.

2:00 PARKING METER THEFT WARNING DEVICE. D. Bergstrom, Assistant Traffic Engineer, Portland.

2:15 A NEW APPROACH TO MERCURY-VAPOR FLOOD LIGHTING. Fred Waker, Crouse Hinds Co, Portland.

2:30 ALUMINUM PRODUCTS - GUARDRAIL, DELINEATOR POSTS. T. M. Memory, Alcoa, Portland; and J.F. Stillwell, Reynolds Metals.

2:45 INFRA-RED SIGNAL DETECTOR. Harland Baxter, Eagle Signal Corp, Seattle.

3:00 POLE FRAME STRUCTURES FOR UTILITY BUILDINGS. P. D. Christerson, President, Western Structures, Inc, Portland.

3:15 WINDLOADINGS AND POLE DEVELOPMENT. G. W. Kolling, Union Metal Co, Portland.

3:30 USE OF DOUGLAS FIR PLYWOOD IN SIGNS. Harry W. Berry, Special Products Dept, Douglas Fir Plywood Assn, Tacoma, Washington.

3:45 TRAFFIC PAINTING, HEATING, AND APPLICATION. W. O. Widdows, Assistant Maintenance Engineer, Oregon State Highway Department.

WELCOME

M. Popovich

I am especially pleased, on behalf of Oregon State College, to welcome you to this first combined Traffic and Road Building Conference.

Information presented at the traffic conferences and road building conferences in past years has been valuable. Published proceedings have enjoyed international as well as national distinction. Requests from Germany, Israel, Rumania, and New Zealand have come to my attention, and I am sure there have been many others from equally distant points.

I should like to commend your Conference Coordinating Committee for the breadth of knowledge being introduced here—construction, planning, contracting, traffic control, use of signs—to mention just a few of the problems to be discussed. I note with special interest two features of your program that I believe are new: the panel, "The Press Views Highway Transportation," and the Friday afternoon series, "What's New in the Northwest."

Also, I want to commend conferees for taking the time to attend and to learn. Progress in science and technology is so rapid that the technical man must continue his education, or the scientific revolution we are in the midst of will leave him behind.

John Kenneth Galbraith, in a current issue of the Saturday Evening Post (Adventures of the Mind series) writes, "Those who guide our worries on large issues regularly ask us to ponder man's losing competition with the machine."

Certainly on the assembly line man is being replaced by electronically controlled automatic machinery. The IBM machines in state highway departments now perform calculations in minutes or hours that only a few years ago some of you here worked on for weeks. Triumphs of machine over man can be recounted almost endlessly.

There are two schools of thought on the man versus machine controversy. Many responsible persons believe we are in danger of being run by so-called "electronic brains." In the words of Dr. Galbraith, however, "This is the age of ascendant man, not triumphant machine. Our first concern must be with arrangements for conserving and developing personal talent. If our society succeeded in supplying itself with machines and failed to supply itself with

adequately trained manpower, there would be cause for concern."

We have always considered the primary factors in production to be materials, men, and money. A century or two ago the most important factor was materials, in the form of natural resources or land. Labor was plentiful and not highly specialized. With the industrial revolution, capital became of prime importance for the development of bigger and better machines. Men were still plentiful, and natural resources in this country were abundant.

In recent years capital has begun to take a back seat. Dr. Galbraith points out that raising money—floating stock issues or corporate borrowing—is a routine matter, usually a cut-and-dried procedure. The supplier of capital or the owner was a very important person, but now the important person is the professional manager. More important than ownership of capital now is ownership of brains and ability.

Industrial firms and government agencies send their most eloquent people to the colleges to hire promising young men. For several years our engineering school at Oregon State College literally has been besieged by interviewers seeking to talk to graduating students. Every year there are more interviewers visiting the campus than there are students to interview.

Currently, progress is more and more dependent upon technological advancement and improvements in the working force, including management. These things come from improvements in men—in personal development.

In your particular fields of activity, machines and capital outlay have certainly played an important part in improving highway construction, and many responsible people credit machines with the progress in the fantastic improvement of highways. These new machines, however, are developed by highly trained men, and men like you put the machines to work to create your designs.

Your challenge today is to continue to add to your knowledge in order to take better advantage of the machines, or to run the risk of having the machines take advantage of you. I see this conference as one of the ways you have of improving your talents toward this goal.

I am confident that this conference will prove to be of benefit to you, to the college, and to the entire Northwest. The fact that you men are here today involves a considerable investment of

time and money on the part of your employers and yourselves—an investment in present worth and future progress.

BASE STABILIZATION OF COUNTY ROADS WITH ASPHALT EMULSION

John McInerny

As engineers, it is our duty as well as our habit, to seek better methods of building and maintaining roads. This is particularly true of the county engineers of the State of Washington, who have under their supervision a gigantic system of 40,000 miles. These must be maintained and improved with small budgets.

In eastern Washington the roadbeds are plagued by unsound areas of poor drainage, rapid run-off, extremes of weather, and long periods of the freezing and thawing cycle.

In Stevens County our interest in stabilizing bases with asphalt began while viewing pictures of street construction in the city of Renton, Washington. Here, pit run material was used for the road base. This was stabilization with an asphalt emulsion.

In most areas our county had a wealth of good gravel pits. We successfully used this material as a base for our asphalt roads, except for a few critical places.

In the spring of 1954, we asked one of the asphalt marketing companies to advise on the use of bitumuls in our county. After testing the available gravel deposits, it was decided to try two sections.

One road, known as the Douglas Falls Road, was programmed to be surfaced. Our problem was that if the roadbed were raised high enough to give adequate drainage, it would necessitate rebuilding three small bridges. We know that in this area of 4-foot frost penetration the base below any light bituminous surface treatment would have to be free of moisture if it were to survive the freezing and thawing cycle.

We placed just enough pit-run material to level the roadbed, and then stabilized or, in this case, waterproofed the top 2 inches with S.S.-1 emulsified asphalt at the rate of 0.35 gallons per square yard inch. After curing, an M.C.-3 seal coat at the rate of 0.25 gallons per square yard was applied, and the following year the second seal coat was applied. The road, as treated, is now going into its sixth year of service. It is in good condition, and the asphalt base treatment apparently was a good choice.

The project was 1.8 miles long. The base treatment and

single seal cost $4487.74, or about $2500 per mile. The subsequent seal in 1955 cost $1337.92, or $745 per mile. Cost per mile for the base treatment with two seals was $3245 per mile.

Our second project was a joint venture with the City of Chewelah to improve the east end of Main Street and the county road which continued easterly from the city limits. The problem in this case involved reconstructing a road over a long, marshy area. Each spring water filled the marsh on both sides of the road. The oil mat soon broke up and the road became impassable. As soon as weather permitted, a new coat of blade mix was laid and the road was good until the following spring. This road was a main county arterial and served the Chewelah ski lift and the cemetery.

The existing oil surface was ripped and an additional 6 inches of pit-run ballast was placed. The upper 2 inches of this pit-run material were stabilized with S.S.-1 bitumuls at the rate of 0.35 gallon per square yard inch. A seal coat of 0.25 gallon per square yard of M.C.-3 was applied. Two years later, an additional seal coat was applied. This road is still in excellent condition.

Accurate cost figures for this project are not available, as both city and county forces were used. Cost records were kept only by the county.

In 1955, the county commissioners decided to oil 1.1 miles of road along the Spokane River. The closest stockpile of crushed rock was 20 miles away, and the small quantity of crushed rock required did not warrant a crusher setup. At one end of the road was a bank of gravel. It was decided to screen out the cover stone. A subsequent test showed that the gradation was poor, and that we would have trouble setting the base for an application of hot asphalt.

S.S.-1 bitumuls were applied at the rate of 0.45 gallon per square yard inch and the treated materials mixed and laid. The base was not stable under traffic, however, so after allowing it to cure for two days, we windrowed the treated material and added additional bitumuls at the rate of 0.10 gallon per square yard inch. We again laid the treated materials, and the resultant product was a well stabilized base.

In 1956, the major portion of our new surfacing was done by stabilizing the base with varying amounts of bitumuls and sealing with one coat of M.C.-3. This method of surface treatment was preferred for the following reasons:

1. Work done previously was giving exceptional service under adverse conditions.

2. Costs ranged from $2300 to $2900 per mile.

3. All equipment required for efficient handling of materials was on hand.

4. The men liked to work with the bitumuls. I think that every man on the job seemed to feel that he had found a new product and was personally responsible for its success. Enthusiasm for this work made it a pleasure to organize these projects.

5. It extended oiling season by about 30 days.

That season we used the bitumuls for base treatment of four county projects and one for the City of Chewelah. Of these projects, only the Williams Valley road presented a special problem. This road traverses an area where the basic soil is decomposed granite. All roads in this area gave good service except during the freezing and thawing cycle. During this period, the road foundations became saturated with capillary water and were often impassable even for light vehicular travel.

The closest gravel was 15 miles from the project, and pit-run gravel had been used many times without solving the problem. Tests from the Washington State Highway laboratory showed that an additional 5 inches of gravel would be necessary for a light traffic road. The laboratory report showed that the material could be stabilized with bitumuls applied at the rate of 0.45 gallon per square yard inch.

We blended 10 percent of blow sand with 3 inches of decomposed granite and then added the bitumuls. This was given a single seal coat of M.C.-3 asphalt, applied at the rate of 0.25 gallon per square yard. Cost was a little under $3400 per mile.

Today, the road is in good condition. There are three small areas of distress, but these appear to be caused by a poor seal coat, and probably could have been avoided if the road had been seal coated the second year.

In selecting the materials for the road base, we preferred pits which contained well graded materials. We preferred those that had a sufficient amount of fine aggregate so that it could be consolidated into a sound base with water. The emulsion added stability by holding the fines in place. It also sealed the surface

water from the base and held down the capillary water where it would cause little damage during the freezing and thawing cycle.

We generally attempted this type of base construction during the early part of June when the spring rains supplied the major portion of the required water. Stabilization was accomplished by our regular equipment and crews. The emulsion added sufficient cohesion to the base materials so that light traffic could be carried without damage until the distributor and oiling crews were able to apply the seal coat.

In Stevens County, the asphalt stabilized base was done entirely with pit-run material. No doubt greater success could be obtained with manufactured base materials. We mixed and placed the base materials by a combination of blade mixing and water processing. The emulsion was spread by water wagons. It took six or seven passes of the blade to mix and place the materials. The seal coat was applied within one or two weeks.

I will not go into detail as to construction procedure as travel road mix plants and stabilizing pug mills both are used with success.

In conclusion, I would say that any engineer faced with problems of wet and unstable bases might do well to consider building a better base by the asphalt stabilization method in lieu of using larger quantities of base materials or more expensive wearing courses.

STABILIZATION OF BASES FOR COUNTY ROADS

Allen S. Koch

Many of you may not be familiar with the location of our county. However, I am certain that youngsters in your family, and most adults also, will have a much better idea of our location when I say that Orange County is the home of Disneyland.

Disneyland has fast developed as the crossroads of the West. It has long been said that anyone with enough patience could eventually meet all his friends at Times Square. I assure you, however, that you will meet the same friends twice as often and much sooner if you wait at the gate of Walt Disney's Magic Kingdom.

Orange County is one of the fastest growing areas in the rapidly growing State of California. From a population of approximately 100,000 in 1940, Orange County has grown to a current population of approximately 750,000. Recent economic studies by the Stanford Research Institute indicate the population will double in ten years.

I mention this tremendous growth and projected continued increase in population because of its direct importance and concern to the County Road Department. This growth factor is of paramount importance and must be considered in all our planning. It means that our present major county highways will be carrying much higher volumes of traffic and that many of the unimportant roads of today will be handling daily many thousands of vehicles within the next decade. Although a large number of our major thoroughfares already have been improved to relatively high standards, practically all of our streets must be further improved, widened, or rebuilt to handle future traffic requirements. This growth means that roads must be engineered and designed for these higher traffic volumes and built to last as long as possible.

With this in mind, and for other considerations which I shall discuss later, we began using soil-cement in Orange County about four years ago. In this four-year period we have used soil-cement or cement stabilization for base, as it is known in many areas, on a total of 12 projects. Three projects are now on the drawing boards that will utilize this type of base construction. These projects have included all types of work—new subdivision streets, reconstruction of existing streets and highways, widening, and improvement of major county roads. Soil-cement has been used both for light and heavily traveled county roads, with traffic volumes ranging from 400 to more than 27,000 vehicles daily.

Soil-cement has been both mixed in place and mixed in central batching plants, and both native soil and imported aggregate have been utilized. Thus, it develops that we have had many varied experiences with soil-cement in these four years.

In every instance where cement stabilization has been used in Orange County, it has been economically sound. It either saved money for the county or was comparable in cost with other base materials. For instance, we will save more than $30,000 in a 3.3-mile widening and improvement project on a major thoroughfare now under construction. Of course economics must be the basic consideration in the choice of road building materials, but in addition to economy there are other considerations involved in the choice of soil-cement as a base material.

We have utilized soil-cement because it performed a job where it was the most satisfactory material for a given situation. Cement treatment has also been used on a number of county projects utilizing existing materials and enabling us to conserve our limited supply of good aggregate material for future use.

To begin with, Orange County has a very limited supply of good rock aggregate material, and this aggregate is located only in certain areas. Native soil in most areas of the county is not suitable for subbase material without stabilization. By using the cement treatment principle for stabilization, we tend to conserve our aggregate for concrete construction and other work where best quality rock aggregate is a necessity. In some instances, cement mixed with the native soil has produced sufficient strength for satisfactory stabilization, thereby altogether eliminating the use of any imported aggregate. In other projects, cement has been mixed with imported select material or low-grade mineral aggregate for base material. Although aggregate is used in these instances, the quality is reduced considerably from that required for an all-rock base.

We have been well pleased with our experience with soil-cement in Orange County. We have taken full advantage of the very fine cooperation of the Portland Cement Association and the technical assistance that the Association's engineers have given us. It always pays to have experts available when you are trying something new, and I would most certainly recommend that anyone starting this phase of road construction for the first time also take advantage of the help this organization has to offer.

I mentioned earlier that we have completed a total of 12 soil-cement projects in the past four years. I would like to highlight

briefly some of this work.

HARBOR BOULEVARD

1. Description of job. Improvement consisted of widening from three 11-foot lanes to a 4- and 6-lane divided highway for a length of 3.27 miles.

2. Ultimate traffic load. An EWL of 30,000,000 was used in design of the improvement. Traffic Index for an EWL of 35,000,000 is 9 - 36,000 ADT.

3. Basic reason for using CTB. Economics was main reason for CTB use. CTB gave a 5-inch reduction in section and excavation. A savings of $0.02/sq ft, or $30,000 for the project was realized.

A pipeline close to subgrade made a reduction in excavation desirable.

An existing concrete pavement remained in place for a distance of 0.13 mile, requiring CTB for rigidity.

4. General classification of native soil. Soil on this project varied from clean sand to silty clay. R-value of soil varied from 16 to 67—predominantly BPR group A-6 changing to group A-2 at north end of project.

5. Design section for road. Design section was 4 inches of PMS over 4 inches class A CTB, over 4 inches class B CTB, over variable ISM varying from 0 to 6 to 8 inches.

6. Type of material used. California State Specifications, dated August 1954, were used for control of CTB. Mineral aggregate used was approximately 60 percent rock with 100 percent passing the 1-1/2 inch screen, mixed with 2-1/2 to 4 percent cement.

7. Construction method. The road mixing method was utilized using a Gardiner bulk spreader and a Woods mixer. An interesting aspect of this job was procedure used in placing the 4 inches of class A CTB over the 4 inches of class B CTB. Contractor so organized his work as to place, mix, spread, and compact the 4 inches of class A CTB over class B CTB within 24 hours after mixing operations of class B CTB were started. As soon as class B CTB was compacted in place, trucks started windrowing material for class A cement treatment, and before close of the following day this material also was mixed, spread, and compacted.

8. Unit cost—surfacing not included

Cement-Treated Base Quantities		
Mineral aggregate CTB	$1.54/ton)	
Cement	3.83/bbl)	$0.13/ft^2
Mix, spread, & compact	0.20/sq yd)	

Equivalent Base Quantities		
Aggregate base	$1.85/ton)	
Roadway excavation	0.28/cu yd)	$0.15/ft^2

SEVENTEENTH STREET

1. Description of project. Improvements consisted of widening from a 2-lane substandard roadway to a 4-lane undivided highway with 8-foot untreated shoulders. Project length was 1.87 miles.

2. Ultimate traffic load. An EWL of 10,000,000 was used in the design of the improvement. An EWL of 10,000,000 gives a TI of 8 - 16,000 ADT.

3. Basic reason for S/C use. To provide a semi-rigid section for placement alongside a concrete pavement.

4. General classification of native soil. Soil on this project varied from silty sand to silty clay. R-value of soil varied from 15 to 69. Predominantly BPR group A-6, changing to group A-4 at east end.

5. Design section for road. Design section varied from 3 inches PMS over 6 inches of class B CTB over NS to 3 inches PMS over 6 inches of class B CTB over 6 inches of untreated mineral aggregate over NS.

6. Type of material used. California State Specifications, dated August 1954, were used for control of CTB. Mineral aggregate used was approximately 60 percent rock, with 100 percent passing the 1-1/2 inch screen, using 3 percent cement.

7. Construction method. Road mixing method was utilized using a Gardiner bulk spreader and a Woods mixer.

8. Unit cost—surfacing not included

Cement-Treated Base Quantities		
Mineral aggregate CTB	$1.52/ton)	
Cement	3.83/bbl)	$0.10/ft^2
Mix, spread, & compact	0.19/yd^2)	

Equivalent Base Quantities		
Untreated mineral aggregate	$1.55/ton)	$0.09/ft^2
Excavation	0.68/yd^3)	

WESTMINISTER AVENUE

1. Description of job. Improvement consisted of widening a 2-lane highway to a 4-lane undivided highway with 8-foot untreated shoulders. Project length was 3 miles.

2. Ultimate traffic load. Traffic Index used in design of improvement was 7.8 - 26,000 ADT.

3. Basic reason for S/C use. To provide a semi-rigid section for placement alongside a concrete pavement.

4. General classification of native soil. Soil on this project varied from silty sand to sandy silt. R-value of soil varied from 36 to 71. Predominantly BPR group A-2.

5. Design section for road. Design section was 3 inches PMS over 6 inches of class B CTB over 4 inches of URB over ISM, varying in thickness from 0 to 12 inches.

6. Type of material used. California State Specifications, dated August 1954, were used for control of CTB. Mineral aggregate used was pit-run with 100 percent passing the 1-inch screen, and from 75 to 50 percent passing the no. 4 screen. Percent of cement was 3.5.

7. Construction method. A continuous type plant was set up at the material source. Mixed CTB was shipped to job site by dump trucks.

8. Unit cost—surfacing not included

Cement-Treated Base Quantities		
Mineral aggregate CTB	$1.47/ton)	
Cement	4.53/bbl)	$0.11/ft^2
Mix, spread, & compact	0.28/yd^2)	

Equivalent Base Quantities		
Untreated mineral aggregate	$2.30/ton	$0.13/ft^2
Excavation	0.65/yd^3	

NEWPORT AVENUE

1. Description of project. Improvement of Newport Avenue consisted of reconstruction of a 2-lane substandard road to two 12-foot lanes with 6- to 8-foot untreated shoulders. Length of project was 2.3 miles.

2. Ultimate traffic load. Traffic Index used in design of improvement was 6.5 - 10,000 ADT.

3. Basic reason for S/C use. To provide a semi-rigid section for placement alongside a concrete pavement.

4. General classification of native soil. Soil on this project varied from silty sand to silty clay. R-value of soil varied from 15 to 62. BPR group A-6 predominantly going to group A-4 between Walnut and Laguna Road.

5. Design section for road. Three-inch PMS over variable class B CTB. CTB varied from 6 to 7 inches.

6. Type of material used. Could have from 60 to 100 percent passing the no. 4 screen and from 3 to 15 percent passing the no. 200 screen, but of such quality as to produce a no. 300 psi unconfined compression strength in 7 days when mixed with 8 percent cement. Actual material used had from 25 to 35 percent rock, with a cement content of 3 percent.

7. Construction method. An asphalt mixing plant was utilized at source of material and mixed material was transported to the job. Utilizing an asphalt mixing plant with its existing scales made close control of cement difficult, but not impossible, and good results were obtained.

8. Unit cost—surfacing not included

Cement-Treated Base Quantities		
Mineral aggregate CTB	$1.28/ton	$0.10/ft^2
Cement	4.08/bbl	
Mix, spread, & compact	0.24/yd^2	

Equivalent Base Quantities		
Untreated mineral aggregate	$1.80/ton	$0.09/ft^2
Excavation	0.90/yd^3	

EUCLID AVENUE

1. Description of project. Improvement on Euclid Avenue consisted of reconstructing a substandard 2-lane road to a 4-lane undivided highway. Length of project was 1 mile.

2. Ultimate traffic load. Traffic Index used in design of improvement was 7.3 - 20,000 ADT.

3. Basic reason for S/C use. Economics: Utilizing native soil and 5 to 8 percent cement permitted a reduction of 9 inches of mineral aggregate and excavation. This reduction in rock and excavation gave an estimated savings of $0.105 per square foot, or $28,000 for the project.

4. General classification of native soil. Varied from clean sand to silty sand. R-value of soil varied from 37 to 63. Predominantly BPR group A-2.

5. Design section for road. Eight-inch PMS over 6-inch cement-treated native soil, having an unconfined compression strength of 300 psi or above.

6. Type of material used. Native soil in place, using from 5 to 6 percent cement.

7. Construction method. Road mixing method was utilized using a Gardiner bulk spreader and a Woods mixer.

8. Unit cost—surfacing not included

Cement-Treated Base Quantities		
Cement Mix, spread, & compact	$3.66/bbl) 0.24/yd)	$0.064/ft^2

Equivalent Base Quantities		
Untreated mineral aggregate Excavation	$2.75/ton) 1.00/yd^3)	$0.169/ft^2

EDWARDS STREET

1. Description of project. Improvements consisted of reconstructing a 2-lane substandard road to two 12-foot lanes with 8-foot untreated shoulders. Length of project was 0.7 mile.

2. Ultimate traffic load. Traffic Index of 5 was used in design of improvement - 6000 ADT.

3. Basic reason for S/C use. To permit construction of a road during a rock strike. However, it also proved economical.

4. General classification of native soil. Slightly sandy silt. R-value of soil varied from 31 to 54. Predominantly BPR group A-4.

5. Design section for road. Three-inch PMS over 7 inches of soil cement.

6. Type of material used. Seventy percent clean river sand and 30 percent of native soil, 5 percent cement.

7. Construction method. Road mixing method utilized using a Gardiner bulk spreader and a Woods mixer. An interesting aspect of this job was the procedure used in mixing sand, native soil, cement, and water in a one-pass operation. Sand was windrowed over a prepared subgrade. Woods mixer was adjusted so that 2 inches of the subgrade was scooped up into the mixer while passing over and mixing the windrowed sand, cement, and water.

8. Unit cost—surfacing not included

Cement-Treated Base Quantities		
Mineral aggregate CTB	$1.25/ton)	
Cement	4.00/bbl)	$0.09/sq ft
Mix, spread, & compact	0.23/yd^2)	

Equivalent Base Quantities If Available		
Untreated mineral aggregate	$2.38/ton)	$0.10/sq ft

Our first utilization of cement treatment was brought about by a strike in the rock and gravel industry which affected our usual base materials. We had contemplated using soil-cement for some time, and decided to use cement treatment in order to continue work without interruption. We conducted experiments with soil-cement stabilization for new subdivision streets utilizing pure river sand as the base aggregate. It may be surprising, but we obtained such excellent results with this material that many private contractors were able to continue road building during a strike in the basic materials industry. Of course, they were unable to pave the streets during this period. The cement base treatment, however, carried construction traffic very successfully and with practically negligible failures. Recent laboratory tests have shown this cement-stabilized base to have a present strength of 800 psi.

We also have found that use of soil-cement base adjacent to existing concrete pavements in widening projects has completely eliminated the cracking that always results from joining a flexible

and a rigid pavement.

I have not mentioned one additional advantage we have experienced in using cement for stabilization. This is a structural advantage. The county's first project proved the strength of cement-treated base by bridging over many small unstable spots below subgrade level with this method of stabilization. From a construction viewpoint, considerable money was saved by not excavating this poor subsoil and backfilling prior to construction of the base.

All of the factors mentioned—economy, best performance for a given situation, structural superiority—make soil-cement a good buy in Orange County. After four years of experience with soil-cement, we have developed a great deal of information about this type of construction. We would be most happy to make this information available to anyone requesting it.

ASPHALT TREATMENT OF BASES

Vaughn Marker

GENERAL

Although man has been constructing roads for thousands of years, it has been only relatively recently that he has begun to study scientifically the various constituents that he has been using for these roads. For example, the scientific study of soils and aggregates has been done virtually in the last 40 years. One facet of this work has been the study of the treatment of soils and aggregates with asphalt. For this presentation the use of asphalt for the treatment of materials to be used as bases will be discussed.

METHOD OF TREATMENT

There are four general methods of treatment with asphalt that have been used to stabilize bases. One of these has come to be known as "membrane stabilization," wherein a large mass of high capillary clays and other cohesive materials have been enveloped with asphalt. The function of the asphalt in this method has been to provide a tough waterproof membrane completely surrounding materials that have been compacted at a desired water content so that there would be no loss or gain of moisture in the mass. Especially prepared asphalts are used most successfully in this treatment.

A second method of treatment has come to be known as "phase stabilization." In general, this consists of coating an aggregation of soil particles with asphalt to provide some degree of waterproofing rather than trying to coat each individual particle.

A third method is the use of special asphalts with high adhesive forces which act as modifiers of plastic soils to reduce the plasticity. For example, cracked asphalts exhibit better adhesive and waterproofing characteristics with certain clays than do conventional asphalts, and have been used successfully.

The fourth method has come to be known as the "intimate mix," in which each aggregate particle is coated with asphalt, and it is attempted either to impart cohesion or provide waterproofing by blocking the capillary pore spaces in the mixture, or both. This method is, by far, the most common and will be discussed further.

INTIMATE MIXES

Generally speaking, only granular materials lend themselves to the "intimate mix" type of treatment. Soils high in clay content

are extremely difficult to reduce to individual particles and coat. The "intimate mix" method, then, is of primary value with materials that are entirely granular in nature or contain relatively small amounts of deleterious fines which prevent the aggregate from providing satisfactory service as a base. The treatment with asphalt immobilizes the deleterious fines, thereby rendering an otherwise borderline quality base material satisfactory for use. At the same time the deleterious fines are coated and immobilized, and the pore spaces in the aggregate are blocked by the asphalt, further increasing the possibility of success with the material by not allowing water to enter.

In addition to the borderline aggregates, the "intimate mix" method is employed with high quality materials and classified as an asphalt-concrete base. To present logically the types of bases employing the "intimate mix" principle, their order of quality is defined as follows:

1. Asphalt-concrete base (ACB). A well-graded, high quality aggregate hot plant-mixed with a paving grade asphalt, machine-placed and thoroughly compacted.

2. Asphalt-treated base (ATB). Borderline sands and gravels treated with paving asphalt, emulsion, or liquid grade asphalts to improve their strength or durability properties. These may be plant- or road-mixed, machine- or blade-placed, and thoroughly compacted.

3. Asphalt-soil base (ASB). In-place granular soil treated with asphalt by any convenient means to improve its properties.

An additional type of base that is commonly used in some parts of the country that might fit in the "intimate mix" category, although no mixing is involved, is:

4. Asphalt-macadam base (AMB). High quality macadam aggregate spread, thoroughly compacted, and then penetrated with sufficient paving asphalt, emulsion, or liquid grade asphalt to impart cohesion to the entire layer. (Good asphalt-macadam base should be rated immediately behind an asphalt-concrete base from the standpoint of quality.)

CONSIDERATIONS

There are almost unlimited numbers of combinations of aggregate and asphalt that can be considered when designing and constructing an asphalt-treated base. All factors concerning availability of material, cost, conditions of usage and construction, weather, and traffic must be weighed before the treatment is

finally decided upon. The more severe the conditions of usage, the higher the type of treatment should be. For mainline, heavy-duty roads, the asphalt-concrete base is recommended or, as an alternate, the asphalt-macadam base. For secondary roads, or those not carrying heavy truck traffic, the asphalt-treated base will probably be satisfactory. The asphalt-soil base is excellent for lightly traveled roads or for large automobile parking areas. It must be remembered that any type of asphalt-treated base should have a surfacing, preferably of asphalt concrete.

A type of material that has been quite successfully used for asphalt-treated bases is sand. Sand has excellent supporting characteristics, provided it can be confined or if some cohesion can be imparted to it. Asphalt serves admirably for this purpose. In general, the types of asphalt that are most successful with sand are the RC liquid grades or mixing type emulsions. In some instances sand has been mixed in a central plant with a paving grade asphalt and placed with a paving machine.

ADDITIONAL BENEFITS

In asphalt-aggregate combinations for use as bases, additional benefits besides waterproofing or plasticity modification are derived. By virtue of imparting cohesion to a layer of material, a measure of stiffness is developed by that layer which increases its contribution to the load-carrying capabilities of the pavement structure as a whole. Thus, it may be possible to take advantage of this characteristic by using an asphalt-treated base for the purpose of reducing elastic deformation or resiliency in the pavement structure. Under certain conditions it may be possible to reduce the overall thickness of the pavement structure by using an asphalt base, although in all cases a careful analysis of the conditions must be made before any drastic reductions in thickness are made. In addition, once the asphalt base is in place and compacted, traffic can use it as a temporary surface until the final surfacing is placed.

ADVANTAGES TO COUNTIES

The use of asphalt bases provides many advantages for the county road system. There is a wide variety of combinations possible in their use, thus allowing a choice from the standpoint of economy. These bases provide stiffness in the structural section without brittleness, thereby minimizing potential maintenance problems because of cracking due to excessive deflections. While asphalt-treated bases provide considerable stiffness in the structural section, they are flexible enough to conform to earth movements, thus maintaining their integrity even though considerable

settlement occurs. Equipment for construction is readily available and no special machinery is necessary. Besides these considerations, it will be possible to frequently improve the structural adequacy of a county road by scarifying, processing, and adding asphalt to material already on the roadbed and relaying it as a base prior to placing a new surface.

FUNDAMENTALS TO REMEMBER

Regardless of the type of asphalt treatment chosen, some fundamental items should be remembered in order to derive the greatest benefit from the investment. First, at least a minimum laboratory investigation for the project under consideration should be made prior to design. A modest investment at this stage can provide considerable savings later on. Second, regardless of the design or type of construction, adequate drainage of all segments of the road must be provided, including drainage of the structural section. This item might be more important than the stabilization technique used. Third, good workmanship must be employed during construction in all phases of the work. Poor construction can ruin the project no matter how well the other phases are handled.

CONCLUSION

It should be emphasized that no one asphalt treatment of a base can be considered a panacea for all low cost road construction. Whether or not to use an asphalt base, as well as the type to use, must be based on sound engineering principles, and the decisions reached must be carried through from the beginning of the design to the end of construction. In this way, asphalt-treated bases can play an invaluable part in any county road program.

SOIL CEMENT—THE MODERN LOW COST PAVEMENT FOR ROADS AND STREETS

L. T. Norling, Sr.

Stabilization of soils and base materials has become an important tool in modern pavement construction. It permits use of substandard materials and thereby conserves the rapidly depleting supply of specification materials. Also, it results in higher quality, low cost construction since more uniform and predictable results can be obtained.

I would like to discuss the leading stabilization material—soil-cement or cement-treated base used in some of the western states. First, let us review what soil-cement is.

Soil-cement is simply a mixture of soil, Portland cement, and water. The mixture is tightly packed while in a moist condition. Action of the cement binds the soil particles into a permanently dense and hardened base. Since the mass is unharmed by water or freezing and thawing, it maintains this densified and hardened state under all conditions. A bituminous wearing surface is placed on the soil-cement to complete the pavement.

Almost any type of soil may be used, ranging from gravelly and sandy soils to the fine-grained silts and clays. Beach sands and windblown silts and fine sands are being used. Old graveled roads and street materials are ideal for soil-cement. Any old blacktop can be pulverized and included in the mixture to be treated with cement. Thus, costs are kept low since well graded or expensive aggregates are not required.

The amount of cement needed to harden a soil is determined by simple laboratory tests which have been adopted as standard by both the ASTM and AASHO. These tests make sure that the base is hardened sufficiently to withstand the destructive forces of weather. As experience with soil-cement has increased, locally developed tests and short-cut test methods have been developed and are being used satisfactorily.

The first engineered soil-cement road was built in South Carolina in 1935. It was built of native soil to test the research that had developed the laboratory tests and field control factors. The project, which will be 25 years old this fall, is still giving good service.

Since this first project was constructed, almost 300 million square yards of soil-cement have been built. This is equivalent to about 25,000 miles of 20-foot pavement. The annual use of soil-cement doubles about every 5 years. What are the reasons for this remarkable growth? In addition to economy, soil-cement must have certain engineering properties that make it superior to other low-cost base materials.

Let us examine soil-cement in the light of these engineering properties. First, soil-cement is more than just a mixture of soil and cement. It is a structural slab-like material. Thus, it can spread the load of traffic over a larger area of the subgrade.

Plate bearing tests on 10- by 12-foot panels of soil-cement and of crushed limestone were made at the Portland Cement Association Research and Development Laboratories. The soil-cement was made of a sandy soil and silty clay loam soil. The crushed limestone meets Illinois State Highway Department specifications for base course for high-type pavement. The panels were placed on a typical Illinois clay subgrade and were covered with a 1-1/2 inch bituminous surface.

In one series of tests the panels were loaded with a 12-inch diameter plate until a deflection of 0.06 inch was obtained under the load and the deflections were measured at various distances from the center of loading. On the sandy soil-cement panel, points of zero deflection were 52 inches from the center of the load. On the crushed stone, points of zero deflection were only 23 inches from the center point. This means that the load on the soil-cement was supported by several times as much subgrade area as the load on the crushed stone. As a result, the soil-cement panel supported 14,760 pounds on the 12-inch plate at a deflection of 0.05 inch, as compared to only 4360 pounds on the crushed stone.

In another series of tests, 4-, 7-, and 10-inch thick panels of soil-cement and crushed stone were loaded with the 12-inch diameter plate until a deflection of 0.05 inch was obtained. The soil-cement panels had substantially greater load carrying capacity than crushed stone. The 7- and 10-inch thick panels of soil-cement carried about three times the load carried by the crushed stone. Also, the load carrying capacity of the soil-cement increased greatly with increase in thickness, whereas little increase in load carrying capacity of the crushed stone was obtained when its thickness was increased.

Soil-cement strength and load carrying capacity develop

quite rapidly, but what is equally important is that it continues to harden for many years. Cores obtained from projects several years after construction show remarkable gains in strength as compared with specimens tested at age 28 days. The higher strengths of field cores show that soil-cement gains in strength even under freezing and thawing and wetting and drying weathering conditions. This built-in safety factor of soil-cement is important. It means that as traffic increases, strength of the pavement also increases.

Obviously, strength and structural properties of soil-cement are important in highway design. Its higher load carrying capacity permits use of thinner sections of soil-cement as compared with gravel or other bases for a given condition of subgrade and traffic. Thus, by considering its engineering properties, an economical design can be made that will result in a long life, low maintenance, soil-cement pavement.

This brings up the item of cost. Since there are many variables such as labor costs, cement factor, size of job, type of bituminous surface, and others, it is impossible to give a cost that will apply to all situations. Cost of a 6-inch soil-cement base, however, generally ranges from about $0.60 to $1.25 per square yard. To this is added the cost of the bituminous surface.

To arrive at the true cost of a pavement it is important to consider, in addition to first cost, the life expectancy and maintenance costs. The service record of soil-cement is proof of its long life. The first projects, now almost 25 years old, are still going strong.

Many examples of the enviable low maintenance record of soil-cement could be cited. An example is a Tennessee county that has been building soil-cement for 10 years. The county has spent a total of only $600 for maintenance on 150 miles of soil-cement roads. Half of this cost was for routine surface maintenance. Similar records from Kentucky, Ohio, Illinois, and elsewhere show the low maintenance of soil-cement paving.

This enviable record of soil-cement has resulted in its widespread use in all applications of paving. Soil-cement is providing many miles of low cost paving on the county road system. Because of its low maintenance, it is providing means for many counties to make headway in their programs for better roads.

More than 500 cities have used soil-cement to pave some

15,000 blocks of streets. Cavalier, North Dakota, where most of the business and residential streets are paved with soil-cement, is a typical example. Larger cities, such as San Diego, Mobile, and Atlanta, have used soil-cement almost exclusively on hundreds of miles of subdivision streets.

There is a minimum of inconvenience when building with soil-cement. If necessary, a street may be opened to traffic the same day it is built.

Many state highway departments are making use of soil-cement. The first soil-cement road built in the State of Washington on SR 3H is still giving excellent service. One mile of this route was built in 1938 and 10 miles in 1947. There are now 600 miles of cement treated base and soil-cement roads in service in Washington.

Many state highway departments are using soil-cement to increase safety and reduce maintenance of shoulders. One of the most important advantages of soil-cement shoulders is that since soil-cement does not consolidate, no "stepdown" is formed at the pavement edge. A similar use is the widening of existing roads that are too narrow to handle today's traffic.

A growing use of soil-cement is for subbase under Portland cement concrete pavement. Materials unsuitable for subbase can be made suitable at low cost by treating them with cement. Cement treated subbases are used to

1. Prevent consolidation of subbases at pavement joints under heavy traffic.

2. Prevent pumping.

3. Prevent intrusion of subgrade soil into open-textured subbases.

4. Provide increased and more uniform support for concrete pavement.

5. Provide stability during paving operations.

Soil-cement is also finding application for parking and storage areas. In many cases the in-place soils are utilized, thereby keeping costs to a minimum.

Construction procedures for these many paving applications are simple. Specially designed machines which permit low cost mass construction procedures are available.

Mechanical cement spreaders are used for handling bulk cement. Fast and efficient mixing machines are used to mix the soil, cement, and water on the roadway. Central pugmill-type mixing plants also are used, particularly where granular borrow materials are being treated.

After the mixing operation the soil-cement mixture is compacted to a high density. If soil contains silt and clay, a sheepsfoot roller is used for initial compaction. Final compaction is obtained using steel-wheeled and rubber-tired rollers. Vibratory compactors, segmented rollers, rubber-tired and steel-wheeled rollers are used on granular soil-cement mixtures.

After compaction, the soil-cement is kept damp for 7 days. Application of a bituminous material is the most popular method. If area will be immediately subjected to traffic, it is sanded to prevent pick-up of bituminous material.

I have attempted to acquaint you with some of the properties and uses of soil-cement. Its structural properties have resulted in its use for all types of low cost paving. The service record, covering almost 25 years, has been outstanding. I believe that soil-cement will continue to play an important role in keeping America's road and streets adequate for the ever increasing traffic.

Figure 1. First fully engineered soil-cement road near Johnsonville, South Carolina. Still giving good service.

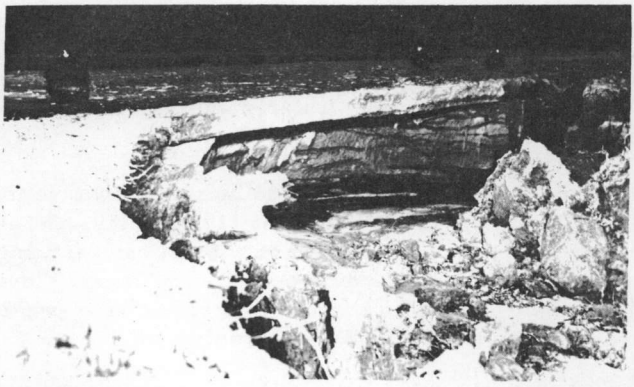

Figure 2. Washout showing slab-like properties of soil-cement.

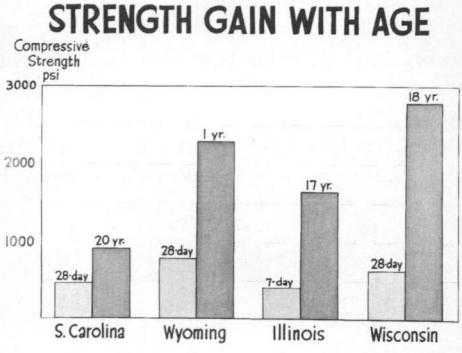

Figure 3. Cores from field projects show soil-cement continues to gain strength over long period of time.

Figure 4. One of many soil-cement streets in Cavalier, North Dakota

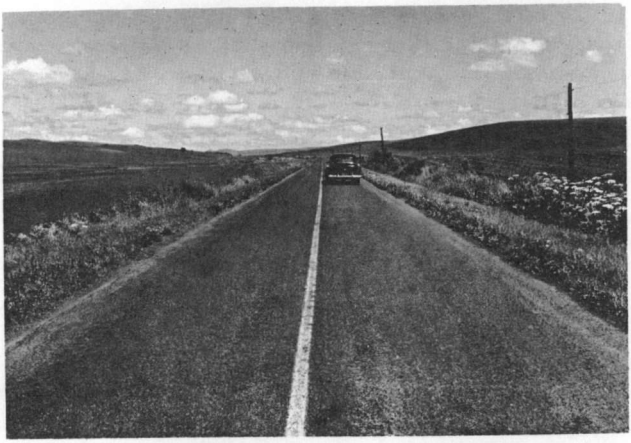

Figure 5. Soil-cement on SR 3H, Whitman County, Washington. Built in 1938.

Figure 6. Final compaction with pneumatic-tire roller gives soil-cement base tight, well-knit surface.

SOILS AND THEIR RELATION TO BASE DESIGN

G. L. Decker

Soil, often called just plain dirt, is the most common construction material in engineering. Since it must have been encountered and presented problems very early in the history of mankind, one could expect a well developed scientific approach, familiar and accepted by all. Such is not the case.

These very early problems and more recent ones must have been resolved one way or another, but we have no recorded evidence of the methods used.

It can be said, then, that around a generation ago very little attention was given to the soil types and characteristics to be encountered in a road or street construction project. The problem was, for the most part, one of cubic yards and how many it would be necessary to move in carrying the project to completion.

Soil today is considered as a construction material of extreme importance. Contrary to the predictable qualities and behavior of manufactured construction materials such as steel or concrete, the engineering properties of soil vary widely from place to place, quite often within the confines of one roadway cut.

As the need for roads, streets, and airfield runways developed that would safely carry heavy loads, attention of the engineer was more and more focused on the reactions of the soil which supported these facilities. The soil's behavior under load became a problem that could not be ignored and must be dealt with. Thus, it was that impetus was given to the recognition soil engineering has gained as a distinct branch of the engineering field today.

Although the first contributions to this field date back to the latter part of the 17th century, by far the greater part have been since World War I. Authorities in this relatively new branch of the engineering field believe that only a beginning has been made. However, a great deal of valuable data has been assembled and widely used by soils engineers. These data have been published by various agencies and are readily available to those who wish detailed information. Also readily available are excellent textbooks on the subject.

Many of the approaches to engineering problems today involve detailed and at times quite technical and complicated analyses. This discussion will be held to basic considerations.

All highway departments now maintain soil or soil and geology sections. An important function of such a section is the study and analysis of soil with relation to base design. Although the tendency in design is towards an analytical approach as used in bridges and other similar structures, the extremely complex and variable nature of soils engineering properties has to date caused the retention of experience and judgment, along with soil analysis, to arrive at a determined base design thickness. Each state has developed its own system. Such a system has been developed and is used by the Oregon State Highway Department. It is believed that soils and their relation to base design can best be illustrated for this group by explaining the various procedures in this method.

As a first step, the origin and nature of soil should be considered. To the engineer the word soil refers to all unconsolidated mineral matter above solid rock, plus any air, water, or organic matter. This includes the well known terms of clay, silt, sand, gravel, and loose talus rock, also peat and muck. He is interested in engineering properties, whereas the agriculturist is concerned with a relatively thin layer near the surface and its adaptation to plant life. The geologist's conception is generally that of the agriculturist. The origin of soil is part of geology.

Soils occur in infinite variety over the face of the earth. It is important to be constantly aware of this fact. Most soils were originally solid rock of one form or another. At this point it is believed helpful in understanding and appreciating the scope of soil problems to discuss briefly how they were formed from this parent rock.

In this respect they may be considered as an incidental material or product of a geological cycle that has been going on relentlessly and continuously for millions of years. This cycle has three principal phases: (1) erosion, (2) transportation and deposition, and (3) earth movement.

The parent rocks are eroded, broken down, and degraded by both physical and chemical agents. They are then picked up by some transporting agent such as water, wind, or moving ice and deposited in various land forms at various distances from the original source. This point of deposition may be very near the original source, or it may be hundreds of miles distant. In time this shifting of material disturbs the equilibrium of forces in the crust of the earth. Earth movements result, exposing new formations to erosion, and the cycle begins anew. A material deposited from one source may be overlain or intermingled with material from a different source

during these cycles. Petrologists have identified well over one thousand minerals as constituents of rocks. As they are degraded into soil particles, each mineral adds its particular characteristic to the soil mass.

Scouring action set up by water, wind, and moving ice is perhaps the most powerful of physical agents of erosion. Other examples are unequal expansion and contraction of the adjacent minerals in a rock during temperature changes, causing them to crack, and wedging action of ice and growing roots in a rock crevice. Both sides of the Columbia Gorge are striking examples of physical erosion.

Principal agents of chemical degradation are water and temperature. Examples of chemical degradation are "hydrolysis," where hydrogen in water replaces one or more of the metallic elements, forming a new mineral; and "hydration," in which water combines with the mineral, forming a hydrous substance. Other examples are "carbonation," "oxidation," and "solution." Caves found in limestone formations are attributed to the solution of limestone rock in water.

Once the parent rock is broken or eroded, the transporting agencies of water, ice, wind, and gravity begin their part of the cycle. If one can picture what occurs during one cycle and then picture many cycles, one upon another, some concept of the extremely complex nature and characteristics of soils may be gained.

In addition to transported and deposited soils, there are extensive deposits of soil which have been moved but slightly, if at all, from their points of degradation from the parent rock which lies directly underneath. They are classified as "residual" soils.

In arriving at a final base design, the Oregon State Highway Department requires certain procedures and certain tests.

The first step is field investigation to determine the kind or type of excavation material. This is called "typical soil." Particular attention is given material which, in the finished grade, will make up the top 3 or 4 feet of embankment. Where this rock is easily identified, sampling and laboratory tests may not be required. Where soil is encountered, judgment is used in gathering sufficient samples for laboratory testing and determination of the typical soil. In this operation a knowledge of the nature and origin of soils is very helpful.

Although additional laboratory tests are run when deemed necessary, the regular tests required are six in number, as follows:

1. Determination of particle sizes by sieve analysis and hydrometer analysis. This separates the soil sample into clay, silt, fine sand, coarse sand, and coarser particle fractions. It permits classification according to percent of each material and, in addition to the names just given the soil, may be classified as a silty clay, sandy clay, loam, silt loam, etc. Amount of each size group serves a very important part in judging, analyzing, and classifying a soil.

Granular size particles, from sand size upward, are known to have good load supporting values over a wide range of moisture content. This supporting value is attributed to internal friction of the granular particle. It is a good, desirable soil for road subgrades.

Silt is the soil size between fine sand and clay. It has several undesirable characteristics. Internal friction is negligible. Moisture content range for good compaction in silt is very narrow, making it hard to handle in a satisfactory manner on the grade. Soils with a predominance of silt absorb water readily, and at high moisture content have poor stability and load supporting power. They are poorly graded, with a resulting high void content and low densities. Silts may also expand when water is absorbed rapidly, and are subject to frost heave. They are not considered as desirable subgrade material.

Clay is soil below the silt size and can be said to be the dominant soil because of its extremely variable nature and characteristics. Clays can be compacted to good bearing capacity under favorable moisture conditions, but lose this capacity when moisture is absorbed. Clays have low internal friction when dry, and this is further reduced as moisture content increases. Strength of clay is dependent upon cohesion, which is defined as the mutual attraction of particles due to molecular forces and the presence of moisture films. This cohesive force varies with moisture content. Completely dry clay would have low cohesion. Cohesion would increase as moisture is added up to where the mixture becomes plastic. Beyond this stage, cohesion would decrease. Wet clay can be oven-dried to form a brick-hard substance. These conditions are best illustrated by the dry, dusty clay road in summer, the muddy, yielding road in winter, and the hardened, baked appearance after a summer rain.

Clays are subject to large volume changes as the moisture content changes. Because of the small pore size in clays, they take up water slowly and, in turn, are hard to dry. This makes them hard to handle on the grade. Gravitational water moves through clay slowly, making it hard to drain. On the other hand, capillary water, or water moving from the wetter portion to the drier portion, is strong. Vertical movement of such water in clays has been measured to 34 feet above ground water level. A predominantly clay soil is one to examine closely before use in the subgrade.

Characteristics of various combinations of sand, silt, and clay will not be discussed.

2. Determination of specific gravity of typical soil. This indicates weight of soil and is used primarily as part of the hydrometer analysis.

3. Determination of liquid limit. This may be defined as the moisture content at which a soil passes from a liquid state to a plastic state. The liquid limit is an index of cohesion. Sandy soils have low liquid limits around 20 or 25, and this test is of no significance in load carrying capacity. Silts may have liquid limits up to 100. Certain clays have liquid limits up to 600, although the range is generally from 40 to 60. High liquid limits indicate soils of poor supporting value.

4. Determination of plastic limit. This may be defined as the moisture content at which a soil changes from a semi-solid to a plastic condition. Some silts and sands have no plastic limits and, in this case, the test has no value in determining bearing capacity. Plastic limits indicate the presence of clay, and in some instances silt. Soils will generally reach their plastic limit at some time of the year, and this test is a factor in base design consideration.

The plasticity index, or PI, while not a test in itself, is a factor in base design. It is defined as the numerical difference between the liquid limit and plastic limit, and gives the range of moisture content at which a soil is in a plastic condition. The plasticity index indicates sensitivity of soils to moisture change.

Plastic limit, liquid limit, plasticity index, along with shrinkage limit, are termed the "Atterburg limits," after Atterburg, the originator of the test procedures. Kids, with their fashioning of mud pies, although totally unaware, very likely observe all phases of the Atterburg limits.

5. Determination of moisture-density. This involves three or more tests to determine at what moisture content a soil can be compacted to the greatest density. This test is made on material passing no. 4 screen. Greatest density obtained is called "maximum density." Moisture content at this density is called "optimum moisture." Since 90 to 95 percent of this density is specified for earthwork construction, bearing power of soil at optimum becomes a part of the base design consideration.

6. Determination of an "R" value. This R value is defined as the resistance of the soil to deformation under a load, and is determined in the laboratory by a triaxial type test on material passing the no. 4 screen.

A series of tests are made on remolded samples of soil passing the no. 4 screen to establish strength characteristics through a moisture range between optimum and liquid limits. Three such tests are generally run on a sample compacted to simulate field condition. R values so determined are plotted against each moisture content and can be adjusted up or down as other factors govern.

Range of R values may be considered from 0 to 100. Granular soils in sand to gravel size have good supporting values and correspondingly high R values, which have been determined up to 90. Since, as previously discussed for granular soils, fluctuation in moisture content has little effect on supporting value, the R value is adjusted to optimum moisture.

Because of the affinity silt has for water, the laboratory R value is adjusted downward in proportion to silt content. This can result in R values of 1 or 2 where silt content is high.

Adjustment of R values for clay is not a predetermined approach, but largely one of judgment and experience. The liquid limit is watched closely as a governing factor. Special tests are made to determine base thickness over expansive clays.

Perhaps the most important part of assembling all the above data into readily usable form was correlating R values with service behavior of road surfaces throughout the state. This part required many years of effort, and many revisions were made before the present relationship of R values to surfacing thicknesses was considered, for the most part, satisfactory and adequate to meet most requirements. Correlations now are assembled to show R values and corresponding surfacing requirements for light,

medium heavy, heavy, and very heavy traffic classifications, based on truck count. Arbitrary decisions, based on judgment and experience, can alter the established R value requirements. This can be readily understood. The time at which a strictly rational approach to base design will be developed and accepted by all concerned is in the future.

This concludes the discussion of soils and their relation to base design. I trust it has been of some benefit. I am sure those in attendance, who are familiar with soil studies and their problems, will recognize the very elementary approach used.

PAVEMENT SMOOTHNESS

R. W. Beaty

One of the most important features of a well designed and properly constructed highway is a smooth riding surface. Too often an otherwise excellent highway is marred by a rough and uneven pavement surface which produces an irregular, uncomfortable motion in vehicles traveling at high speeds. As vehicle speeds increase, pavement smoothness becomes more important, not only with respect to comfort and safety of the traveling public, but also in terms of pavement service and vehicle operational and maintenance costs. Impact loading resulting from roughness is a definite factor influencing the service life of any pavement, and it obviously follows that pavement roughness has a bearing upon vehicle service, especially with respect to such items as tire wear and maintenance of suspension systems.

The motoring public may not recognize or appreciate the significance of engineering and construction skills required to construct a modern, high-class highway, but there is no doubt that it does recognize and appreciate a smooth riding pavement. Despite the importance of the adequacy of design of the total roadway structure and the materials and workmanship involved in its construction, quality of the completed highway will probably be judged by the average highway user on the basis of roughness or smoothness of the pavement surface.

In general, pavement roughness can be classified into three types: surface roughness, profile roughness, and side-sway roughness. Surface roughness is that roughness characterized by short, sharp humps and sags in the pavement surface, with relatively small deviations from true grade. Open, coarse textured surfaces such as coarse seal coats producing rumble and minor vehicle vibration are contributors to surface roughness. Profile roughness results from longer, more rounded waves, usually deviating quite markedly from the desired profile. Side-sway roughness is a form of profile roughness, with an added refinement; it also involves variations in the transverse slope of the pavement, causing a vehicle to sway or roll from side to side.

Any of these types of roughness can be annoying and uncomfortable to the driver and passengers in a vehicle, depending on the degree of roughness encountered. Surface roughness is especially tiresome to the driver, as the vibration and shock resulting from roughness is transmitted to the steering wheel. Profile and

side-sway roughness tend to "throw" a car, the effect being somewhat more severe on a rear seat passenger.

Usually, roughness of cement-concrete pavement is of the surface roughness type; that is, short, local humps or sags. Profile and side-sway roughness seldom occur on newly constructed cement-concrete pavements because of the nature of engineering and construction methods used. Grade elevations are staked at short intervals, normally 25 or 50 feet, and side forms are set carefully to these elevations, assuring good control of profile grade and transverse slope. Surface roughness of cement-concrete pavement may be the result of any one of several causes:

1. Poorly prepared subgrade
2. Improper setting of side forms
3. Non-uniform concrete mixture
4. Inadequate consolidation of concrete
5. Poor finishing procedures
6. Faulty workmanship in joint construction

Profile and side-sway roughness characteristics are more commonly found on asphaltic concrete pavements, although not all these pavements are free of surface roughness. Long, rounded waves in the profile result from poor preparation of the subgrade and base courses. If extreme care is not exercised in the placement and preparation of each course of the base material, from the subgrade on up, it is very likely that a wavy profile or variable transverse slope will result. The asphaltic concrete pavement, due to the method of construction employed, will generally reflect the shape of the underlying base, smoothing only the small, local irregularities. Surface roughness will result if the finishing machine is maladjusted or is operated improperly, usually manifesting itself in the form of short, regularly spaced ripples in the profile. Other localized surface irregularities in asphaltic concrete pavement may result from poor compaction procedures or faulty construction of transverse joints.

Specifications for pavement smoothness which establish a maximum allowable deviation from the plane of a 10-foot straightedge are reasonably effective in detecting the short irregularities defined as surface roughness, and afford some means of requiring correction of causes of this type of roughness during construction of the pavement. This type of specification is not effective in controlling profile or side-sway roughness, so it is necessary to establish controls over methods and procedures involved in each phase of construction of the roadbed and pavement to eliminate the causes of this type of roughness. The specification for smoothness

of cement concrete pavement recently adopted by the California Division of Highways establishing maximum allowable roughness, as measured by the California profilograph, appears to be a realistic approach toward controlling roughness in that the plane of reference for measurement is increased to 25 feet.

Many devices have been developed by highway engineers in an effort to measure pavement roughness. Mr. F. N. Hveem, materials and research engineer for the California Division of Highways, has written an interesting history of the development and application of some of the various roughometers, viagraphs, profilometers, and profilographs used through the years. This article appears in the January-February 1960 issue of the California Highways and Public Works magazine.

In 1936, engineers of the Washington State Department of Highways, convinced of the need for some method of measuring pavement roughness, acquired a car-mounted roughometer instrument of a type then used in California. This roughometer has been used for many years in checking the surfaces of Washington highways. The car-mounted roughometer measures the cumulative amount of vertical oscillation of a front wheel with respect to the frame of the car. Results obtained with this instrument are not a direct measure of pavement roughness, but rather a measure of motion induced in the wheel and frame of the car by the character of the surface. This type of roughometer is much more sensitive to surface roughness than to profile or side-sway roughness, and is completely insensitive to the long, smooth profile waves that affect vehicles traveling at high speeds.

Although it is recognized that the car-mounted roughometer is not a precise instrument, the instrument has performed valuable service in making comparisons of the relative roughness of pavements in the state. Being permanently installed in a car, it has been convenient for making tests during pavement construction, and on many occasions has served to point up the need for correction of paving procedures to eliminate the causes of roughness. Perhaps its greatest value has been that it has removed roughness from the realm of personal opinion, and has stimulated interest among engineers and contractors in construction of smoother pavements. A roughometer report has been issued to engineers and paving contractors each year, showing roughness indices of newly constructed pavements as measured by the roughometer. Of course, the use of results obtained with this instrument as a specification control has never been contemplated.

During the past year, the Department of Highways has constructed an experimental profilometer, embodying the basic principle of the hand-pushed profilograph developed by the California Division of Highways. This instrument consists of a frame 25 feet in length, supported at each end by bogie wheels and with a recording wheel mounted at the center of the frame. At the present time, the recording is made with an electric counter actuated through an overriding clutch and microswitch. Consideration is being given to the use of a recording mechanism which traces a profile of the path traveled by the recording, or sensing wheel.

The profilometer is somewhat larger and heavier than the California profilograph in order that it can be attached to the side of an automobile which propels and guides the instrument. Attachment to the car is made by means of roller bearing guides, allowing free vertical movement of the profilometer with respect to the movement of the car. Tests are made at a speed of approximately 7 miles per hour, with the instrument positioned in the right wheel path of the traffic lane. With the wheels removed, the frame can be pinned to the brackets on the car for transport from one test section to another, or the frame can be dismantled and carried on a cartop rack on longer trips. Although it has been tested for only a short period, it is believed that results obtained with the profilometer are more representative of the true nature of pavement roughness than are the results obtained with the car-mounted roughometer.

Figure 1 shows a general view of the apparatus attached to the car, in position to make a roughness test.

Figure 2 is a detail of the recording wheel and overriding clutch, which drives a drum with cams on its periphery. These cams actuate a microswitch which in turn actuates an electric counter. The wire shown connects the microswitch with the counter mounted on the instrument panel of the car.

The apparatus may also be used as a hand-pushed profilometer by attaching outrigger wheels at each end of the frame. Thus, tests may be made of newly constructed cement-concrete pavement. Our experience with this use of the instrument has been very limited at this writing.

One important factor that cannot be overlooked is the attitude and interest of engineers, contractors, and workmen with respect to the problem of eliminating pavement roughness. The Asphalt Paving Association of Washington, an organization composed of paving contractors, has sponsored and carried out an effective

quality improvement program during the past several years. This program has had a salutory effect on the attitude of contractors and their workmen with respect to improving the quality of all features of asphaltic concrete pavement construction.

In 1958, the asphalt paving contractors became interested in a project rating program being practiced in District VII of the California Division of Highways, and suggested that a similar program be initiated for rating asphaltic concrete pavement projects in the State of Washington. After studying the details of the California system, the Department of Highways devised a somewhat similar system with the modifications required to meet the needs of a statewide rating program.

The project rating program was initiated in 1958. All asphaltic concrete paving projects are evaluated, regardless of size or whether the work involves new construction or resurfacing. Inspection and rating is performed entirely by the Department of Highways. Although the interest and support of the contractors are vital to the success of the program, our system allows them no voice in rating the projects.

It has been our observation that our better asphaltic concrete pavements show the results of careful attention to the small details of the work that so frequently are overlooked. It is the difference in the quality of work involved in these small details that separates a first-class pavement from the average job. We believe that the rating program stimulates interest in all features of paving work by calling attention to some phases of the work neglected most frequently.

The following features of the work are those upon which the projects are rated:

1. Pavement smoothness - maximum value: 40 points. This rating is based entirely on results of roughometer or profilometer tests. The rating of a project is made by subtracting the average roughness index from the maximum value. For example, a pavement having a roughness index of 12.7 inches per mile would have a pavement smoothness rating of 27.3.

2. Roadway finish - maximum value: 21 points. This feature is rated on the general appearance of the roadway and slopes, conformity to true profile and transverse slope, uniformity of pavement surface texture, appearance and condition of joints, and the general condition of plant sites and stockpiles upon completion of the work. Inspection and evaluation of the roadway finish is

made by the Headquarters Construction Division in cooperation with the district construction engineer. A rating of 18 or above is considered excellent; 15 to 18, good; 12 to 15, fair; and below 12, poor.

3. Inspection and control of materials - maximum value: 16 points. This feature is rated by the Materials Laboratory, based on uniformity of control of gradation, asphalt content, stability, cohesion, and correlation between field and laboratory test results.

4. Traffic control and safety - maximum value: 4 points. Rating of this item is based on the effectiveness of project signing and traffic control, accident records, and safety precautions taken by contractors and engineers.

5. Prosecution and progress - maximum value: 16 points. This rating is made in cooperation with the district construction engineer, and is based on promptness in beginning work, organization of the work, quality of supervision, sufficiency and condition of equipment placed on the job, and time required for completion.

6. Complexity of project - maximum value: 3 points. Rating of this feature of the project is an attempt to allow for the complicating factors affecting the work, such as high traffic volumes, interchanges, varying widths of pavement, etc.

The sum of the ratings of these features of the work is the total rating for the project. Top-rated projects in the eastern and western regions of the state are selected annually, and appropriate awards made to the paving contractors involved. Awards are also made for the second and third ranking projects in each region.

As seen in this description of the rating procedure, pavement smoothness weighs heavily in the total rating. The system could be adjusted to place more emphasis on other features of paving work, such as control of materials, should this be advisable. At the present time we feel the emphasis on pavement smoothness will generate the most interest among all concerned.

Member contractors of the Asphalt Paving Association of Washington have given their unqualified support and cooperation in the formulation and operation of the project rating program, and are using the program to generate the interest and spirit of competition among their employees in constructing durable, smooth riding asphalt highways. If the program has any value, and we are convinced it has, the ultimate beneficiary is the fellow who pays the

bills—the highway user.

Figure 3 is a reproduction of the form used in compiling rating data, and shows the procedure used in rating a sample project.

Figure 1. Profilometer attached to car.

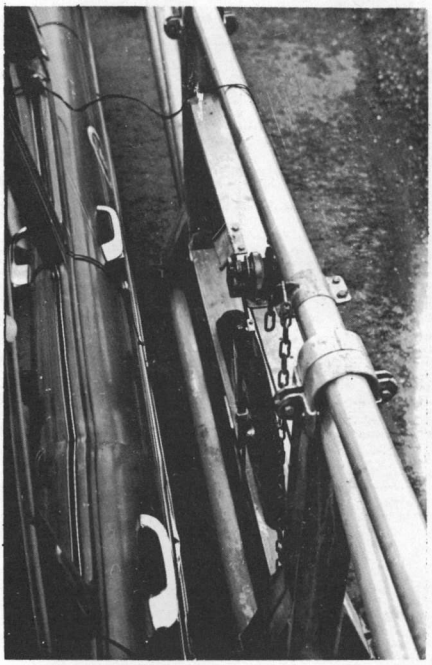

Figure 2. Detail of recording wheel and overriding clutch.

WASHINGTON STATE HIGHWAY COMMISSION
DEPARTMENT OF HIGHWAYS

YEAR 1959
DISTRICT NO. 8 PROJECT RATING PROGRAM

CONTRACT NO.	1234
SECTION	Simpson Hump to Stackhouse Hollow
HIGHWAY	P.S.H. 23
CONTRACTOR	Chattery Paving Co.
RESIDENT ENGINEER	I. Q. Naut
STREET INSPECTOR	J. F. Rednose
PLANT INSPECTOR	Blacky White

MAX. RATING	ITEM RATED	JOB RATING	REMARKS
40	PAVEMENT SMOOTHNESS	27.3	Some short, choppy waviness. Few rough joints
21	ROADWAY FINISH	16.8	
10	Profile	6	Profile only fair--numerous sags 100'
10	Surface Texture	7	to 300' in length.
10	Transverse Joints	7	Texture somewhat non-uniform, especia
10	Longitudinal Joints	8	on east 1.5 miles.
10	Pavement Alignment	9	Transverse joints fair to good.
10	Shoulders	9	Shoulders very good.
10	Slopes	8	Slopes very neat appearing.
10	Plant Site Cleanup	10	Plant site cleanup excellent
16	INSPECTION AND CONTROL OF MATERIALS	7.5	Some segregation in stockpiles. Too much variation in asphalt content. Excellent temperature control.
4	TRAFFIC CONTROL AND SAFETY	3.5	Traffic handled very smoothly. No accidents reported.
16	PROSECUTION AND PROGRESS	14.7	Equipment, organization and
10	Organization	10	supervision very good.
10	Supervision	9	Contractor's attitude toward
10	Attitude	8	quality of work could be improved.
10	Equipment	9	
10	Progress	10	Excellent progress.
3	COMPLEXITY OF PROJECT	2.0	Very heavy traffic through job. One interchange with ramps, etc.
100	TOTAL RATING	71.3	
	RANK IN DISTRICT	5th	
	RANK IN REGION	14th	

Figure 3. Sample of form used in compiling rating data.

WHAT PAVEMENT CAN YOU AFFORD?

V. L. Goodnight

At the meeting of Northwest Highway Engineers on February 25, 1949, a paper was given entitled, "Selection of Surface Types for City Streets." It was the thought in that paper that citizens would be interested in selecting concrete pavement for street surfaces. The data in the report pointed to the cost and maintenance of four surfaces: gravel surface, oiled surface, asphaltic pavement, and concrete pavement. The summary indicated concrete pavement was more economical for the 40-year index.

You are acquainted with the usual city operation of giving the property owner the privilege of selecting the type of permanent surface. The city assures maintenance after paving, and the property owner insists low first cost, which makes it nearly impossible to use concrete pavement.

The subject assigned for this meeting is "What Pavement Can You Afford?" Obviously, who are you first comes to mind—government, state, or city? Along with this comes, where are you —Alaska, New York, California, or Corvallis?

For this paper, let us set the stage in Corvallis, with a very small amount of frost, average high summer temperature not over 95 degrees, and the year 1936.

The street improvement program consists of placing a little gravel on previously graded and lightly graveled streets. Also, if the property owners join in oiling the street, the city will at its own expense, place gravel on this light oil job.

The above policy was still in effect when I was appointed city engineer in 1941. It took five years to abandon this policy, which was costing nearly $30,000 annually to fill potholes.

At this time (1947) the City Council adopted the policy of requiring a permit for any oiling of city streets and, further, all expense had to be paid by the property owners. Shortly after this policy was made it was amended so that no permits would be issued for oiling if sewers, water lines, etc., were in place.

We were also told that we were in a five-year program to pave 50 blocks per year for five years, and that in the first year, 1948, we had paved 38 blocks. Here is the sequel for the subsequent years: 80, 72, 43, and 72 blocks for an average of 61 blocks per

year for that five-year period. Since 1952 we have averaged 48 blocks per year; 63 for the past year.

With these projects behind us, and discussions with engineers on their improvements, it seems appropriate to review what has taken place in these eleven years.

When my subject was assigned to me for this meeting, I talked with our friend, Mr. Carl Larson of the Asphalt Institute. He loaded me down with reams of cost data on paving in California. From the data it appears the cost of base materials varies greatly, as does the cost of cement for stabilization. However, comparative approximate costs were obtained as follows:

Table 1. Costs in California

Date	8-in. conc pavement on 10-in. cement stabilized base sq yd	3-in. asphaltic conc on 10-in. cement stabilized base sq yd
1955	$4.28 - 24 projects	$2.75 - 19 projects
1956	4.90 - 29	2.83 - 22
1957	5.30 - 26	2.92 - 24
1958	5.15 - 34	2.80 - 27

(Note increase in concrete pavement costs over period 1955-59.)

Table 2. Costs in Oregon

Oregon State Highway - Freeway

Using asphalt pavement:		
18-in. compacted base	$1.34/ ton	= $1.22 sq yd
2-3/4 in. minus compacted base	1.44	= 0.17
4-in. asphaltic concrete	5.70	= 1.37
		2.76
Using concrete pavement:		
8-in. gravel base	$1.34/ton	= $0.54 sq yd
1-in. crushed gravel	1.44	= 0.09
8-in. concrete		= 3.35
Reinforcement, dowels, and cutting joints		= 0.25
		4.23

Note: Compare costs with California.

Following are listed projects for street improvements, including excavation, haul, gravel base, catchbasins, connecting drains, curbs, and pavement, but excluding trunk storm sewers.

Table 3. Listed Projects for Street Improvements

Date	6-in. conc pavement without gravel base		2-1/2 to 3-in. asphalt on 6- to 7-in. compacted bank-run gravel	
	Sq yd	Cost	Sq yd	Cost
1911			18,364	$2.62
1914			1,677	2.05
1924	4660	$4.35		
1925	5226	2.88		
1931	1356	2.28		
1949			9,000	3.27
1950-57			75,000	3.68
1958-59			30,000	4.10

Note that no concrete paving was laid after 1931.

The following are comparative bids on proposed 1949 projects:

Plan A. To construct complete street with curbs using 6 in. gravel and 3 in. of asphalt. Asphalt bid: $14,330 or $4.35 sq yd.

Plan B. To construct complete street with curbs using 2 in. of crushed gravel and 6- to 7-in. concrete pavement. This project required 3300 sq yd. Concrete bid: $22,730.90 or $6.90 sq yd.

A most interesting project this last year was for a street improvement where part was on a grade of 227. This project called for 700 sq yd of concrete pavement and 1820 sq yd of asphaltic pavement with a rolled curb section. Project was bid at $7.50 a sq yd, and the roll curb at $60 a cu yd. The last item is usually bid at $37 for standard curb. Our estimate was $14,360, but the bid was $20,280.

By breaking this job into units, the following is found:

	700 sq yd conc sec	1820 sq yd asphalt sec	2720 sq yd revised proj str curbs, asph
	26-ft width	26-ft width	28-ft width
a) Exc, haul, drainage	$1000.00	$ 2,597.00	$ 4,199.50
b) Curb construction	1550.00	4,030.00	2,016.00
c) Rock base	192.50	1,118.00	1,886.00
d) Asphalt pavement		3,840.00	5,953.50
e) Concrete pavement	5952.75		
	8695.25	11,585.00	14,055.00
Total cost sq yd	12.40	6.35	5.15

	Total project
a) Exc, haul, drainage	$33,597.00
b) Curb construction	5,580.00
c) Rock base	1,310.50
d) Asphalt pavement	3,840.00
e) Concrete pavement	5,952.75
	50,280.25
Total cost per sq yd	8.05

From the above Corvallis information it is found that for a complete street improvement using asphalt the cost ranges from $4.35 to $5.15 a sq yd. Also, from Corvallis bid quotations using 6- to 7-inch concrete on 2-inch crushed rock base, the bid price varies from $6.90 to $12.40 a sq yd, with the probable average for normal concrete paving at $8.20.

Using the above information, we arrive at the listed average costs as follows:

Table 4. Typical Cost of Street Improvements, 1959
Based on 300-Foot Block, 34 Feet in Width

	Cost per block
1. Grading and hauling	$ 490
2. Concrete curbs	850
3. Drainage	300
4. Six-in. compacted gravel base	590
5. Two-in. compacted crushed rock	250
6. Three-in. asphaltic concrete	1800
7. Six- to 7-in. concrete pavement*	4532

*Using $4/sq yd rather than local bids of from $5 to $7.50.

Summary:

1. Concrete pavement
   Items 1, 2, 3, 5, 7 above = $6422/block - $5.50 sq yd
2. Asphaltic concrete
   Items 1, 2, 3, 4, 5, 6 = $4280/block - $3.68 sq yd
3. Gravel street
   Items 1, 2, 3, 4, 5 = $2480/block - $2.10 sq yd

The foregoing information has been presented to substantiate our following conclusions:

Table 5. Annual Maintenance Cost

Type of improvement	Per sq yd	Per 300-ft block
Concrete pavement	$0.0142	$16.37
Asphaltic pavement	0.0322	36.45
Gravel street	0.0446	50.50

Consideration must be given to average annual capital charge plus maintenance to choose fairly the pavement you can afford. We use a 300-foot block as the unit.

Table 6. Capital Cost

Improvement	Orig cost per block	Yrs allowed for capital charge	Avg annual rate 3%	Annual capital cost per block
Concrete pave	$6422	40	0.0433	$279
Asph conc	4280	30	0.0510	218
Gravel street	2480	*	0.0838	208

*Gravel is replaced 1/2 in. per year

Table 7. Comparative Capital Cost

Type of improvement	Annual capital cost	Annual maintenance	Total cost
Concrete pavement	$279	$16.37	$295.37
Asphaltic pavement	218	36.45	254.45
Gravel street	208	50.50	258.50

Note: Had we used $5 per square yard cost for concrete pavement instead of $4, the comparative capital cost would have been $346.37.

Note: Oregon State Highway Department Bulletin No. 7 is given credit for the formula used to derive average annual rate.

Average annual rate of payment for capital plus interest is as follows:

C = total cost

C_{ac} = capital recovery

r = rate of interest

$$C_{ac} = C\left(r + \frac{r}{(1 + r)^n - 1}\right)$$

$$\frac{C_{ac}}{C} = r + \frac{r}{(1 + r)^n - 1}$$

Illustration:

$$C_{ac} = 0.03 + \frac{0.03}{(1 + 0.03)\ 40 - 1} = 0.433$$

From the data presented, we have reached the conclusion that you cannot afford a gravel street, but our opinion is that you will not, in this modern age, tolerate the nuisance of dust, litter, etc., as well as the danger to your health caused by unpaved streets. It is herewith recommended that all streets within your city be paved at your very earliest convenience.

We are told motor vehicle registrations reached 70 million in 1959, and are expected to reach 100 million in 1975. This would be nearly a 43 percent increase. This traffic increase, coupled with the fact that during the past 10 years urban areas have absorbed 98 percent of the nation's population growth, gives the cities a real challenge.

THE MAGIC WAND OF CHEMICAL VEGETATION CONTROL

W. E. Greene

The chemical industry has no magic wand. It has only the tools and know-how for developing your weed and brush control program.

The chemical industry, as one of the five basic industries of America, represents great investment, research, factory facilities, and market management. They are working hard to evolve new tools for such common practices as vegetation control and soil fixation, and at the same time such futuristic ideas as plastic guard-rails.

The chemical industry looks to other industries, such as railroads, irrigation, etc., as a proving ground. Why? New products formulated need uses, and when uses are found problems arise. Is it safe? Does it do the job? Could it be better? These questions can be answered only by experience.

After spending 1 to 5 million dollars on originating and developing, major chemical companys such Dow, Dupont, and Stauffer look to an immediate market. Thus, they look to industry as a means of evaluating these new tools where there is a need, and for assurance that they are safe in the field.

Do not misconstrue this statement. We do not mean that there is nothing known about the new material. The products are tested and evaluated for five or six years by trained people in colleges and experimental people in various areas before they come to you for test plots. Bear in mind that industry is constantly looking ahead and creating from basic materials, such as coal and salt, the tools that will control plant disease, weeds, brush, and insects as a minor part of their research on additives for paints, plastics, and generally all the basic raw chemicals used in industry.

These companies have their own products of which they are proud. Shall we say their "own children." In the field, competitors frequently refer to them as "illegitimate children," but they are not. They are generally developed at the expense of considerable time and investment.

You in the field frequently are led to believe that competition is in the sales people. It is not. The competition is in the research departments of the chemical companies developing new

products, products on which they are willing to gamble the investment of factories, advertising, developing new markets, finding other uses, and learning use factors throughout America on a national scale.

Our vegetation control originally began with the farmers; unfortunately, with spot treatment of noxious weeds. This built up resentment against the words "weed control" by many county and highway people. We prefer to think of chemical vegetation as conversion of an existing maintenance expense; using new tools to obtain results more efficiently. The typical American way is do it cheaper, do it easier and, most importantly, do it better.

Instead of waving a "magic wand," we should look at this in a little different light. Rather than telling the product manufacturers what we expect the tools to accomplish, do as you do with your other tools. Learn what the tools can accomplish. Incorporate these tools in a long-range program. You would not think of building a mile of road anywhere at a given price of say $50,000 a mile without knowing all of the factors such as rainfall, timber to be removed, grade, number of bridges, even the water going under the bridges, soil structure, erosion factors, and stress of timbers you need. Yet when you ask for a package of chemicals, you want a "magic wand."

You are overlooking the fact that chemicals are closely engineered—in fact, more precisely engineered than many other background tools you use today. Chemicals must be incorporated into a long-range maintenance program for cost efficiency. Mother nature is not subdued by any one innovation of man or subdued at one time. If this were true, roads would soon be built, gravel would be laid, and brush would be cut, but it is a continuing process. First you should evaluate your budget as to what you can spend to start, and once started, keep your program going. Do not go from one area to another each year unless it is incorporated into a long-range program.

Two chemical companies employ in excess of 80,000 people; each company in the business of manufacturing, researching, and developing products. A very substantial "magic wand," wouldn't you say. We should utilize what these people have learned—using their knowledge to complete our local background. They have built a background of plant pathology and chemistry soil factors that influence results, growing conditions, vegetation types, resistance and tolerance of various species to chemicals, and sum up the various reasons why chemicals work and why they fail.

If you are to utilize these modern tools you must utilize the background—utilize the technical men—the technical men of your service distributors. Put these men on your payroll at no cost by using their products and insisting on service.

Too much accent has been placed on the salesman who comes in with a "miracle" type of chemical that "eats, crawls, and crunches," or with a real price shenanigan. He leaves you with the feeling that you have made a superior deal, obtained a superior chemical, and yet you have never approached basic problems that go with evaluating or engineering chemical tools for your program.

As an example, in evaluating chemical tools for roadsides, let us compare hand cutting with a chemical brush control program. Hand cutting costs between $250 and $450 per acre of brush; frequently $600 or more when it is necessary to haul away, chip, or burn. This is often done with excess labor—people who do not like to cut brush. Compare this with an initial year of chemical brush control program at $40 to $50 per mile, $20 to $30 the second year, approaching $15 the third year, and down to $7 to $10 from there on. Not only is there a reduction in cost, but this gives you clean roadsides without blackberries and large broadleaf weeds, and leaves a grass-controlled bank.

Again, we have traded one problem for another. By removing the competition of brush we have ended up by having grass take over. We can now enter into the phase of grass control. By using a sterilant we can secure clean berms and clean ditches. In areas where erosion is a factor we can use retardant on the grass, holding it at the height wanted. We can delete much of the cracking of highway edges by application of sterilants, and recover more gravel with a minimum of blading.

Drainage offers a big challenge for chemical tools. We can remove the cattails with the use of radapon in July and August and burn out the ditches in the fall. More water can be obtained more quickly through ditches that are clean. Root structures are left to support the ditches and ditch bottoms. If there is no erosion factor we then can go into a sterilant program on ditches that have the type of soil structure to support it, and also around culverts and bridge heads. We can have better air drainage, less fire hazard, and better water flow.

On intersections we can maintain visibility and grass control around guardrails. It has been estimated that the cost per acre of cleaning out guardrails exceeds $400. Compare this with an original

per acre application cost of $120 to $140. Maintenance is at $40 to $50 per year for spraying with a truck at 4 to 5 miles per hour with an easily designed boom made in your own shop.

A plea should be made here to consider the upkeep before construction of a new road. We have a terrific job before us to catch up with the accrued grass, brush, and weeds on established roads, but on new roads maintenance can be set up from the beginning at a very low cost. Center strips in California are being maintained at approximately $21 per acre mile. This not only reflects in savings alone, but also in ease of cleaning up diapers, beer cans, etc. The public is generally reluctant to throw its debris in clean areas. This also deletes mowing, hand work, and burning in the fall the weeds and brush that catch snow.

How do we justify this new expense in the budget? There is no such thing as a balanced budget, but in the alternation of the budget we have items such as cleaning out drainage ditches and haul away, also hand labor in cutting the brush, which frequently is a hidden cost. By setting up problem areas and keeping hand costs versus chemical programs, your money control management is soon convinced. Then, over a period of time the budget can be reallocated to these specific tool usages. This way you can further stretch your maintenance dollar, normally accomplishing from 33 to 50 percent more.

We have added hazards in the chemical business; one being public relations. Your highway is the property of your public, so the chemical program is one of the first instances in which they become alarmed. Dead, brown brush creates a hazard. Highway people are referred to as the "flaming torches of the country" by garden clubs and "keep green" societies. The "hound dog societies" profess that you are taking away the hiding place of the animals. Through education, bulletins, paper releases, and meetings, we are convincing these people that they are saving in taxes, they can better see the scenery, it is a temporary thing, there are less deer killed, and the roads look better, have better drainage, and roadbeds are easier to maintain.

Personnel using spray equipment becomes quite a problem. Generally, because this is a new phase of our operation, we are given one of the less necessary and important people for our operation. We must teach this man public relations. He has to explain chemicals to people. He must follow a prescription that we give him based on cost, tolerances, type of leaves, and whether they are waxy, shiny, or hairy, because he must vary his surficants—his

wetting agents. He must watch his timing and growth factors, keep records, and be ready to answer to you for the conduct of his people. He must be methodical and he must be near. We have trouble with the spraymen who take the prescriptions we give them —the dosages—and increase, decrease, add oil, or come up with gimmicks they are sold on that frequently cost more.

This brings us to the subject of calibration. Calibration is the formula for taking a carrier such as water, putting in an amount of concentrate and wetting agent, and applying to a given acre. This is done by varying pressure and speed through an orifice in the nozzle. It is engineered and takes understanding. Failure results in higher costs by putting too much or too little pressure and speed through the nozzle. Calibration is as necessary for accuracy and cost as design is in bridges. Chemicals have different formulas. One formula may be low volatile. By this we mean it will stay where it is put, not that it will not drift, but that volatility after application is at a minimum. Others will have a relative volatility of 80, 90, and 100 in comparison with a low of 10 or 15. This increases the public relation hazard. Some formulations are more stable. They will stay in solution through adverse conditions, and also will stay on plants through hot and cold.

Other formulations will have lower parent acids. They may have a high ester content but lower parent acids; a gimmick of the smaller manufacturers. The law compels the companies to put on their labels correctly and to have backgrounds for label use, but there has been no law yet that will make a darned fool read the label.

My suggestion to you gentlemen is to learn to read your labels, learn to use your products, know your companies, and depend upon them. Maintain in your files phytotoxicity reports, work with the papers, give them data on taxes, savings, what you are trying to accomplish, and when there is a problem contact the people who furnished your materials and insist on service.

Let us look at some of the problems involved in organizing a program. You have area variances from the coast inland, rainfall patterns, biochemical tolerance differences in plants, and biophysical differences. In other words, difference in root structures, in leaves, and in soils which increase the variance in growth factors.

We can spray brush in the winter with basal treatments, in the spring with tree bud dormant treatments, and in the summer

with foliage spray. We can work our timing so that we keep the crews going nearly all year around. This results in better spray crews—people who are familiar with the equipment and with the problems. The sterilant program can start in October, and in November you can be doing basal on brush and delete the hazard of drift from foliage in urban areas. Spray cattails on the roads in spring, and foliage in the summer in areas where it is permissible. A year around program with a centralized crew offers the most advantage in personnel. You can generally purchase your materials as needed to hold down the cost of investment, and save over bid. This gives better control of materials and less theft and wastage.

Equipment should be designed to fit your needs. Small sprayers used for spot work and basal slip into your truck and are inexpensive. Large sprayers can be built on old water trucks. Plans and pictures are available through our company and others to assist you in doing this in your shop. Pumps, nozzles, and parts are standardized. Contract work can be done. We frequently contract work along road lines. We take one highway man and train him, then start him on his own rig, sometimes contracting part of the work.

In summarizing, how do we go about organizing an adequate chemical control program? A survey first should be made of your entire area, evaluating your problems, cost, terrain, and timing and vegetation factors. Cost should be evaluated for grading road shoulders. Chemicals must compete with this at $30 to $40 per mile for bare ground along the pavement. Costs should be evaluated for cleaning out ditches, haul away, and cleaning out around culverts and bridges.

By comparison, chemical work should be set up and the public informed. Records should be kept, a large map should be established, and then the earliest plan taken each year. This is not a haphazard operation. This must be a planned operation. No more than you would build a road and walk away and leave it, can your chemical program be a one shot operation. As any good plan, it must be watched, revamped, and reconditioned on an annual or biannual basis. Reports before and after with pictures should be given to the monetary control. Data should be given to them so that they can answer for these expenditures by showing savings and improved highway appearance.

An example of what can be accomplished is the Lane County Highway Department. Mr. H. O. Wallbert is administrator, Mr. Harold Strombom assistant administrator, and Mr. Ed Deschamps

spray foreman. They have two 100-gallon small tanks that they use in basal from November 1 to March 15. They have covered 600 miles of road on basal work at $30 a mile of road; chemicals, labor, trucks, diesel oil, and administration. Their hand brushing had been running from $250 to $300 per mile and up. Last fall they applied sterilants to approximately one-quarter of their trouble road area and ditches, guardrails, and problem areas at a cost of around $75 per acre mile. This will be reduced with the next application to approximately $25 to $30 per year cost for keeping clean the drain and ditch areas.

They have had an active spray program for the past three seasons. They operate two large trucks in the summer in five districts with central supervision and central material control. They start at the coast early with foliage and work inland, taking advantage of a maximum amount of time. They have 1500 miles of road and plan on a four-year program, eliminating all hand brushing. They have kept adequate daily records as to area, giving weather, temperature, dosages, operators, costs, and coverage. These are translated to a large map, color-coded so the program can be followed in detail. The supervisor, Mr. Deschamps, talks at farm meetings. They have cooperated on an area highway meeting in Eugene and have transformed a belligerent press into a cooperative press by taking out the editors and pointing out the benefits and savings. In short, they have made a program of the chemical tools to reduce their costs and get better highways for the county. Copies of their progress reports are available through the County Highway Department at Eugene, Lane County Highway Department, in care of Administrator.

Your public is our public. I ask your tolerance, gentlemen, in this chemical program. Give the people who build chemicals an opportunity to help you evolve a program based upon technical factors, technical knowledge, product usage, cost data, and personnel training in order to make your chemical program a success.

KEEPING DOWN BRIDGE AND CULVERT COSTS

Harold R. Sweet
Joseph Andreotti

In Yakima County we have approximately 800 structures over 6 feet in length. Many of these structures are located over irrigation laterals, canals, and drains, and were built soon after conception of the various irrigation and drainage districts.

A majority of the structures were timber, and all reached the end of their usefulness at approximately the same time. This necessitated a revamping of our schedule of maintenance and replacement. In order to determine the condition of all structures in the county, a survey was made of all bridges and culverts. It included taking core samples of timber structures.

Equipment needed for obtaining cores consists of a brace and hollow core bit and lots of manpower. After sample cores are removed, the holes are plugged with hardwood dowels that have been dipped in red lead. The sample core tells us if the timber is sound, punkey, or decayed. These findings are recorded on a report sheet showing conditions of the various components of the structure. We also attach to the report sheet a photograph of the structure. As a result of this survey we found 261 structures not capable of carrying legal loads, and they were posted as such.

In order to make such a survey of 800 structures it was necessary to have several crews making the inspections. Many individuals on the various crews had never investigated structures, so it became necessary to instruct all of the crews on what to look for, where to make the tests, proper nomenclature of various timber components of the structures, and how to record uniformly their findings.

To formulate a program of replacement, consideration was given to the accessibility of structures capable of carrying legal loads, school bus routes, and finances—the latter being the essence of this discussion. We were confronted with replacement of these structures, involving several millions of dollars, with a budget unable to withstand this demand without seriously sacrificing other phases of the overall road program. This prompted us to make a series of investigations to determine the economics of various designs and materials to see if a solution could be resolved.

Cost data for bridge and culvert replacement prior to this period for our area were available, so we had a starting point. As

we studied results obtained in the past, it was evident that merely trying to improve on these methods would not give the results desired. The next step was in the field of design, which was interrelated with materials to be used.

We were cognizant of the fact that labor cost was a predominant factor in construction of any structure. Keeping this in mind, and permanency of materials used, we directed our energy to developing or finding a design that would help reduce the cost of labor. Also, a majority of bridges and culverts over laterals and canals must be constructed during winter months after the irrigation season, thus presenting the problem of cold weather.

We designed a semibox, precast, concrete culvert for crossings from 6 to 8 feet in length. They were constructed in 6-foot units, which included a deck section and two wall sections placed in a poured-in-place grooved footing. This particular culvert is used where we have no headroom and deck elevation is at the grade of the finished roadway. At present we have constructed 30.

After footings are poured it takes a 5-man bridge crew, with an A-frame mounted on a 2-ton truck, 4 hours to erect 42 feet of this type of culvert. Average cost for this culvert in place, with a 4×6 opening, is approximately $40 per foot. We have found this type of culvert very convenient to place in the winter months when we are confronted with problems of cold weather.

Our first thought concerning manufacturing of precase deck and wall sections was to do it with county forces. Therefore an investigation was made to see what necessary equipment and facilities would be needed. While we were estimating our cost for manufacturing precast sections, we interested a Yakima cement company in making an estimate. They were provided with specifications that allowed a tolerance of 1/16 inch in any one dimension, so you see we did give the manufacturer some leeway. It was realized that the forms would have to be held rigid to prevent any bowing or bulging. The only material that seemed to possess the demanding qualities necessary to meet the requirements set forth was steel. After we had made our investigation and the cement company had made theirs, it was decided sections could be purchased cheaper and faster than we could make them. The sections are steam-cured for 24 hours to gain the required strength for handling, and permitted to gain full strength by the natural process of nature.

Where we have sufficient headroom for 1 foot of cover below grade, use of corrugated metal pipe has proved to be a decided advantage. We can place such a pipe with a minimum of labor. It can be placed under any weather conditions and in streams which have water flowing the year around. We have used approximately 25 such culverts in the past year; their sizes ranging from 30-inch equivalent to 72-inch equivalent.

For spans over 8 feet in overall length, we have adopted the "hog trough" design which we were exposed to a few years ago. Since that time we have constructed 88 of this type of structure. They have been placed on concrete abutments with footings, on concrete pilings and caps, creosoted piles and caps, and on precast concrete walls placed in grooved footings mentioned in conjunction with precast culverts.

We have modified the design of this particular precast section to more satisfactorily meet our needs and to further reduce their cost in place. For spans up to 14 feet, an overall depth of 12 inches is used; for spans of 15 to 22 feet, an overall depth of 18 inches is used; and for spans of 23 to 34 feet, we use an overall depth of 24 inches. This was depth used in the first design of this type of structure that we received. The manufacturer considered shallower deck sections more difficult to construct, and slightly increased his price. At this point it appeared that we had knocked on the wrong door for the answer to our problem of reducing costs, but after considering all of the factors we found the reduced section would render a saving. Prime saving was realized in cartage and in placing sections.

We also found that when shorter lengths were placed on existing concrete abutments, desired deck elevations could be obtained by adjusting depth of the sections rather than raising or lowering existing abutments. Cost for this type of structure ranges from $100 to $200 per foot, depending on whether abutments are square or skewed, and on height of abutments.

We presently have two concrete firms that are set up to manufacture the hog trough section. All steel adjustable forms are used in order to maintain necessary tolerances.

Until two years ago we had not tried a multispan bridge of this type, but since the single span structures had worked out so successfully for us we decided a multispan precast concrete deck bridge would be economical if we could tie the sections together and give support at the points of junction of the spans involved.

After studying the factors involved, we tried a structure 78 feet long involving three spans; two 23 feet and one 32 feet long. Precast deck sections were placed on precast piling with concrete caps and supported at the ends with concrete abutments and footings. It proved to be everything we had anticipated cost-wise and in the time required for its erection.

Contractors in our area were not in accord with our belief that the cost of this type of structure was cheaper than a monolithic bridge. In order to prove or disprove this point, we decided to let a contract with two alternates, thus letting the contractor decide for himself which one was cheaper to construct from his standpoint. As a result of bids submitted, contractors who bid this particular bridge with a length of 104 feet supported on cast-in-place or precast concrete piles, bid approximately 10 percent less for the precast deck type than they did for the monolithic design.

We have many drains in our county that cross county roads. Difference in elevation from the top of the roads to bottom of the drains may vary from 10 to 20 feet. Apertures at the top of these drains were large, and when the drains were dug they were spanned with timber bridges. Many of these structures now require replacement. Working with the drainage districts we found that openings provided by the bridges were much larger than required. We investigated the use of pipe and found that desired capacities could be obtained. Because of the year around water conditions and equipment required for placing, corrugated multiplate metal pipes and pipe arches were selected. We have nine such structures in and have found that we have saved from 30 to 40-1/4 percent of the cost of the permanent type bridge. This saving included all necessary fill material and surfacing. We have many more cases in which we anticipate using this type of structure.

There are also situations, such as canal crossings, that require larger central spans that cannot be obtained economically by using precast concrete sections or prestressed sections because of the distance from prestressed structure suppliers. Therefore we were forced to use monolithic type structures.

We have been using a hollow box girder, and the merits of this type of structure have been well established. We wished to continue with its use, but started an investigation to try and find methods of reducing the cost of this type of structure. We started the investigation by compiling the factors involved in placing the concrete, and found the forming to be paramount. As a result, we directed our energies to reducing or simplifying the forming, and

came up with a square, hollow-box type girder.

This design has probably been tried many times before, but it was new to us. It was "not much for looks but hell for stout." We have constructed four such structures and found the contractors have agreed with us because we received prices of $10 to $15 less per cubic yard of concrete in place than we had received prior to this design.

We have a few pictures of a hollow box girder across the Yakima River. This is the first bridge of this size that we designed with our own personnel. It is 510 feet long with a central span of 184 feet and depth of boxes 8 feet.

I have tried to give you a look at what we have been doing to cut costs. There are still many areas we must study which surely will present other savings. Our investigations have shown us that each situation must be considered on its own merits, and then a decision must be made as to what materials to use.

MERITS OF ACCOMPLISHING MUNICIPAL PROJECTS BY CONTRACT

Don Allen

In order that a clearer understanding may be had by all of you as to why I am discussing on this panel the merits of accomplishing municipal projects by contracts, a brief outline of the actual conditions that exist in the City of Eugene, Oregon, should first be made clear.

The City of Eugene was incorporated in 1905 and operates with a charter, as do all incorporated cities. One of the charter provisions is that in all municipal projects that are accomplished, the benefits of said projects are to be assessed to the abutting property owner, and shall be put out for bid to private contractors. Therefore, unless a charter revision is approved by vote of the people, the Public Works Department of Eugene has no other choice but to do work by contract.

One acquainted with the large variety of municipal projects can see immediately that there are other types of work that can be accomplished by public forces. Therefore the City of Eugene does experience work both by contract and force account. As a result, it would be possible for me to jump from one side of the fence to the other in this panel discussion. I have experienced merits in contract work as well as force account work, and also have experienced "ye pitfalls" of both types of construction.

The City of Eugene, during the 1959 construction season, completed 8.3 miles of street paving, 5.6 miles of sanitary sewers, 1.6 miles of storm sewers, and 3.5 miles of sidewalk. All of these projects were by competitive bid and private contract. Largest percentage of construction by contract is in the field I have just mentioned. This program encompasses some 60-odd separate contracts and involves just under a million dollars in total. This work was accomplished during our seasonal construction period, starting in May and the major portion completed in October.

In my opinion, one of the most important advantages to be realized by accomplishing the construction of projects by private contractors is that a wide variety of specialized contractors are available at a bid call to offer a competitive market of their services. These general contractors also have at their disposal a more specialized service in that of a subcontractor than could ever be assembled under one municipal working force. Also, these

contractors in most cases are reliable and competitive and outfitted with the most modern equipment on the market. The same contractors also are able to hire the cream of equipment operators, who naturally demand wages above those of municipal employees.

It is true that in smaller cities the competition in the contracting field is not keen. Advantages experienced in the higher degree of labor and equipment become less with a decrease in competition among contractors. All of us know, however, that the best equipment and operators do not make a going concern of any contractor. He must also have a high degree of leadership in his foremen and administrative officers.

It is also my opinion that a much higher degree of control can be placed on the work if done according to our standard contracting method, by use of up-to-date specifications, fully realizing advance methods and equipment available on the market, and that this work can be assured by the bonding of the contractor.

This type of work is also controlled to a higher degree by more rigid design drawings than probably would be forthcoming if this work was to be done by public forces. Thus, a lot of unforeseen hidden costs that creep up in force account work are elminated, in my opinion. Establishment of completion dates, with penalties or so-called "liquidated damages" are a definite incentive for work to be completed in a reasonable time as established by the contracting agency. I have found this an important factor in our public relations, and I am sure everyone is agreed that the sooner contracts can be carried to a successful completion, the better the attitude of the public.

Most of the contracts as experienced in the City of Eugene are of a seasonal nature, and weather in the area limits the actual time that projects can be successfully attacked. Approximately 80 percent of these jobs are accomplished within a 6-month period; therefore, employment of a wide variety of operators and laborers for such operations would be prohibitive to a municipal budget.

There is a fluctuation from year to year as to the number of projects to be accomplished. This is due to the fact that most public improvements are petitioned by property owners. This factor limits hiring policies. We have found it impossible to hold a highly specialized operator at muncipal salary levels for seasonal work. We are able, however, to concentrate our efforts on the field of inspection and design, thus helping to assure a satisfactory finished product.

In summation, I think the advantages of doing work by contract should be considered by any governmental agency on any construction project that can be more economically constructed by this method than that of labor or force account methods. Secondly, use of contracts should be utilized when project can be completed and placed in service for the public in a shorter period of time than if constructed by public forces. Thirdly, contracts should be utilized on all large construction projects of a difficult nature requiring special construction skills and equipment not ordinarily encountered by regular public forces. Thus, every official has a problem in determining when it is more economical to award a contract and whether or not savings and time will result from contract or a force account method. Size of the city will naturally determine whether or not efficient forces are available for construction of certain types and sizes of projects.

There are other phases of municipal work, such as maintenance and engineering, whose accomplishment by either contract or public forces also could be discussed. This, however, would open up an entire new line of discussion for which there is not sufficient time.

In closing, we can safely state that in Eugene, the Public Works Department will continue to utilize both methods of completing projects, and it will be a matter of opinion as to whether the desired advantages are reached, regardless of the choice of method.

WORK BY CONTRACT AND PUBLIC FORCES

J. H. Davis

Today I must take the affirmative with Mr. Paul Rynning on, "Resolved, it is more efficient and economical to do certain public works by use of public forces."

I am happy to take the affirmative in this particular discussion because I have long been a believer that much work can be done better by use of public forces. Let me make it very clear in the beginning that I will not attempt to justify doing all types of public works by use of public forces. The line to be drawn where work should be done by contract and by public forces will vary considerably in different communities and under various governmental setups.

No public body should ever attempt to do any type of public works unless it is fully qualified with personnel, equipment, and overall know-how to do the particular job. I believe Salem has been outstanding in cities in Oregon, and possibly in the Northwest, in doing the major portion of its public works by use of its own forces. This has been limited to street work, sidewalks, and sewer construction. In the past we have done some bridge work, but ordinarily this is contracted.

I am not speaking of maintenance, I am speaking of new construction, and will confine my remarks to this phase of governmental operation.

Now this question of personnel or know-how—I do not believe either the public bodies or the contractors have any monopoly on brains. You will find good men in all organizations. Public bodies, however, in order to do good work and do it efficiently must maintain a staff of these so-called "brains" on a year around basis, exactly the same as does any good contracting organization.

We often hear the question raised, "What do you do with these men in the off season?" I, in turn, ask the same question of any contracting organization. The answer, I believe, is that public bodies have ways, means, and enough variation of work that they get more out of their men on a year around basis than does the average contractor.

In Salem we make no attempt to keep throughout the winter all of the labor used in the summer on street work. We do keep the "brains," however, as we will call them, and they are very

necessary throughout the winter for any organization. We have ample maintenance and other types of work where we can utilize these forces until they never have a spare moment throughout the winter season. We will admit that occasionally you will find an employee working below his classification during the winter season.

Let me point out a few instances where I believe public bodies are in a position to do a better job on public works projects than the average contractor.

Take the item of scheduling work. One city I know of in Oregon awarded several contracts for street work in the same area. I believe there were three different contractors working in the same area at the same time. This made general confusion, not only to the public, but to the contractors and engineers in charge of the work. I believe that some of you will remember that considerable vibrations went back to the City Council about this type of scheduling. Work done by public bodies definitely can be scheduled to the best advantage to the property owner so that it can be completed in a more orderly manner.

Another instance of poor scheduling of work was where one of the larger contracting firms was working for a utility in Salem. It was three o'clock on a Friday afternoon. They cut across an alley in the downtown area, barricaded the same, and by four o'clock were on their way back to Portland. I received many complaints about this cutting of an alley so late in the week, and I believe the complaints were justified. True, it probably was efficient for this contractor to cut this alley because he had an hour's time for his men to put in before returning to Portland. When I carefully looked over this job, however, there was more than an hour's cleanup work that should have been done without cutting the alley.

Another instance happened a couple of years ago in Salem. State Street was widened for a distance of 5000 feet. It was a state-city cooperative arrangement under supervision of the state. The prime contractor made all of the excavations, including the removal of the old curb on both sides of the street. The curbing subcontractor arrived on the job three weeks after the excavation was finished. All straight curb was then installed, followed by the radius sections. In other words, the whole street was torn up for several months.

I claim these are examples of poor scheduling and that the average contractor does not give as proper consideration to the

general public and adjacent property owners as will a public body and public forces.

Now, let us take some of the small things that happen along an ordinary street job, such as notification to the property owner that a car must be moved out of a garage or that work in the street will require it to be moved immediately. The average city foreman, I believe, is better trained than the average contractor's man in public relations on getting this car moved and giving the property owner the proper information as to when it can be returned or where he possibly could store it.

Again, I have seen the case where a small rosebush needs to be moved because it is in the line of the curb. Moving of shrubs is not included in the specifications. Therefore, the contractor merely removes the shrub with a power shovel. Public forces would probably move the shrub back onto the property and replant it in a new location designated by the property owner. In Salem we do this.

Also, the little item of weekend protection on any construction job should be considered. I have found many contractors who put out their lights and barricades on the job on Friday night and hope they will be there by Monday morning. On many occasions I have been unable to find contractors' people in the city to take care of those that have been stolen, lost, or broken up, and have had to send city forces to maintain their lights and barricades.

There is one more important item we should consider. In the past 10 years the City of Salem, with its own forces, has completed nearly 2 million dollars worth of street construction. Over the past 10 years a 34-foot improvement using an 8-inch plus base, 2-1/2 inch single-course asphaltic concrete pavement with standard 16-inch curbs and including all excavation, drainage, and a 10 percent engineering fee, averaged $5.58 per front foot. This figure does not include cost of street or alley intersections. I could give you much additional cost data, but believe this record would be hard to beat for any contractor.

Time and time again I have been told that we cover up some of our costs. My answer to this is always the same, "Come and examine the city records and see for yourself." Two large contracting firms have done this. Neither one gave us a clean bill of health, but we did not hear any more from them.

WORK BY CONTRACT AND PUBLIC FORCES

H. O. Walberg

Work by Contract

In the ensuing discussion on doing work by contract, some necessary background needs to be reviewed in order to understand better the county view toward the contract method of construction.

First, we do not suggest that all work be done by contract. There are many projects too small to warrant the cost of plan preparation, and there is maintenance work that can be done feasibly by the day labor method.

Secondly, in some states there is a limitation by law as to the maximum amount that can be spent on a single project and constructed by public forces. A single individual project on one road exceeding that limiting amount has to be done by contract.

Thirdly, the determination of whether a job is done by contract or by public forces rests mainly with the policy-making body within the county. In some instances the engineer may exert some influence on the decisions.

Historical Background—Effect of F.A.S. Projects on Counties

The Federal Aid Secondary Program exerted the greatest influence on counties in becoming contract minded; basically because regulations controlling expenditures of F.A.S. funds required that construction be performed by the contract method, except in a few special cases when it could be definitely shown that it was in the public interest to use the day labor method. Small counties that were not properly organized and capable of handling F.A.S. projects by force account soon recognized their deficiencies and changed in most instances to the contract method. A commissioner from Colorado, who had a force account F.A.S. project in this county, told me that they lost money on the agreed unit prices but gained the needed experience required to set up a unit cost accounting system in the county by virtue of having to do the same on the F.A.S. project.

In trying to understand the general acceptance of the contract method by the counties, it must be borne in mind that sufficient financing has a lot to do with decisions. Funds available to counties may vary as much as $3 per mile of road to $2000 per mile, and those in the latter bracket are few. It would be expected

generally that if some so-called free money came along, such as 50-50 matching required on F.A.S. projects, a clamoring for such funds would follow. This is not the case.

In initiation of the F.A.S. program there was no widespread clamoring by counties for the funds available to them, and it was clearly evident that general acceptance of a program to improve the transportation system serving local residents could be achieved only by convincing the people of the amount of benefits to be derived by the program.

Counties were not accustomed to a construction program involving plans and specifications. Some were skeptical about standards to be established for improvements and expressed apprehensions about the possibility that costs for engineering and the higher standards might require more local funds for matching F.A.S. than had heretofore been expended for the entire cost of construction of like mileage of local roads.

Many counties contended that their road equipment was geared to an effective utilization of all available highway revenues and that withdrawal of a portion of those funds for matching F.A.S. improvements, to be accomplished by the contract method, would cause their equipment to be idle while they would be required to sustain an element of cost for depreciation on a contractor's equipment.

Some counties preferred to make crushed aggregate available in stockpile at a stated price for the F.A.S. project, of which the contractors could avail themselves, or produce their own if they thought it could be done more cheaply.

Many differences were resolved before programs got going in the counties, but once a beginning was made its continuation followed by public demand, and monies allotted for contract work usually were matched and utilized.

Engineering in Counties

Something must be said about engineering in counties, or lack of it, which, in my estimation has been a deterrent force against contracting more work by counties than they are now doing.

In order for a contractor to bid on a job there must be plans and specifications. To get paid for work done there must be an accounting of quantities. This also takes engineering, both in the

field and office.

From the records of some 3000 counties in the U.S.A., the great majority are understaffed both in field and office, and many have no engineering capabilities at all. In many rural communities engineering is frowned upon and not encouraged. This may seem amusing to those who do not have any connection with county road management, but it is not amusing to hundreds of county road department heads, who struggle along to put together a proper organization.

Several years ago I had occasion to ask three commissioners, not in this state, why they did not have an engineer. They had stacked up $60,000 available F.A.S. money, but had no plans nor had even started an attempt to get any. Their answer was, "This surveying costs so much."

It is encouraging to note that in recent years there is steady progress in the betterment of road administration.

Unit Cost Accounting

One of the most important assets to a county road organization is a unit cost accounting system. With this tool properly set up and utilized, all of the discussions of contract versus force account would be settled without generating any high blood pressures within the ranks of the A.G.C. and county policy-making bodies. All that would have to be done by the awarding authorities would be to make an honest comparison of costs and then assign the work accordingly.

In making this comparison of cost, it is of utmost importance that all day labor costs be included in the force account project.

Type of Projects for Contracting

Assuming that we have unit cost accounting established and operating to a point where selection of projects for contract can be made, what types of projects would normally be selected for contract?

The following is my personal estimate:

Structures

1. All large bridge projects, concrete and steel
2. Tunnels

3. Overpass structures
4. Buildings

Roads

1. Roads such as F.A.S. projects
2. Road projects with large quantities both in common excavation and rock
3. Hot mix surfacing projects
4. Dedicated roads

Crushing. All quarry operation in production of crushed rock.

What Projects Are We Contracting Today?

Since a lot of the foregoing may be construed to be conjecture, the question may fairly be posed, "What are you doing this current year?" The board of Lane County commissioners have let the following projects in the current budget year:

1. Combined road and dike project for $93,000. This was in combination with the S.C.S. and other governmental units. Job completed.

2. One concrete structure - $79,000. Not started.

3. Crushed quarry rock for surfacing projects - $563,000.

The following jobs are to be let:

1. Three bridge projects under F.A.S. - $600,000.
2. Road project - approximately $80,000.

Conclusion

In general, public works construction by contract, on large projects, is the best way to assure the taxpayer that his dollar is economically spent because:

1. Lowest possible cost is secured through advertising the project in open competition with other contractors.

2. Amount of contract is known before job starts through unit cost bidding.

3. Completion dates are set.

4. Adequate engineering and inspection assures a properly completed project.

FORCE ACCOUNTS VERSUS CONTRACT

Paul B. Rynning

This subject has been discussed and debated many times before, and I realize there are two sides to every question. We should differentiate between the good and the bad in comparing good contracting with poor force account work, or vice versa.

I have been an engineer and road administrator for more than 35 years, and most of the work under my jurisdiction has been by the force account method. I also have supervised many contract jobs.

I wish to make it clear at the start that I cannot defend so-called WPA projects or force account work handled by elected politicians who are interested only in votes and jobs for their friends who help them get elected. If I am stepping on some toes, I will not apologize for it, but can only feel sorry for the toes stepped on. I will also eliminate force account work by large governmental agencies such as those of the federal or state governments because of remote controls. Force account work is done mostly by counties or cities, and I will relate to you how this type of work can be efficient and economical.

The following factors must be considered in the successful operation of any job: labor, equipment, materials, financing, overhead, and administration. Without proper administration no job can be operated successfully. Therefore, this position is very important and must be considered first.

An administrator must be qualified to handle any or all types of work which the governmental agencies expect him to do, and he should follow the policies formulated by his superiors. Is there any reason why such a person cannot be obtained for force account work?

Labor, both skilled and unskilled, is vital to both contract and force account work. Is there any reason why good labor cannot be obtained for force account work as well as for contract work?

Equipment and machinery are a must in this era of heavy construction work. Is there any reason why the same type of machinery and equipment cannot be obtained for force account work as well as for contract work, and just as cheap?

With good administration, efficient labor, and proper equipment, why cannot work be handled as cheaply by force account work as by contract?

I am not so naïve as to say that the average cost of construction can be done any cheaper. Why then force account? A contractor, in order to be successful, must add to his cost profit certain overhead charges which force account jobs do not have—proposal bonds, etc. Overhead costs on contract work as a rule are usually higher because a contractor is required to move from the location of one job to another, whereas an agency using force account is in the same location the year around and jobs are fairly close together. Contract work also requires more inspectors than are used or needed on force account work because the superintendents and foremen on force account jobs are, in themselves, inspectors.

As an example of what I consider a good organization for force account work, I will describe the organization and operation of the Jackson County Road Department. The county court is the elected governing body and determines the policies to be adopted. It appoints the engineer to administer the work and does not interfere in the selection of those under him. The engineer appoints the general superintendent, bridge superintendent, equipment superintendent, and three division maintenance foremen. Duties and responsibilities of each are fixed by the engineer.

The general superintendent is in direct charge of all grading, rock and gravel surfacing, and paving. In the absence of the engineer he also assumes control over all other superintendents and foremen. The bridge superintendent is in charge of all bridge and concrete box culvert construction and maintenance. The equipment superintendent is in charge of all machinery and equipment maintenance and upkeep. The three maintenance foremen each have a district and take care of normal road maintenance. Each of the superintendents and foremen is responsible for hiring and firing of all men under him.

Generally, a three-year program is under constant consideration in order to know what will be needed in manpower, equipment, materials, and finance. Work is laid out so that manpower and machinery can be used continually throughout the year with a minimum of labor turnovers and capital investment in machinery and equipment can also be kept to a minimum.

During the dry season, grading and surfacing construction is of prime importance and pushed as fast as possible. The same

is true of bridges and culvert construction, especially where stream flow may be a problem.

There is the closest cooperation between the various superintendents and foremen. Should any of the superintendents or foremen be in need of extra help or equipment, the general superintendent will order transfer from jobs under other foremen, which, in his judgment, would be to the best advantage of the overall program. With a number of jobs going at the same time, this is very simple. Also, should a breakdown occur, such as a powerplant on a rock crusher, and there is no use for the other equipment around the plant such as trucks, shovels, etc., then the trucks are dispatched immediately to other jobs with no loss of time for employee or equipment.

Jobs also are laid out in such order that one job will use trucks on short hauls during the time another one is using trucks on long hauls. As the haul becomes shorter on one job or longer on the other, the trucks can be shifted very easily to balance the use of trucks.

The county does contract some of its work if in its program certain jobs arise that require machinery over and above what it owns, or requires more labor than it usually carries on its payroll.

The county has on its payroll approximately 150 employees, with a turnover of less than 10 percent. Equipment it owns also is kept in continual use throughout the year, with the exception of such items as a road oil distributor that can be used only during the dry season. The county has a very good machine shop, and has a policy of keeping its machinery in good condition at all times in order that breakdowns may be kept to a minimum.

From my experience, I know Jackson County has profited financially and in time by having its own forces. Others could do the same if they would carefully study their needs and plan accordingly.

With good administration, personnel, and equipment, advantages to the owners can be summed up as follows:

1. Save on overhead such as bids and proposal bonds
2. Save on moving great distances with labor and equipment
3. Save contractors' profits
4. Save on cost of extra inspectors

5. Personnel turnover kept to a minimum

6. Able to transfer labor and equipment from one job to another wherever needed without loss of time or equipment

7. Same crews and equipment can be used on construction, betterment, and maintenance

THE PRESS VIEWS HIGHWAY TRANSPORTATION

Marshall N. Dana

My life has been long enough to encompass the modern beginnings of improved highways.

As a boy, the first axiom I heard uttered about a road was that the bail of a kettle is no longer horizontally than vertically. This meant, of course, that going around a hill entailed no greater travel than going directly over it—and the custom then was to project the road straight ahead, regardless of hills.

The next great step in highway improvement was the King road drag. Two logs were fastened V-shaped, reinforced at the broad side of the triangle. This device then would be dragged over the muddy road and, as I reflect now upon the process, the result must have been a puddling of the mud so that water flowed off of the surface rather than into the composition, maintaining for a period at least, a surface in which fear need not be so acute that the horse and buggy or the wagon would be hopelessly mired.

Then there grew into the consciousness of road users the name of another man who, I think, really was the forerunner of the modern improved highway. His name was Macadam. With him became established the rocking or (British speaking) "metaling" of roads.

I do acknowledge these as progressive steps of comparatively modern times, not to be viewed oblivious of the ancient Romans' roadbuilding art, so well memorialized in the Appian Way, which I once traveled myself and found it capable of a spanking 20 miles an hour.

My respect mounted for the highway engineer—who really was attaining a professional status as the steps of progress were taken—when I heard more frequently repeated another axiom, "Balance your quantities." This meant that if the highway was to be plane and the crooked road straight, excavated material from the hills would be used to fill the valleys.

This is the rule today as we enter into an era of highway building which is the greatest in the memory of man.

My recollection travels into yesteryear to find that improved roads as a campaign appeal awakened as much opposition and derision as enthusiasm. I did hear diligent producers of farm

crops say that a good road was just a waste of money and that it would speedily go back to a cloud of dust in summer and a streak of mud in winter. It was rather an accepted practice, yet sometimes protested, when the county commissioner thought the deity of improvement had been well served by building a stretch of good road in front of his own home.

There was also a difficulty met by a newspaperman who wanted to use the power of the press to advance the cause of good roads. I remember half a century ago of making my painful way out on Macadam Street in south Portland accompanied by a photographer whose pictures when they were printed in the Oregon Journal looked like lovely scenery and not at all like the ruts, "thank-you-ma'ams," holes, and pools which in this thoroughfare belied the name of Macadam.

Now we have come with almost complete public acceptance and support to a time when the broad highway passes far beyond the concept of Jeffery Farnol in his older but delightful book of that name. We are building highways that are thoroughfares, freeways, and supers. We are spending billions of dollars on aggregates, cements, and structures. We are operating cars that even with decades of driving experience we must glance frequently at the speedometer to learn whether we are proceeding at controllable speeds.

The highway engineer has brought our highway science to a point of smooth progression, regardless of the vehicle or weight of the load. This is not to say perfectionism has been reached. There is yet much room for research, improved methods, and all of the steps that can be taken to make highways smoother, more enduring, and safer.

Everything has changed—except the human.

Thus, we face the sore problem of safety. If all of us had learned safe driving as well as the highway engineer has learned to incorporate safety factors in construction, then we would kill fewer than the 30,000 or 40,000 a year whose blood reddens our streets and highways. Then we would spend less than the 5 or 6 billion dollars a year as the cost of lives wasted and property destroyed. Then we would add pleasure and reduce tragedy as we traveled along.

Once the mud and dust forbade us to see the beauty of the scene; now we must be careful that we do not lose the inspiration of scenic grandeur because of speed, because of congestion, because

of the overt violation of the Golden Rule which commands us to be considerate of others as well as to be solicitous for ourselves.

Having spent a material part of the last seven years as secretary of the Oregon Highway Lifesavers, I have become convinced that the real limitations are not upon the highway nor upon the vehicle, but upon the reflexes of those who sit behind the wheel. Unhappily, these limitations are accompanied by an apathy and, indeed, a fatalism which lures the driver into the expectation that while accidents may rudely interrupt other drivers, it WILL NOT HAPPEN TO HIM. How very often this banal thought explodes into violence and death!

While I hold that the primary responsibility for safe driving and for reduction of traffic accidents rests upon the "man behind the wheel," there are regulations that, in their observance, will reduce the margin of hazard. There are laws which need to be passed by the Oregon legislature that are especially necessary in curbing the rash impulse of the minor percentage of drivers who will not otherwise conform to the rules of safe driving. Some real progress has been made toward the enactment of such legislation by the 1961 Legislature.

The Oregon Highway Lifesavers have come out for a chemical test for alcohol by implied consent. A favorable position has been taken by OHL on arrests for probable cause. Currently, the arresting officer must be witness to the violation when it is a misdemeanor, and many escape due penalty because of this fact.

Progress has been made toward agreement on a speed ceiling for the Oregon Basic Rule. The Basic Rule reads:

> 483.102. Basic Speed Rule. (1) No person shall drive a vehicle upon a highway at a speed greater than is reasonable and prudent, having due regard to the traffic, surface and width of the highway, the hazard at intersections and any other conditions then existing. (2) No person shall drive at a speed which is greater than will permit the driver to exercise proper control of the vehicle and to decrease speed or to stop as may be necessary to avoid colliding with any person, vehicle or other conveyance on or entering the highway in compliance with legal requirements and with the duty of drivers and other persons using the highways to exercise due

care. (3) Subsection 2 of this section does not change the rules of pleading and evidence relating to negligence and contributory negligence.

A speed ceiling on the basic rule would simple mean that an automobile may not be driven at a higher speed than, say, 70 miles an hour, and this under regulations of the Speed Control Board and the State Highway Department. The uniform citation already has approval.

Numerous legislators have subscribed to the remedial legislation outlined. At a recent meeting of the Highway Lifesavers, State Senator Carl Francis, chairman of the Senate Judiciary Committee, and Representative George Layman, chairman of the House Judiciary Committee, indicated a favorable attitude which will be more or less influenced by the nature of bills yet to be introduced.

The Interim Committee on Highways, of which Senator Anthony Yturri is chairman, has taken a strongly favorable position on the correctives indicated—indeed, to such extent that the fear that traffic safety measures will be buried in committees has been greatly allayed.

The State Department of Motor Vehicles is pursuing a very aggressive campaign for traffic safety, including declarations favorable to safety legislation. This department includes the State Division of Traffic Safety.

Governor Mark Hatfield has, without reservation, declared that traffic safety legislation is the duty of the legislature, and he has pledged all of the influence of his office to secure it.

There has been hanging over the issue of traffic safety legislation for some time something that I would rather construe as a promise than a threat, and that is if states fail to pass necessary laws, the federal government through congressional act may take over. It is plain to see that the enormous problem of fatal accidents is proceeding toward solution.

My tribute is to the highway engineer and the swift progress of his building science. My tribute is to the builders of highways and to the public which enthuses over them, travels them, and pays for them. But, my lament is directed not to the public en masse, but to the individuals who disregard all of the rules of safety that

common sense and the instinct for survival set up. We have stop signs for dangerous intersections; we have warnings for railroad crossings. As drivers we sorely need a warning beating continuously in our own minds: "Drive and stay alive."

As a newspaperman seeing the highly provocative title, "The Press Views Highway Transportation," my urgent advice—nay, my hope—is that safety will be given as prominent a place in our highway program and in our driving as are engineering and construction.

It is a compelling goal, one worth the efforts of all of us, to establish a truly balanced highway program—good roads, good cars, and good driving. Billions for modern highways is sound economy—but billions for accidents is senseless waste.

THE PRESS VIEWS HIGHWAY TRANSPORTATION

Elmo Smith

While my personal schedule has become somewhat complicated since I agreed some six weeks ago to participate in this discussion, I overcame a first thought to send apologies and proceeded to spend some time preparing the comments which will follow. I wanted to keep this date because I have a very definite opinion on the topics assigned to me or which were suggested that I cover. I probably have had more experience dealing with these problems than most people. I do not know whether that is a fortunate circumstance or not, but in any event I would like to give this group the benefit, if any, of what that experience taught me.

Mr. Cameron suggested several related topics that I might cover. They are: "The Engineer and Legislative Bodies; What Can be Done to Promote Better Understanding of Each Other's Problems Relating to Highway Publicity," "How Can the Engineer Improve, Assist or Secure Better Publicity for Highway Planning, Design, Construction, etc.," and "Better Relationships Between Highway Engineers and Town and City Officials." Each of these, of course, could require a considerable amount of time for discussion, depending on the depth we wanted to go into in probing the associations.

First, let us discuss the engineer and legislative bodies. When highway engineers and planners think of legislative bodies, or rather members of their legislature, they should keep in mind that a great many of these people have gained membership in the legislature by promising the people at home what they can get for them in the way of additional highway benefits if they would only send them to the State Capitol to attend to this matter. Of course, most of them have a sincere belief that they can accomplish such improvements and that they are meritorious above the requests of any other part of the state.

I am sure that most of you have undergone the experience of having a feeling, when appearing before a legislative committee, that you were the sacrificial goat on the altar of political expediency. I served on the Highway Committee in the Oregon State Senate for three sessions, during which highway legislation faced some very stormy times. During my first session on the Highway Committee, there was a considerable feeling that R. H. Baldock, the Oregon State Highway engineer, did not respect the legislature properly, or at least the importance the various members placed on that honor, and did not appear personally before the committees often

enough to permit them to get the straight story on highway matters. More important, they wanted to be sure that Mr. Baldock understood their home road problems, which often, as stated by the legislators, usually reflected arguments of their respective Chambers of Commerce. I felt that this was a rather bad situation for the Highway Commission, and that more attention should be paid toward public relations and currying the favor and understanding of these legislators since they were in a position to vitally influence the highway program. This, I believe, was in 1949.

Acting on the advice of myself and others, Mr. Baldock made himself available during the 1951 session to the extent that I am sure the Highway Department suffered some in its administrative organization. Mr. Baldock became embroiled in a very bitter taxation fight. He answered all questions legislators asked, and he did not give ground if he felt he had suffered an unfair attack or was defending a worthy policy of the Highway Department. So, we went from one extreme to the other.

Along came the 1953 session, and the picture had completely reversed itself. You could hear Mr. Baldock being accused of trying to run the legislature, trying to dictate the highway program and relevant legislation, and being very obnoxious by spending so much time around the legislature.

So, I am happy to report that in the 1955 session Mr. Baldock again confined most of his activities to highway engineering and the legislature confined its activities to listening to the various experts from Mr. Baldock's department, and doing the best they could, each from his respective approach to the problems.

If I am supposed to reveal in this discussion just what the engineer should do about the matter of promoting a better understanding with the members of the State Legislature, you are going to be disappointed.

I will make a few suggestions, most of which can be found in a primary public relations book, which say that a better, or the best, factual understanding of all problems involved insofar as they can be explained consistent with good administration, should be made available to legislators in a manner they can understand.

Oregon has been singularly fortunate over most of the period of its modern highway planning to have avoided the legislature interfering in the planning of highway routing. This policy, I am unhappy to say, was violated by the 1957 Legislature, which attempted to

pay off political debts by legislating the highway in Coos and Curry counties and legislating the Astoria Bridge. Both projects at that time did not meet with the economic levels recognized as being necessary for sound highway projects. They may be meritorious, but if the legislature continued to pursue such a policy it would completely wreck sensible and orderly development of a highway system.

Publicity, which is just another way of saying proper presentation for better acceptance of a worthwhile product, is an intangible. That may be one of the factors that makes it difficult or appear difficult to people working with tangible products, such as highway engineers.

I am not familiar with other states, but I do feel that Oregon's Highway Department has maintained good public relations. The press has been appreciative of and sympathetic to the problems faced by the Highway Department. News media have always been willing to publicize highway programs and keep the public informed of new projects and progress on others.

I do not want to go into detail on highway signs and detour handling except to say that on the matter of detours the motoring public is handled much better in recent years than in earlier days of highway construction. I believe there are a few contractors who require more supervision than others. They should be watched to avoid attracting unnecessary criticism being reflected on the Highway Department or highway engineers through their disregard of a sense of public relations in their own organizations.

In the matter of the highway engineer and town and city officials, I again can call on personal experience because some years ago I served as a city official with the responsibility of street planning in connection with highway development through a city. One of the points raised by Mr. Cameron was to comment on whether or not relations between highway engineers and city and town officials could be improved. I am a little dated because I am not familiar with the present status on the relationship, but since I have not heard any serious complaints it would seem that the relationships are good.

Problems faced by cities and city street planning officials and state highway officials require for proper solution a good understanding of the problem in general and the problem as it applies in the field of responsibility of each agency. We all know that at least 90 percent of the people are no problem in matters where a

a difference of opinion is involved if all factors and facets faced by each are made known to all. I do not believe further legislation would improve this situation because it becomes pretty much a matter of personalities. When these clashes occur, one way or another, they are usually resolved before too much damage can be done. Too often legislation designed to expedite turns out to be a hampering device over a period of time. I think we should operate with as much of the area of decision as possible left to the decision of competent engineers and public minded civic administrators.

In closing, I want to very earnestly and frankly state that in my experience as a public servant who has had considerable contact with the problems of highway engineers, and as a newspaper man, that an excellent job is being done in the overall picture of highway engineer public relations. I believe acceptance that the public gives to the manner in which you carry out your assignment is extremely good, particularly when it is recognized that the product you develop affects the daily lives and daily pursuance of economic tasks of almost every citizen.

PRESS RELATIONS WITH HIGHWAY ENGINEERS

Donald J. Sterling, Jr

Everyone wants to have "good public relations," which simply means getting along with other people with the minimum possible friction. The contacts which public officials, including highway engineers, have with the press have a very important and beneficial effect on their public relations. It is worth remembering that in dealing with the press you are really dealing with the public. No newspaperman legitimately asks for special favors for himself or his paper, but only for that information about public business which any citizen is entitled to receive.

Undoubtedly, professional highway engineers can think of more examples than can an outsider of ways in which the press can help them do their difficult and important job—for instance, in explaining the need for and the eventual benefits of construction projects that seem to offer only inconvenience and even serious financial hardship to the public, or in convincing voters, county courts, and the legislature of the value of bond issues and appropriations for road work, or in curbing vandalism on the highways, etc.

At the same time, the public has an absorbing and legitimate interest in how their roads are built and maintained. It is a fact of life that Americans love their cars and travel and have a great curiosity about anything involving them. Of course they also foot the bill for all the work that public highway engineers do, and their private finances and private lives can be affected deeply by the decisions made by highway planners.

If we assume then, as I do, that newpapermen and highway builders should work closely together, what specifically can be done. Let me suggest some of the ways you help a newpaperman help you. These ideas are based largely on my experience as a former reporter of the affairs of the Oregon State Highway Commission, which does an excellent job in putting most of them into practice.

1. Meetings of highway commissions and other bodies having to do with highways should be open to the public, and the press should be notified of them in advance. The same is true of sessions of city councils and county courts dealing with road matters, as well as with other public matters.

2. Highway officials should make themselves easily available to reporters to answer questions and to explain problems involved

in particular projects.

3. Nothing explains a highway job better than a map. Make maps available to the press.

4. Publish your annual budgets and other roadbuilding plans as soon as possible so that the public can have adequate advance information on what you plan to do and when.

5. Announce bid openings before they are held and contract awards after bids have been tabulated. This is one of the ways the public learns when a project is being started, who is going to do the work, and how much it will cost.

6. Invite along the press on highway inspection trips. This does not mean organizing junkets for the press, incidentally. Good newpapermen expect to cover legitimate news and to pay their own ways while they are doing it.

7. Hold public hearings on controversial projects and give the public through the press and other agencies adequate advance notice of them.

8. Publish annual reports or other periodic written summaries of work your office has been doing. If you have particular difficulties on which public understanding is required, discuss them frankly.

9. When special news develops involving your department don't be too shy to tell the press about it by mail, telephone, or personal visit. Newspapermen try to keep up with what is going on, but they know they cannot cover everything. They appreciate being notified of such news as start or completion of projects, promotions or retirements on your staff, changes in traffic routes, etc.

The answer to the question of whom you should deal with on specific matters will depend on the subject and size of the paper. In a small town, one or two men may do everything in the newspaper office. In a large city such as Portland, the staffs have widely varying responsibilities. In general, when you have a matter of editorial support of general policy on your mind, the editor or the owner probably is the man to talk to. If you have information about a specific news event, in most cases you should talk to the city editor, who directs all local news coverage. In the long run, your news story likely will be written by a reporter, and the more

helpful you are to him the more complete, accurate, and satisfying to you your story is likely to be. In many cases you will be seeing this reporter regularly as he makes his rounds in the courthouse or office building where you work.

Some people have a misconception of what a newspaperman is looking for. He is as glad as the next fellow to produce a product that will sell. In fact, like everyone else, he has to. Stories which, over the long run sell newspapers, are not the sensational tales of scandals and misdeeds. You need not fear that a newsman is nothing but a human vacuum cleaner, snuffling for dirt. What he wants is to give his paper's readers information that will make their lives more pleasant and more interesting. News about highways certainly fills these specifications.

You have a right to expect from newsmen that their stories will be fair and accurate. In turn, the man who has the best relations with the press, and through it with the public, generally is the man who is frank, truthful, and just plain human.

WHY TRAFFIC ENGINEERING?

J. Al Head

My appearance before you today is neither "fish nor fowl." I should be an expert, but I lack several of the prerequisites. I am not far enough away from home, and I also lack the complete knowledge and wisdom required to present this total subject to you to qualify as an expert. I would like to relate, however, why I am here before you presenting this talk.

The Steering Committee for this conference met at the Marion Hotel in Salem, October 1959, and discussed general topic material they felt would be good for inclusion in the program. At that time it was felt advisable for someone to discuss "Why Traffic Engineering?" The thought was that there was a need for using the talents and tools of the traffic engineering profession to greater advantage than they were being used, and that many agencies, or should I say many cities and counties, were not availing themselves of professional traffic engineering services, but would if they were more conscious of the working tools, services available, etc. Mr. Forrest Cooper, deputy state highway engineer for the Oregon State Highway Department, very graciously volunteered my services to accomplish this mission!

WHAT IS TRAFFIC ENGINEERING?

The last few weeks, while I was quite desperately searching for something on which I could develop a theme for my talk, I kept going back in my mind to prior meetings we have held and to discussions we have had throughout this area, the West, and the United States. One thing kept haunting me, and that was, "What is traffic engineering?" For this I went to the definition established by the Institute of Traffic Engineers, and I would like to read it to you.

> Traffic engineering is that phase of engineering which deals with the planning and geometric design of streets, highways and abutting lands, and with traffic operation thereon as their use is related to the safe, convenient and economic transportation of persons and goods.

Now that is a complex definition. It is, nevertheless, an all-inclusive one and does what, in my opinion, is a very excellent job of defining the total concept of traffic engineering. That is, the planning aspect, operational aspect, and interrelation of the

two to the total good of the community. An eminent Oregon State Highway engineer has suggested that possibly the following definition would be more apt:

> Traffic engineering is that phase of engineering that is concerned with (pardon the personification) the behavior of motor vehicles on streets and highways and the methods, procedures and devices used to direct them to their destination and to maintain air space between them and other movable or fixed objects, including pedestrians.

Today, however, I wish to dwell more on the traffic operational phase as related to safe, convenient, and economical transportation of persons and goods, rather than to the more broad, intangible planning and geometric design phase of the total concept of traffic engineering.

OBJECTIVES OF TRAFFIC ENGINEERING

Only last week a review of a short course in traffic engineering came across my desk from Mr. James Reading, traffic safety coordinator for the City of San Diego. Mr. Reading is past president of the Western Section of the Institute of Traffic Engineers and was, prior to accepting his present assignment, traffic engineer for the City of San Diego. He was responsible for chairmaning this short course in traffic engineering for the San Diego community and, in reviewing the results of this particular conference, I was intrigued with the objectives as set forth at that meeting. I feel they bear repeating here.

> To examine engineering techniques used to reduce the frequency and severity of traffic accidents.

> To encourage uniformity in the use of traffic signs, markings and devices, not only county-wide, but nation-wide.

Turning to another statement in his objectives, and although the reference is to San Diego residents, it is just as applicable here as anywhere.

> We are all in this together. San Diego residents are violating traffic laws and causing

accidents in other cities and vice-versa. Many people live in one city and work in another. Whatever any one of us accomplishes should help all of us.

Other detailed objectives are as follows:

How to get facts on accidents and conditions.
How to analyze and study those facts.
How to correlate the findings and determine which are pertinent and usable.
How to select and apply the best corrective steps.
How to measure the effectiveness of the treatment.

I think that Mr. Reading, in setting forth the objectives of the San Diego conference, touched upon the same basic concept that your Steering Committee had in mind when they asked that I discuss with you the topic, "Why Traffic Engineering?"

Traffic engineering was conceived as a science that would allow the bringing together of basic principles available from physics, mechanics, and the like wherein the laws of motion are put to advantage in relation to the motor vehicle and the roadway over which it travels and their interrelation to people. It also brings into play a knowledge of psychology in habits of the motoring public. This latter point we will not dwell on because it in itself would make material for a total conference.

DEVELOPMENTS IN TRAFFIC ENGINEERING

I would like to point out one or two basic points which I feel those of us who have not availed ourselves of the working tools of the traffic engineering profession should be aware of.

There are several good texts in the field of traffic engineering, such as the Traffic Engineering Handbook, National Manual on Uniform Traffic Control Devices, A Policy on Geometric Design, and Highway Capacity Manual, for those engineers confronted with the responsibility of exercising traffic engineering decisions. There are also many publications on traffic engineering studies and many other related manuals that have been prepared which are available by consulting directly with your highway departments or the Institute of Traffic Engineers.

I believe some of the developments over the past 30 years in the field of traffic engineering have been outstanding, because it is only an infant when compared with the sciences of road building, bridge building, etc. During this period, through study of what was done and how effective it was by before and after analyses, certain basic precepts were developed. The precepts in their development show that it is possible to establish warrants for installation of traffic signals, warrants for placement of stop signs, warrants for establishment of arterial streets, warrants with respect to parking restrictions and regulations, warrants for speed zoning, warrants relating to almost any phase of traffic engineering.

I believe I can say in complete sincerity that here in Oregon your highway department is always at the service of any community to render services to them and apply warrants for them in the field of traffic engineering. The department may have to limit some of its services, depending upon the magnitude of the project, but they are always willing to consult with you and give you advice on any matter regardless of its magnitude. I also am confident that other highway departments in the Northwest will assist you. We urge you to feel free to call upon them to seek their advice. If you need information on traffic volumes, accident data, etc., generally speaking the highway departments have these data already tabulated and they are available to the requesting agency.

There will be a very interesting discussion tomorrow on uniformity of signs, signals, markings, etc., which touches upon one of the objectives that Mr. Reading set forth for the San Diego short course. I will not dwell on this subject, but I do urge you to listen to the presentation for it illustrates the need for uniform practices and uniform action by all of us. The motorist driving an automobile is not cognizant of who has jurisdiction over the street or road that he travels. He is interested only in safe, convenient, and economical transportation between his origin and destination for the trip he is making at the moment. He is looking for uniform treatment with respect to stop signs, sight distance restrictions, removal of brush, turning radiuses at intersections, parking restrictions, traffic signal placement, paint application, etc.

PROFESSIONAL APPLICATION

As I mentioned earlier, there is considerable area for use and application by all groups of some of the nationally accepted standards and warrants that are available and that have been tested and proved to be quite acceptable. I would like to draw the analogy

between the traffic engineer and other professional people.

For an example, let us take the interrelation of traffic engineering to accounting, law, or medicine. All of these professions start by observation and recording of facts. They next analyze these facts by arranging them in proper sequence—grouping, regrouping, and comparing—then it logically follows that by comparing, relating, and studying they bring the significant elements of the basic facts into proper focus. A final step in these professions is to determine and apply on the basis of the correlated factual information, the design, equipment, or remedial treatment which is indicated as being the most appropriate.

These four steps can be stated as "observe," "analyze," "correlate," and "apply." Any successful business in a competitive field avails itself of professional accounting guidance and business management principles and surrounds itself with competent people in the field in which it is engaged. They exercise these same four steps so that the firm may be successful and remain in business and yield a profit.

The lawyer gets the facts, arranges them in their proper order, prepares his brief, compares them with other cases of similar nature and decisions that have been handed down, and is guided by these precedents.

The medical profession also uses these same steps. They observe, analyze, correlate, and apply. Their word, however, is more appropriately "diagnose," which covers the first three of these four steps, and then they apply the diagnosis to develop a treatment and cure.

In the field of traffic engineering we are confronted with the same basic steps. We must determine what we have, how much we have, how efficiently it has been operating, how it compares with other similar situations, and what is the solution. So, regardless of whether we are diagnosing a medical ailment at the professional level of the doctor, or seeking a solution for a simple traffic problem, a professional traffic engineer uses the same basic lines of reasoning as does any other professional person.

POLITICAL APPLICATION

I think it can be stated that although the traffic engineer has many of these tools at his disposal and exercises them with diligence,

probably the following statement relating to traffic signal warrants, taken from Vol. 15, No. 7, April 1945 issue of "Traffic Engineering," summarizes the results of an engineer in developing warrants which possibly were a little more practical than were the application and analysis of the cold, hard facts of traffic volumes, accident experience, speed characteristics, geometric design, and interrelation of these units. I quote to you the following in relation to his revised traffic signal warrants:

> This is a bit of whimsey, for which we are indebted to an Indiana traffic engineer, whose name shall remain unknown lest he bring down upon his head the wrath of politicians and others who might resent labeling this as nonsense. Ed.
>
> In considering the warrants for traffic signals, the statement should be made that in every case possible the evaluated warrants should be made to approximate 100 points or percent. If speed is the predominant factor, it should be rated accordingly. If volumes, turning movements, pedestrians and accidents all have a share in determining the advisability of installation, then each one should be rated for comparative purposes.
>
> In our experience in making city traffic surveys, there has been developed a set of traffic signal warrants that seem to more nearly reflect the actual conditions than do the standards generally used. These are as follows:
>
> 1. If there is a schoolhouse within three blocks distance of the intersection being considered - 15 points. If within two blocks - 25 points. If within one block - 50 points. If on the same corner - 118 points.
>
> 2. If there is a church within one block distance - 20 points. If on the same corner - 76 points. If two churches are on the same corner - 111 points. If three churches are on the same corner - put in an entire signal system.
>
> 3. If a city councilman's aunt lives within one block distance - 20 points. If she lives on the same corner - 48 points. If councilman lives in that section of the town - 40 points. If he lives within

one block - 69 points. If he lives on the corner - 153 points.

4. If there is a drugstore, with cigarettes - 38 points.

5. If there is a service station with a public-spirited attendant - 57 points.

6. If there is a petition with 50 to 500 names - 271 points.

7. If there have been three near accidents at intersection within past year - 40 points. If two near and one actual accident - 50 points. If one near and two actual accidents - 85 points. If three actual accidents - 196 points.

8. If the Mayor has trouble crossing the intersection - 77 points. If he has trouble turning - 40 points. If he thinks he would have trouble if he drove upon that street - 18 points.

9. If there is a lot of traffic through the intersection (200-400 per day) - 35 points. If street is just full all the time (599-800 per day) - 57 points. If you have to wait sometimes for an hour before you can cross (1000-2000 per day) - 92 points.

10. If a few points are still needed, an engineering survey, thorough and complete, is worth from 10 to 30 points.

It is the old story of proceeding from unwarranted assumption to foregone conclusions unimpeded by facts.

I realize that we all are confronted with these same decisions as to when we exercise cold, hard facts and when we exercise political expediency. Somewhere there is a meeting place where the two items can be brought together and a proper equitable evaluation achieved.

I will not dwell on the political aspects other than to relate one thought which comes to my mind. When we use the word "political" we think of "politics"—and when we look for the derivation of the word "politics" we go back and find that it is a "people." The people, after all, are the persons that we serve, that we help, that we must work with. We can apply good sound traffic engineering judgment, and yet if it is not acceptable to the

people, then we must be conscious of politics, for the elected representatives of the people speak for them. Yet, I think in these same elected representatives who comprise your city councils, your county courts, your state highway commissions, etc., you will find that when you discuss with them rationally and present to them in a logical sequence the factual data on your problem and why you wish to do it, almost invariably they will accept your recommendation wholeheartedly and work with you in its implementation.

WHY TRAFFIC ENGINEERING?

Let me state one last thought. What has all of this to do with "Why Traffic Engineering?" Traffic engineering came about because we needed to develop more capacity out of our existing facilities, many of which were created and designed for the horse and buggy and improved for the slow, cumbersome motor vehicle. We are still trying to use many of the same facilities with the high-powered motor vehicle of today. Were it not for developments in the field of traffic engineering in putting to use the many sound, scientific facts that have been developed throughout this country and elsewhere, traffic would undoubtedly be stagnant.

Keep in mind that traffic engineering is a desirable tool to be used to implement the safe and convenient flow of traffic in an economic manner, and that without these tools for orderly flow of traffic there would be no order, and without order there would be chaos. If we cleave to uniformity, assist each other, and work together so that this uniformity can be extended throughout the total area in which we are operating (I think in this instance the area includes the United States, Canada, and Mexico), before long the orderly operation of the motor vehicle will extend well beyond these limits. Thus, the next step in the "why" of traffic engineering is to expand its out-reach into the total of the world so that there will be order in the operation of transport facilities.

I recently read a paper on "The Application of Traffic Engineering Principles," by R. J. Smeed, Road Research Laboratory, Department of Scientific and Industrial Research, London, England. I felt that the first part of the introductory paragraph and the concluding paragraph were analagous to this particular discussion, and I wish to quote them to you.

> A talk on the application of traffic engineering principles should start by considering what is meant by traffic engineering. The job of the highway

> engineer is to produce roads on which road users can travel in comfort and safety, and this involves very much more than a knowledge of the depth of construction required and of the proportions in which he should mix sand, aggregate and binder. It is necessary, in addition, to know how wide the road should be, how much superelevation should be used, what maximum gradients and curvatures can be tolerated, what should be the layout of the junctions, and what signs and signals should be used. All these matters have, for some time, been dealt with by what are called traffic engineers in America, and there is no doubt now that the name has come to stay in this country....
>
> It is a standard joke in America that the number of traffic engineers in a town is equal to its population, but it is not that kind of traffic engineer that is required here. Our views and action need to be based on scientific investigations as is done in other branches of engineering.

Bringing this back to our local area, let me state once again that in Oregon your highway department is always willing to assist and work with you in any problem, and do not hesitate to call upon it. You will find it a most cooperative department and willing to assist.

I would be remiss if in closing I did not mention that there are many competent consulting engineering firms who specialize, particularly in the field of traffic engineering and planning, and their services are available to you for a fee. It might be that the magnitude of the problem is too great for your highway department to assist you, and you might wish to avail yourselves of these other services.

LOOKING AHEAD AS TO TRAFFIC OPERATIONS AND SAFETY

Burton W. Marsh

It is grand to have this opportunity to return to this wonderful Northwest region and to this attractive and important campus. Each trip to your wonderland area has been one of remembered significance and enjoyment. It is always enjoyable to revisit an area where so much fine work is being done and where I have so many friends.

This evening I must be careful as to what I say and do because several of my bosses are here. As you know, the various AAA affiliated automobile and motor associations and clubs are our bosses, and they are represented here. In addition, Bill Bugge is vice chairman of the Highway Research Board and is scheduled to be its next chairman, and as a member of its Executive Committee, he too is my boss.

Other friends are many. Here in Oregon: Dutch Williams, with whom I am associated on the National Advisory Committee to the AASHO Road Test; Forrest Cooper, whose wit and engaging personality made him a favorite with all of us at the Sagamore Conference on Highways and Urban Development; Bruce Crandall, Al Head, Fred Fowler, and Bill Weller, with whom it has been wonderful to be associated in the Institute of Traffic Engineers.

In Washington, Arch Bollong, with whom I share the city traffic engineering pioneer role; my friend, the present Seattle city traffic engineer, E. E. Lewarch; Harry Aumack, a man with whom I always like to discuss ideas; C. K. Glaze, one of your fine chaps we wanted to "steal" at one time; and many others in the Northwest who have meant a great deal to me over the years.

It is a pleasure, too, to recognize achievements. In doing my "homework" for this talk I found virtually identical, highly commendatory comments for both Oregon and Washington in the National Safety Council-administered 1958 Annual Inventory of Traffic Safety Activities as to engineering: "Highway engineering activities met 94 percent (Oregon), 96 percent (Washington) of evaluation measures...." Both of these percentages are just about perfection.

Also, I found this identical wording, "Again, Oregon (or again, Washington) reported an outstanding program in traffic and highway engineering."

Such high commendation is not tossed around carelessly, IT IS EARNED THE HARD WAY. Congratulations to both Oregon and Washington.

I did not intentionally omit other Northwest states, but time is limited and I thought these would be good "samples" or examples.

Moreover, my homework developed that Portland won third place in its size class in the most recent annual Pedestrian Program Appraisal sponsored by AAA. Seattle, in the same Appraisal, was recognized by a Special Citation for outstanding program activities. It should be pointed out that Roy A. Betlack, chief Washington State Patrol, was given an Award for Leadership in Pedestrian Safety—one of nine state pedestrian program representatives thus honored.

WHERE DO WE STAND?

As a basis for looking ahead, let us take a reading on where we now stand nationally in meeting the problem of traffic accidents.

Despite a very bad first half year in 1959 we ended the year with a less bad record than had been anticipated. The estimate was still a whopping 38,000 killed and nearly a million and a half injured. That is an increase of a thousand from the previous year, and that is not good. Yet, considering the increase in amount of traffic, which provides the fairest measure of exposure, fatalities per hundred million vehicle-miles went down slightly to a new low of an estimated 5.4.

Let us remember that the general public does not make its judgments in terms of mileage death rates, but by raw total numbers of deaths and injuries. There were nearly a million and a half traffic casualties in 1959!

Let us look at a few figures for Oregon and Washington. For Oregon, traffic fatalities in 1940 were 357; in 1959 they were 487—an increase of 36 percent. Taking into account the great increase in vehicle-miles in traffic, however, the death rate (per 100 million vehicle-miles) went down from 11.0 percent in 1940 to 6.0 percent in 1959—a fine improvement.

Oregon's pedestrian traffic deaths in 1940 were 139. In 1958 (latest year data available) there were 65—a 53 percent decrease. This is the more significant when compared to the

non-pedestrian traffic fatality record of 217 in 1940 to 383 in 1958; a 76 percent increase.

For Washington, traffic fatalities in 1940 were 509; in 1959 they were 547—a 7 percent increase. Taking into account the great increase in vehicle-miles of traffic, however, the death rate (per 100 million vehicle-miles) went down from 10.4 in 1940 to an estimated 4.4 for the first nine months in 1959—a fine improvement.

Washington's pedestrian traffic deaths in 1940 were 211. In 1958 there were 125—a 41 percent decrease. This is the more significant when compared to the non-pedestrian traffic fatality record of 298 in 1940 to 448 in 1958, a 50 percent increase!

Is the individual accident likelihood large or small? We all know that the traffic accident toll is very high and challenges us to more effective work. Yet in tackling the job of reducing this unacceptably high toll we should realize that the incidence of serious traffic accidents is actually rare—one fatal traffic accident for every 21 million vehicle-miles of travel and one injury accident for every 740,000 vehicle-miles, or at 10,000 miles of driving per year, an average of one injury accident to over a lifetime of driving.

On the other hand, if we consider all accidents and if, as is not the case, each crash-driver had only one accident in 1957, one driver out of every four would have been involved in some kind of traffic accident. Thus, the likelihood of a serious accident is small, but the likelihood of being involved in a lesser traffic accident is considerable.

We must realize that the average driver regards his likelihood of getting into a serious traffic accident as very slight, and this should guide us in our various activities. At the same time he is definitely interested in avoiding accidents.

What opportunity to reduce accidents? That the opportunity to reduce traffic accidents substantially exists in most places is demonstrated repeatedly by accomplishments in numerous places throughout the country.

Accident prevention requires an across-the-board attack, and the Action Program of the President's Committee for Traffic Safety provides a splendid guide. How are we doing in an across-the-board attack? In the overall, we are not doing very well. Very

great improvement is needed almost everywhere in many parts of the balanced program for traffic safety.

How are young people doing as to traffic accidents? They are not doing well. As one quick measure, I am told that additional insurance premiums now paid on family cars operated part of the time by individuals 25 years of age and under total $200 million a year!

How well are we driving today? While far from faultless, most of us most of the time are driving rather well, all things considered. One of the most common comments of visitors from other countries who come to our offices and talk about highway and traffic matters, is on the orderliness of our traffic compared with theirs. I tell them that because of our very heavy concentrations of traffic we must have fair orderliness or there would be chaos on our streets and highways, and that actually our orderliness is not adequate for our needs.

Few errors—much trouble. If our general orderliness in traffic is fairly good, why do we have so much trouble? The point is that it requires only a small number of combinations of errors and adverse factors to create a great deal of traffic trouble. This is an important point.

Erroneous ideas. We are learning that some things we were quite sure of are not so. The relationship of speed alone to the incidence of accidents is one example. The idea that correction of some one pet trouble will virtually stop accidents is another. A third is that bypassing through-destined traffic ruins business. Another erroneous idea is that you cannot do anything with pedestrians. Another is that highway signing, including route marking, is a simple, easily handled problem.

New facts are bringing surprises, and we are in for more surprises! This reminds me of the new teacher with an entering class of first graders who were the sons and daughters of brilliant scientists working on missiles, rockets, etc., near one of our major research bases. The new young teacher, thinking to get off to a good start, asked if anyone could spell "cat." Almost every hand in the room went up. Then she asked if anybody could count to ten. Lots of hands went up. She called on Johnny and he counted, "10-9-8-7-6-5-4-3-2-1" —and then from all the room— "damn!"

What is coming in the 1960's? Let us give consideration to

some of the things which seem reasonable to predict for the 1960's —a decade which certainly will bring tremendous changes.

1. One hundred and ten million drivers. As indicated at the outset, over 110 million drivers by 1970—in increase of over 27 million.

2. Traffic increase. Ninety-nine million motor vehicles as against some 68 million now—an increase of 46 percent. Thus, traffic and vehicle miles will increase by about one-half. This increase must be appraised in relation to highway improvements, and even according to the most optimistic appraisals highway improvements will not keep up with needs of growing traffic.

3. Urbanization trend. Concentrations of population in urban and suburban areas will increase. Indeed, by 1970 about three-quarters of our total population will be living in or near a city of at least 50,000 population. The trend toward regional cities or super cities will continue and will pose many serious problems. The over 600 miles from Boston to Richmond, Virginia, may then be virtually one urban concentration.

New kinds of metropolitan or regional government will have to be developed, and this is an important factor as regards traffic and driving because there simply must be effective planning and development of major facilities by some mechanism which overrides the multiplicity of present governmental agencies in metropolitan areas.

It is the suburban areas that are growing fastest. In fact, they have increased in population nearly seven times as rapidly as central cities.

4. Traffic concentration zones. We shall be faced with greatly increased traffic concentrations, mainly, of course, in our urban and metropolitan areas and on our most heavily used highways.

5. School-age population growth. There will be a tremendous growth in school-age population as a result of the very high birth rate following World War II. Present rate of growth among school-age children (ages 5-17) is approximately twice the rate for the total population—estimated number for 1957, 40 million; estimate for 1963 is 48,800,000 with, of course, further increases during the latter part of the decade. It has been estimated that there will be 4 million youths coming of driving age per year in 1970.

6. School bus transportation. The increasing consolidation of schools and use of school bus transportation will continue.

7. Many more senior citizens. There will be many more senior citizens. By 1970, 62 million people in the United States will be over 45 years of age. This virtually involves a doubling of the number of senior citizens. Naturally, many of them will desire to continue driving!

8. More multicar families. Increasing numbers of families will have more than one car. This trend is well established. In 1948, 5 percent of car-owning families owned more than one car; in 1957, it was 12 percent. It is surprising but true that the percentage increase in cars is greater than the percentage increase in number of licensed drivers.

9. Increasing societal controls. More societal controls are inevitable. With the increasing concentrations of people, there is no question but that there will be more and better societal controls. Many of these will affect driving. Examples: better driver licensing, re-examinations, increasing driver improvement programs, better laws, improved enforcement, and increasing pedestrial regulation.

10. More leisure and its use. People will have much more leisure with shorter work weeks, and driving will be involved in much of the use of that leisure.

11. Freeway increases. There will be greatly increased freeway mileages, and of course much more freeway driving at the higher speeds for which freeways are designed, and with the various other special aspects of that type of driving. There will be MANY new freeway operational problems. The public expecting a superior level of service on freeways will expect solutions to those freeway problems. Solutions will be difficult to achieve on important freeway problems because what they really require is unified or integrated management and operation—something hard to achieve with our multiple political entities having freeway responsibilities.

12. Increased night driving. There will be more night driving.

13. Vehicle changes. Many vehicle changes will take place with varying effects upon traffic. One example is the trend toward increasing size of commercial vehicles and combinations. Another is the likely development of blowout proof, airless tires, perhaps filled with foam rubber.

14. Improving traffic efficiency. There will be greatly

improved traffic operations, forced by the heavy concentrations of traffic. Helicopter service will help "spot" and indicate ways to alleviate congested road conditions and, on certain major arteries, so will closed circuit television.

15. Roadbuilding lag. There will be a continuing lag in programs to meet traffic needs—or at least that is the present outlook.

SOME THINGS TO THINK ABOUT!

Traffic death rate decreases. We know that the public is far less impressed with comparisons of death rates and far more interested in the total number of people killed and injured. If, as predicted, we are going to have by 1970 an increase of about 50 percent in vehicle-miles of driving, we can realize that at the present rate this would mean some 57,000 traffic fatalities in 1970. The only way that we can keep the total number of fatalities down is by greatly improving the death rate. This means that a very much better job must be done all along the line, and this is indeed one of the challenges to all of us.

The 1960's are going to herald the rise of a "push-button" public. The wonderful mechanical and electronic improvements that are here and coming are going to be very popular. Yet, the growing ease with which we can get things done may involve a fundamental problem of a lessening degree of self-reliance, of capability to do things for one's self, of dynamic drive, and of willingness to work hard. Along with our wonderful material advances and greater ease and comfort, there must be effective ways and means of maintaining a strong, virile, self-reliant, disciplined public.

Orderliness and driver behavior. As indicated above, increasing traffic and traffic concentrations will necessitate greatly increased attention to traffic orderliness and to securing the most efficient use of traffic facilities. Such improved orderliness will result in reduced accidents because, to an important extent, safety is a partner of orderliness.

Various authorities can plan, design, operate, and maintain highway facilities so as to encourage improved orderliness, and increased attention will be given to such procedures. A major factor in obtaining the desired improved orderliness, however, must come from improved driver behavior. It is well to think, therefore, about how improved driver behavior can be obtained. It will be the result of many factors:

1. Improved driver licensing
2. Improved driver education
3. Better driver improvement programs (including driver or violator schools, for example)
4. Improved individual driving discipline, resulting for example in more and better voluntary observance of traffic laws and sound driving practices
5. Improved traffic law enforcement

When we speak of improved driver behavior, there are those who take a rather pessimistic view. They say that human nature is mighty hard to change. It changes only slowly. This is true. On the other hand, humans have repeatedly shown that they are very adjustable or adaptable to needed changes in behavior to meet many environmental conditions.

Material progress—social deficiencies. All around us we see on one hand tremendous, exciting scientific and material advances. On the other hand we see, if we look, decidedly sobering inadequacies of progress in social and spiritual areas.

Certainly much that is involved in material progress is beneficial, or it can be. Yet, is it not a fair question to ask if it isn't time for a new stock-taking or reappraisal? Isn't the camera being too often focused on one objective—material things? Shouldn't it more often be focused on human values? Isn't it urgent that many more of our best minds and best leaders be brought to putting many times more thought, effort, and time into improving social and spiritual conditions?

You may say, "Does this have any relationship to the engineer's interest in traffic problems?" It has a very important relationship! The best engineering applied to traffic will be effective only if there is proper use of the results of engineering. Such proper use requires appropriate driver and pedestrian behavior. Such behavior requires a cooperative and informed people who accept personal responsibilities in traffic. It is indeed highly important that engineers realize how dependent they are in work relating to street and highway traffic, on how people will react to engineer-devised measures, and on what people accept as their traffic responsibility in general. Yet, it is not right or fair to attempt to unload responsibility onto the driver or pedestrian.

Extent of driver responsibility for traffic troubles. I had a dream the other night. I was the victim—driving a car—with lots of people constantly moving along with me and eager to jeer and

blame me if I made a single misstep. The car had inadequate headlights, a weight distribution which hurt its stability on curves, its windshield wipers did not clean a sufficient area and I could not tell promptly when the car ahead was braking to stop, an approaching car's headlights glared into my eyes, the road was very skiddy when wet, culvert heads were right next to the edge of very narrow lanes with no shoulders, there were blind hillcrests at curves, bridges were not wide enough for two cars to pass, and road surfaces had high crowns.

Then I was driving through a city and I was supposed to follow a route number, but I could not find the signs. They were hidden by limbs of trees or they weren't there. I was supposed to read certain direction signs which had too much wording on them, with lettering too small and no night illumination or reflectorization. Pedestrians were not properly disciplined, so I had to watch them while I tried to find out where I was going.

Through all of this, these voices going along with me kept saying, "If there's any trouble, you are to blame; you can drive safely if you only want to; you are to blame for any accident."

"What do you think I am," I kept asking. "I am only human; you are asking me to do the almost impossible. I can respond satisfactorily to a reasonable number of factors or conditions, but when too many complications confront me at one time I may not always be able to act properly. Hence, you've got to consider the conditions and complications under which you ask me to drive well and to drive safely. Don't you see, it's the combination—you can't put all the responsibility on me."

They only laughed and jeered at me further, except one, and he said, "Perhaps you have something, but what are you going to do about it?"

I said, "I am going to try harder than ever before to get everyone to see that it's the road-car-driver-pedestrian-traffic-weather conditions—it's the 'whole system' that must be considered together and worked on and improved if we are going to make the progress we want to make, both in traffic safety and in efficient traffic movement. It's the interaction between many factors, and the goal should be to improve the effectiveness of the entire system."

MORE PROGRESSIVE AND MATURE APPROACHES TO TRAFFIC PROBLEMS!

Fortunately, there is a very marked trend, it seems to me, toward recognizing the interrelationship and interaction of factors dealing with traffic problems. Furthermore, there is an encouraging increased realization of the essentiality of basing our attack on far better factual information—more and better research and investigation.

One of the main reasons that I wish to pursue this point further is that for much of our future traffic progress, engineers and scientists are going to give important leadership. Yes, to a much greater extent than has generally been realized even by many engineers. There is a major engineering responsibility for efficient, attractive, and safe highway transportation!

Let me cite a few important developments as to more progressive, factual, and mature lines of attack and, as I do so, please think of engineering responsibilities in relation to these points:

1. "Highway Research Needs in the United States." May I refer to this excellent report prepared by a special committee of the Highway Research Board under the chairmanship of E. H. Holmes, assistant commissioner for research of the Bureau of Public Roads. The report deals with a point of the very greatest importance—the urgent need for a greatly stepped-up highway research program.

Mr. Holmes' committee invited the various departments and committees of the Highway Research Board to present proposals as to greatly needed research. Out of the many that were submitted and after much study, nineteen projects were selected with a total estimated cost of $34 million. More than half of these projects bear importantly on traffic operations. The nineteen projects chosen were ones urgently in need of attention. Yet, at the moment there is no clear indication of sources of funds for this research.

The utter inadequacy in amount of research on highway transportation problems needs strong emphasis and repetition. This inadequacy can perhaps be appreciated better by comparison.

The Holmes' report shows that in 1958 less than two mills of the road dollar, or 0.2 percent of total highway expenditures,

were devoted to research. In sharp contrast in the field of industry in 1956, the proportion of sales devoted to research is much more in the neighborhood of 2 to 3 percent, according to the soon-to-be-released study of the National Science Foundation.

2. Freeway operations conferences. Twelve regional conferences on problems of freeway operations have been held over the past two years under sponsorship of the Institute of Traffic Engineers, and with active participation of the Bureau of Public Roads, highway and police officials, and other interested groups.

For three days an average of 100 persons (mainly engineers) explored and discussed the many problems of freeway operations and what should be done. Cities and states both were represented. There were specialists in design, construction, operation, enforcement, maintenance, planning, and education. A new realization of interdependence and of need for teamwork resulted and also the urgent need to develop answers to the many unresolved problems.

3. Highway and urban development. A significant conference was held at the Sagamore Conference Center of Syracuse University on "Highways and Urban Development," at which there was a new spirit of teamwork in dealing with the very important relationships of highway improvements to the development of cities. In this case, highway engineers were the ones most prominently involved and they worked for a week with city planners, educators, and others in a highly productive way.

4. Updating traffic devices manual. The Manual on Uniform Traffic Control Devices is being updated, modernized, and improved under a national committee, the chairman of which is E. H. Holmes, assistant commissioner for research of the Bureau of Public Roads. Here, again, to the maximum extent possible, research findings are being utilized in a more sound and mature approach.

5. "The Federal Role in Highway Safety." Here is a new "bible" for all who are interested in accident reduction. By whom was this report prepared? It was a project of the Bureau of Public Roads, and the main author is a national engineering leader in traffic safety—Mr. Charles Prisk.

6. Intensive interdisciplinary accident studies. Two intensive case history studies of traffic accidents are now under way: One under the outstanding leadership of J. Stannard Baker of

Northwestern University, and the other under the leadership of Dr. Alfred L. Moseley of Harvard. The latter involves some $809,000 for a 5-year project.

In each of these cases relatively small numbers of serious or fatal accidents are investigated in depth by teams made up of specialists with different talents and experience, including an engineer, a doctor, a psychologist or psychiatrist, and in one case, a sociologist. Such interdisciplinary teamwork will, I am confident, prove highly beneficial to the better understanding of traffic accidents and to methods of reduction.

7. Enforcement and driver behavior study; a $210,000, 3-year study of the effects of different enforcement factors or approaches on driver behavior. This study, too, is to involve a team of different types of specialists bringing their talents and experience into combination in seeking the truth. This study is under the overall direction of Ray Ashworth, director of the International Association of Chiefs of Police, Field Service Division.

ENGINEERS' CONTRIBUTIONS TO TRAFFIC PROBLEMS

I want to re-emphasize that much of our future progress in traffic will come from engineers.

One clear evidence of what engineers can accomplish in highway safety is the very much lower fatality rates for freeways compared with fatality rates for ordinary highways. The freeway fatality rate averages perhaps one-third of that for normal highways. In 1958 the fatality rate on the New York Thruway, a well-operated, high-grade freeway, was 0.9 per hundred million vehicle-miles compared to 5.4 for the country as a whole!

To an important extent, these vastly superior fatality rates on freeways are the result of BUILT-IN SAFETY—something we are going to have to use to the maximum possible extent in the years ahead. Thus, this is an engineering achievement. Nonetheless, it would be less than honest if I did not point out that on freeways, as elsewhere, there must be proper teamwork in order to achieve the desired improved accident records. It is not engineering design alone, it is also the result of good management, high-grade highway patrolling, good marking, effective signs, very high-grade maintenance, and effective education.

Let me cite another area in which engineering is achieving much toward traffic efficiency and accident reduction. Traffic

engineers are continuing to find and institute ways of correcting existing undesirable situations involving delays, congestion, undesirable traffic patterns, detriments to desirable community development, and accidents. Traffic engineers accomplish these results through signs, marking, signals and signal systems, islands, routings, one-way measures, reverse-flow plans, parking programs, terminal plans, traffic-planned shopping and other areas, etc. As a result of sound traffic engineering work, there are piling up year after year thousands of examples of where the application of engineering principles results in substantial traffic and community benefits.

INCREASING IMPORTANCE OF ATTAINING MAXIMUM EFFECTIVENESS OF STREET AND HIGHWAY USE

Right here I wish to make a very important point. We must have increasing mileages of high-grade highways, especially freeways for heavy traffic, and I hope there will be increasing emphasis on full access control, for I fear the danger of gradual erosion of access control which partial access control almost invites.

Despite the most optimistic predictions as to the mileages of new freeways and other improved highways that are going to be built, new highway mileage will not keep pace with traffic growth. Hence, not only will something like three-fourths of all traffic still be on ordinary roads and streets, most of which now exist, but this percentage is likely to INCREASE!

There is only one conclusion that can be drawn from that situation: Very greatly increased attention must be given to traffic operations, or traffic engineering, so as to get (and so as to retain with changing conditions) the maximum of efficiency, convenience, and safety in use of existing roads and streets.

RECOMMENDATIONS TO ENGINEERS

In conclusion, may I present six recommendations to each of you engineers:

1. Study anticipated developments in the 1960's and their meaning to you and your work.

2. Think further about the inevitably growing importance of traffic operations to future highway transportation and how this will affect your work.

3. Help get organized an active, continuing freeway operations planning team in your state or city. There are many problems

that need team study and action.

4. Urge greatly stepped-up research in all areas of highway transportation, using every effective occasion and way that you can devise.

5. Help your state and city make progress in meeting its priority needs in traffic and safety. Several guides as to such needs are available: (a) your state submitted a carefully developed list of such needs to the President's Committee for Traffic Safety in connection with four 1958 regional conferences on highway safety, (b) see the Annual Inventory of Traffic Safety Activities (especially Section 4 - Traffic and Highway Engineering) available through the National Safety Council, and (c) see annual AAA National Pedestrian Program Appraisal, available through your AAA automobile club or write to the American Automobile Association.

6. As an individual, accept full personal traffic responsibility at the wheel, afoot, and as a citizen.

PLANNING AND THE HIGHWAY AT COUNTY AND CITY LEVEL

James Bell

A great deal has been said in recent years about the need for active participation by cities in planning state highways in urban areas. Much also has been said about the need for better liaison between cities and state highway departments in matters of urban highway design and construction.

In recent months the Bureau of Public Roads has set forth as one of its general objectives ". . . the attainment of a current and realistic urban arterial highway plan for each urban area, cooperatively developed and endorsed by all agencies concerned."[1]

The Bureau also has emphasized that ". . . highway plans not only must be adequate for future needs but also must be in harmony with and be an integral part of overall plans for urban area development and growth. Such highway planning should take into account desirable future land use patterns; residential, commercial and industrial development; social and recreational improvements; costs and other similar factors related to the orderly development of the community."[2]

The American Association of State Highway Officials recently resolved ". . . that the urban sections of the National System of Interstate and Defense Highways be constructed as planned under the provisions of the Federal Aid Highway Act of 1956 and that the state highway departments which have the responsibility of initiating such projects cooperate with local government and planning officials, to the end that land use and urban development features will be given proper consideration."[3]

Last fall the League of Oregon Cities adopted a resolution urging the state highway commission to ". . . establish an office devoted exclusively to the problems of cities and their relationships to the highway department."[4]

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[1] USBPR, quoted in American Institute of Planners Newsletter, Feb. 4, 1960, pp. 3 and 10.

[2] Ibid.

[3] Ibid.

[4] League of Oregon Cities, Newsletter, Nov. 9, 1959, pp. 2-3.

NEED FOR PARTICIPATION AND LIAISON

The League of Oregon Cities' resolution pointed to several reasons for the need for more active participation by cities and for better liaison with highway departments. The League's resolution stated ". . . the growth of cities (in Oregon) has resulted in a 24 percent increase in city street mileage over an 8-year period and this growth will continue in the future as a result of annexations, new subdivisions and new incorporations and traffic volumes within cities will continue to grow with overall state growth."[5]

At present there are about 5-1/2 million people living in the Pacific Northwest. The Stanford Research Institute estimates that by 1975 this figure will have increased to over 6-1/2 million. About two-thirds of the people in the United States presently live in urban areas.[6]

A recent study by the Bureau of Municipal Research and Services at the University of Oregon indicates that over 50 percent of Benton County's population lives here in the city of Corvallis. The study also indicates that about 70 percent of the county's population lives in what has been termed the "Corvallis urbanizing area." It is interesting to note that during the 58-year period from 1900 to 1958, the proportion of Benton County residents living in the city of Corvallis increased from 27.1 to 50.4 percent. It is expected that Corvallis' population will represent an even greater proportion of the county population in the years to come. Present trends indicate that in the next 15 to 25 years the population of the city of Corvallis will reach 40,000. The state census board estimated that about 20,000 people lived in the city in 1958.[7]

At present there are about 70 miles of city streets in Corvallis, 430 miles of county roads in Benton County, and 120 miles of state highways in the county. In addition, there are many more miles of streets in Monroe, Philomath, Alsea, and other communities in Benton County. The expected increase in population will mean an increase in the mileage of streets, roads, and highways in the county.

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[5] Ibid.

[6] Howard C. Nielson, Population Trends in the United States Through 1975, (Stanford Research Institute, Menlo Park, Calif), pp. 1-57.

[7] Corvallis City Planning Commission, Population Trends in Corvallis, (Bureau of Municipal Research & Services, Univ of Oregon), pp. 1-19.

A street, road, and highway system plays an important part in urban development. It comprises the framework around which urban development takes place. Russell Black, emphasizing the importance of the street system to urban development, writes:

> . . . the size, form and orientation of building lots and the design, efficiency and setting of individual buildings are more or less controlled by street arrangement. Streets serve many purposes other than provision of vehicular movement and access to home, store and factory. They form the city's drainage system, and carry the city's sewers, water mains, gas pipes, electric and telephone wires, and other utilities.[8]

In addition to the overall population growth of the Pacific Northwest and its concentration in urban areas, there are a number of trends in urban development that will affect our present street systems. These include the rapid development of residential suburbs, the increasing suburbanization of industry and business, and the increase in use of private transportation. At the present time there are over 6000 people living in the fringe area surrounding the city of Corvallis. These people account for over 20 percent of the people living in the urban area. They would account for an even larger proportion of the total population if Oregon State College students were not counted as residents of the city. It is expected that the number living in the outlying area will increase in the years ahead. The streets in these areas are part of the county and state road system.

The increasing proportion of industry and business locating outside the corporate units of cities is a national trend in urban development. Perhaps this trend is not as evident with respect to retail establishments in our smaller cities. Most convenience-type retail establishments, however, are seeking locations nearer to the residential areas of the community. One of the most difficult problems facing the Corvallis City Planning Commission today is the need for developing standards for allowing convenience shopping centers in residential areas. At the present time the commission has two zone change requests before it involving convenience shopping centers in residential areas of the city. In addition, the newly formed West Corvallis Zoning District west of

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[8] Russell VanNest Black, Planning for the Small American City, (Public Administration Service, Chicago, Ill.), p. 22.

the city faces a possible court test as a result of the desire of a property owner for commercial zoning.

Most of the industrial development in recent years in the Corvallis area has taken place in the urban fringe. It should be noted, however, that industry has not been as important to the development of Corvallis as to most other Northwest communities. Oregon State College is the largest employer in the community and has had the greatest influence on the growth of the urban area.

Perhaps, with respect to the street system, the most important trend taking place in urban development is the increasing use of private automobiles. National registration figures indicate that motor vehicle ownership has doubled since World War II. The Federal Reserve Board estimates that an additional 50 million vehicles will be in use in the United States in the next 20 years.[9] This will result in just about double the present amount of automobile traffic. Vehicle registration in Benton County increased from 7360 in 1940 to 16,181 in 1958. The county's population increased from 18,629 to 37,900 during the same period. This means that over the 18-year period there has been a 120 percent increase in the number of vehicles in the county and a 103 percent increase in population. In 1940 there were 2.54 persons per vehicle in Benton County, and in 1958 this ratio had dropped to 2.34.

All of these developments—rapid population growth, centralization of the population in urban areas, spread of urban development to areas outside cities, and increasing number of vehicles—point to the need for more active participation by cities and for better liaison with the State Highway Department. Equally important is the need for participation by urban areas and for better liaison between urban areas and highway departments.

PRESENT PARTICIPATION AND LIAISON

Recognizing these changing patterns in urban development and the problems they create, many communities in the country have developed planning programs in an attempt to guide urban development. In 1919 the Oregon Legislature authorized Oregon

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[9] Federal Reserve Board, quoted in Joint Committee on Highways of the American Municipal Association, American Assn of State Highway Officials, Committee on Urban Research of the Highway Research Board, National Academy of Sciences, National Research Council, and Syracuse University, The Sagamore Conference on Highways and Urban Development, p. 10.

cities to establish city planning commissions. At present there are about 220 cities in Oregon. All of the cities with over 5000 population and a large number of smaller cities have planning commissions. In 1947 the Legislature authorized Oregon counties to establish county planning commissions, and today about half of the 36 counties in the state have planning commissions.

The three major planning tools for guiding urban development are zoning ordinances, subdivision regulations, and capital improvement programs. In theory, these tools are used for carrying out a long-range development plan for the urban area. The long-range development plan includes a land use plan, a traffic circulation plan, a public utilities plan, and a community facilities plan. The circulation plan shows the location and types of existing and future traffic routes. One major component of the circulation plan is a major street plan.

State highway departments are also working on long-range street plans in urban areas. It is estimated that about 10 percent of the nation's street, road, and highway mileage is located in urban areas. State highways, planned and developed by state highway departments, account for a large part of this mileage. One major street proposal included in the street plan developed by the Corvallis City Planning Commission that relates closely to highway department plans is a suggested bypass of the downtown business district for through traffic. The plan calls for utilizing First Street along the west bank of the Willamette River for U.S. Highway 99W instead of the present one-way couplet of Third and Fourth streets. The city has shown this possible relocation in its plan since 1945. It is the city's understanding that the Highway Department looks with favor on this long-range plan for U.S. Highway 99W.

Recognizing the need to accelerate the progress of the development of all Federal Aid highway systems, particularly the Interstate System, Congress passed the Federal Aid Highway Act of 1956. Among other items, the act authorized the expenditure of about 25 billion dollars for modernization of the National System of Interstate and Defense Highways. It is expected that the 40,000-mile system will be modernized over a 15-year period. About 50 percent of the funds will be spent on highways in urban areas. Planning and development of the Interstate System is done cooperatively by highway departments and the Bureau of Public Roads.

In addition to the city, the state highway department, and the Bureau of Public Roads, counties also plan and develop parts of

of the street, road, and highway system in urban areas. An example of county road planning here in the Corvallis area is a proposed periphery road south of the city that would connect U.S. 99W with the Belfountain road to the west. The City Planning Commission recently suggested to the county that a road in that area be planned for future development. A number of property owners in the area also became interested in the idea and pressed the county to study the feasibility of such a road. Following a recommendation of the county road viewers, the County Court decided not to participate in a road in the suggested location at this time.

It is of interest to note that regardless of the county's position, the city can assure that a street is finally developed in that location by exercising its jurisdiction over land subdivision in that area. In Oregon any platting of land in the area within 6 miles of the city is subject to the approval of the City Planning Commission unless the county has a planning commission and has adopted subdivision regulations. Benton County does not have a commission, and has not adopted subdivision regulations. Only two of the nine counties in the Willamette Valley—Benton and Linn counties—do not have planning commissions.

There is a great deal of similarity in the thinking of highway engineers and city planners with reference to what factors influence the location of highways in urban areas. Highway engineers and planners are both concerned with the impact of the highway on the community, present and future traffic volumes, cost of the development, effects of the highway on the local street system, compatibility with local plans, aesthetic considerations, and national defense.[10]

RECOMMENDED PARTICIPATION AND LIAISON

As outlined, there are sometimes as many as four different governmental agencies involved in developing the street plan in urban areas. Therefore, one major problem facing our urban areas is the question of who is responsible for planning which portions of the urban street system.

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[10] Joint Committee on Highways of the American Municipal Assn, American Assn of State Hwy Officials, Committee on Urban Research of Hwy Research Board, National Academy of Sciences, National Research Council and Syracuse Univ, Sagamore Conference on Highways and Urban Development, p. 9.

A recent National Conference on Highways and Urban Development, held at Syracuse University, brought together a selected group of highway officials, city officials, civic leaders, and technical advisers to discuss highway programs in urban areas. With respect to the question of who is responsible, the recommendations of the conference are of particular interest. Some of these recommendations were as follows:

State

1. State highway departments should be properly organized and staffed to work cooperatively and effectively with local authorities in planning, designing, constructing, and operating streets and highways in urban areas.

2. State highway departments, in cooperation with local governments, should develop a tentative program of urban highway improvement for a period of at least five years in advance, as a basis for planning at the local level. This program should be in accordance with a jointly agreed-upon long-range plan.

3. State highway departments should consult with local authorities on a continuing basis in highway planning.

Local

1. Local governments should fulfill their primary responsibility for community planning to insure maximum benefits to the local area.

2. Local governments, in fulfilling their responsibility, should prepare a comprehensive plan for the physical development of the community, embracing a land use plan, a transportation plan including public transit, and a program of land use controls. To achieve this objective, urban areas should have competent and continuing planning service.

3. Regional planning should be initiated in every metropolitan area.

4. Local governments should consult regularly with the state highway department in the preparation of comprehensive plans for urban areas.

Joint

1. All levels of government should strengthen their support of city and regional planning. All federal agencies dealing with urban development should continually review their policies to achieve coordination with state and local objectives in urban

development and transportation.

2. Public support and adequate finances are essential to carry out desirable programs based upon comprehensive planning. All agencies of government should seek this support through presentation of all facts relating to the plans.

3. To provide the basis for transportation planning and broad community planning, all agencies concerned should promptly undertake studies to develop the necessary basic facts, using appropriate techniques. [11]

SUGGESTED PARTICIPATION AND LIAISON IN SMALL COMMUNITIES

Several major steps have been taken recently in Oregon in developing participation and liaison between cities and the Highway Department. Late last month the State Highway Department announced the creation of a new position to maintain liaison with cities and counties with reference to Highway Department plans and policies affecting local agencies. The new position will be in the office of the State Highway engineer, and will carry the title of administrative assistant. This is a definite indication of the Highway Department's interest in working more closely with the communities in dealing with various problems of urban highway planning.

In addition to city and county planning commissions in Oregon, there have been three area or regional planning commissions formed. They are the Central Lane County Planning Commission which includes Eugene, Springfield, Lane County, and three school districts; the Mid-Willamette Valley Planning Council which includes Salem, Polk and Marion counties, and the Salem School District; and the Portland Metropolitan Planning Commission which includes Portland and Multnomah, Washington, and Clackamas counties. These commissions function as advisory agencies to the city and county planning commissions represented on the area commission. In addition, the Central Lane and Mid-Willamette Valley planning commissions enable the participating agencies to provide the urban areas with sufficient funds to hire technical planning staffs. The Central Lane County Planning Commission is supported financially by all the agencies represented on the commission, and the staff hired by the commission serves as staff to all the represented agencies.

[11] Ibid, pp. 2-3.

A number of counties and cities are participating in jointly financed planning studies without actually forming area planning commissions. In recent years the federal government has provided funds on a matching basis for planning in small cities and counties and for joint city-county projects. These funds were originally authorized in the Housing Act of 1956. The funds are administered in Oregon by the State Board of Higher Education through the Bureau of Muncipal Research and Services at the University of Oregon. About 30 Oregon communities have taken advantage of the planning assistance program and are preparing long-range plans. Seven of these projects have been jointly financed. Most of the projects include the preparation of major street plans.

In all instances the plans are being developed for the urban area. One problem in the program has been that many of the plans may be approved by the city involved, but not by the counties or the State Highway Department. Leadership is needed first in coordinating the thinking of the responsible agencies in the urban area and the State Highway Department. Most of the coordination taking place today has been at the staff level. For example, the planning staff of the Bureau of Municipal Research and Service has been coordinating its studies as much as possible with those of the State Highway Department.

Staff coordination is desirable, but it is more important that there be legislative coordination. The city and county legislative bodies through their planning commissions and planning staffs need to develop and adopt street plans for urban areas. The Highway Department staff should be encouraged to participate in the development of the plans before they are finally approved by the legislative bodies. The legislative bodies need to approve these plans as a matter of policy.

In our smaller cities where funds are limited, the counties should provide the planning staff. A county with a staff of two or three professional planners could provide technical assistance in developing plans for urban areas to all the cities in the county. Where county planning staffs exist, they should be encouraged to work with cities in the county. In addition, the cities should provide part of the funds needed to strengthen county planning staffs.

Planning only for the area within the city limits is an obsolete approach to the problem of guiding urban development. We need to talk instead about urban area planning. We need more of the kind of urban area planning now being carried on in the Eugene-Springfield, Salem, and Portland areas. The Corvallis-Albany

area of the valley presently does not have a regional planning organization. Study should be given to the possibility of forming such a commission. The commission could include representatives from Corvallis, Albany, Philomath, Benton, and Linn counties. The idea of forming area-wide planning commissions should be studied in central Lincoln County, Coos Bay area, and in the Rogue River Valley, among other areas of the state.

There is a need for more active participation by cities in planning state highways in urban areas. There is also a need for better liaison between cities and state highway departments in matters of urban highway design and construction. Perhaps the greatest need, however, is for participation and liaison between urban areas and the highway department. In many instances this can be accomplished through the joint community planning programs in urban areas. These programs should necessarily include cities, counties, and any other public agencies concerned with urban development.

REVIEW OF VEHICLE DIMENSIONS AND PERFORMANCE CHARACTERISTICS

K. A. Stonex

The purpose of this paper is to review the trends of dimensions and performance characteristics of American-made passenger cars because of the close relationship of vehicle and highway design.

At the 37th meeting, dimensional characteristics of passenger cars were reviewed and the trends studied for a 30-year period up to and including 1957 models. (1)

Engineering test data showing characteristic performance trends were last reviewed before the Highway Research Board at the 33rd annual meeting which included a 25-year trend up to and including 1953 cars. (2)

Because of the increasing interests among highway and traffic engineers in the dimensions and performance characteristics of automobiles, it is timely that these data be brought up to date to include the more important characteristics of current automobiles.

One of the dimensions most interesting to highway designers is that of the driver's eye height. For more than 20 years the AASHO design policies with regard to stopping distance have been based upon a driver's eye and an obstacle 4 inches high, which is presumably the practical case of the smallest obstacle a driver would need to avoid. This is illustrated in Figure 1.

In spite of the data shown in Bulletin 195, there is still growing concern among highway designers that, with the increased emphasis on reduction of overall height, the driver's eye position may go down and down to the point where the 4.5-foot standard will no longer be applicable and the design criteria for the crest vertical curves will be invalid. The trend of overall height of representative domestic cars from 1927 through 1960 is illustrated in Figure 2. A separate curve showing the average of the domestic smaller economy cars is given. Heights of individual 1960 compact and foreign cars are indicated by separate points.

In Bulletin 195, a laboratory test in use at the General Motors Proving Ground to measure comparative driver visibility was discussed. This procedure was developed 25 years ago and it included a value of driver's eye height which had been determined

from the average of a number of male drivers.

An independent observation on male employes by another division in General Motors, at approximately the same time, checked this value approximately. Based on this observation, a driver's eye height of 28.5 inches above a firm seat was established. Observations showed that the average seat cushion of that day depressed about 2 inches under the driver's weight, so that the test procedure provided the location of the driver's eye to be 26.5 inches above the undepressed seat cushion. In Bulletin 195, adjustments were made in the driver's eye height of the most recent years where actual depressions of seat cushions in modern automobiles had been measured.

A recent critical review of this test procedure indicated that this value of average driver stature should be modified because of the increasing number of female drivers and because more data of other and larger population samples have become available.

Figure 3 shows data which have been found in the literature[3]; included are certain other observations made by the Proving Ground and other General Motors groups. At the left of the chart are some observations on various classifications of Japanese; on the right of the chart are observations covering Army and Royal and American Air Force personnel. In the central portion of the chart are data from several sources indicating that the average male seated eye height should lie in the range between 29 inches and 30 inches above a firm seat; this group of data shows ranges from minimum to maximum, and these ranges are roughly comparable for all studies.

It should be noted that in many cases the conditions covering the observation of the data reported shown on Figure 3 are not given sufficiently specifically to make direct comparisons possible. In some cases, observations are described as "erect sitting," "relaxed sitting," and in other cases, the conditions are not stated.

A driver may slump 2 or 3 inches after some extended period of driving on the road. Because the data shown in Figure 3 are not defined specifically in many cases, it was necessary to make supplementary observations to gain additional information on the amount of driver slump.

In the Proving Ground laboratory test, it was necessary to establish the stature heights of normally relaxed drivers from the depressed seat cushion to the eye point. When this value is

established with some degree of confidence, it is comparatively simple to convert the results of laboratory tests to terms of driver eye height above the road. Our primary interest, however, was in developing a technique by which visibility from representative cars can be compared.

Figure 4 shows frequency distributions in percent of measurements of the vertical distance from the depressed seat cushion to the eye point of samples of males. The upper curve is a sample of 196 male employes at the Proving Ground which show a mean value of 29.4 inches. The lower curve is from a group of 205 males observed as they were driving on a public highway. The mean here is 30.1 inches. These distributions show a relatively wide range of from approximately 26 to more than 33 inches.

After extensive study, it was concluded that the best single value representative of the average American driver is 29.1 inches above the depressed seat cushion. This is an average of males and female drivers, weighted 60:40 in favor of males because of the preponderance of male drivers.

Figure 5 is a percentile distribution of "average" driver eye heights above the road on 1960 cars. A separate curve is shown for 1960 smaller economy cars.

Figure 6 shows percentile distributions of our best estimate of average driver eye height above the ground since 1936. This shows that the median driver eye height above the ground has decreased from 56.5 inches in 1936 to 47.5 inches in 1959.

It is conceded that the trend toward lower driver height will have some bearing on the crest vertical curve sight distance and some of the existing highways built according to the minimum standards may be rendered obsolete with the change in the driver eye height[4]. Any forecasts of future automobile trends must take into account two basic problems in vehicle design, entrance and visibility, that must be worked out. Since automobiles must conform to the existing highways, it is not anticipated that the minimum height of volume production passenger cars will be much lower than the 52 or 53 inches predicted in Bulletin 195, or that average driver eye heights will fall below the values of 42 to 43 inches predicted there.

The reduction in overall height of the vehicle has permitted a reduction in the center of gravity height. Figure 7 shows the trend of the center of gravity heights for cars of domestic manufacture since 1935 through 1959. The center of gravity height has

been reduced from an average of approximately 24.7 inches in 1935 to an average of approximately 21.5 inches in 1959. Thus, it is shown that it has been reduced more or less proportionately with the overall height.

The significance of the effect of the center of gravity height on vehicle stability is discussed in another paper at this meeting (5).

The overall length of domestic passenger cars has increased somewhat during the last 30 years as shown in Figure 8. However, it will be noted that the longest car has not changed appreciably since 1939, and the shortest car has become approximately 15 inches shorter since 1946. A separate curve shows the average of the domestic smaller economy cars.

Figure 9 shows the trend of overall widths of domestic passenger cars since 1927. There was a steady increase in width of all cars until the 1942 models, at the point where the widest cars began to become complicated with some state regulations. There has been little change since. The widest cars have not increased in width for the last 15 model years, and the average of the late domestic economy cars is not far different from that of the narrow cars of previous years.

Figure 10 shows the trend in the wheelbase of domestic passenger cars from 1930 through 1960. It may be noted here that the longest postwar car is shorter than several of the prewar cars, that the average has not changed significantly since 1938, that the minimum car has been of the order of 108 inches to 112 inches since approximately 1936, and that the average of the domestic economy cars is about the same as the minimum wheelbase.

To the designer of garage and driveway and parking lot ramps, the approach, departure, and ramp break over angles are of significance. Figure 11 shows the trend of the angle of approach. Since 1948 the maximum angle has increased to 30 degrees and the minimum angle has varied from 15 up to 19 degrees and then down to 14 degrees.

The trend of angle of departure is shown in Figure 12. The minimum value here decreased to approximately 10 degrees in 1954 and has stabilized at approximately that value.

The ramp break over angle trend is shown in Figure 13. There has been a steadily decreasing trend of the average value, but the minimum has stabilized at approximately 10 degrees since 1957.

It should be noted that an SAE Technical Committee has been reviewing this problem and it is hoped that SAE standards on three angles will be approved in the near future.

The trend of minimum ground clearance is shown in Figure 14, and it may be noted that the minimum value appears to have stabilized at about 5 inches.

One of the features which makes the domestic passenger car desirable in the eyes of its owner is its flexibility in the traffic stream. Flexibility is a significant factor in the most effective use of modern traffic facilities, especially entrance ramps. This flexibility is reflected as the time and distance required to complete a passing maneuver at road speed—40 mph has been used as an example[2, 6, 7].

Figure 15 shows schematically how this measurement is observed, and gives representative passing times and distances for several cars, ranging from the highest performing to the poorest performing in the 1959 domestic production.

In the schematic at the top of the diagram, we assume that car "B" is proceeding uniformly at the speed of 40 mph, and that the driver of car "A" wishes to pass. In the meantime, car "C" is approaching from the opposite direction, also at a speed of 40 mph. It is evident that a car which will complete this passing maneuver within the shortest distance preserves a greater margin of safety and flexibility than a car which requires a longer distance. In this maneuver, we assume that car A starts in the left lane with its front bumper even with the rear bumper of car B, accelerates full throttle until it passes car B and pulls back into the right lane at a distance 200 feet ahead. The distance measured is that required to gain 60 feet on car B, plus the 200-foot clearance, plus the distance which car C would travel in this same length of time. As shown on the chart, the car with the optimum performance in the 1959 fleet would complete this maneuver in 648 feet and in 3.3 seconds. In contrast, the car with the lowest performance in the 1959 fleet required a distance of 1023 feet and a time of 6.5 seconds.

There is considerable variation in the passing distance capacity of cars. Figure 16 is a frequency distribution showing the variation in the passing distance capability of the 1959 cars at 40 mph start full-throttle acceleration; the mean value is 790 feet.

For comparison purposes, the data in Figure 16 are expressed as a percentile distribution in Figure 17. This is computed

by accumulating the frequency in each class interval from Figure 16, expressed in percent. This gives a curve beginning with a minimum passing distance of 600 feet, and a maximum distance of 1050 feet, as noted on Figure 16, and a median distance of 775 feet.

Figure 18 shows the percentile passing distance curves from 40 mph start for the successive model years from 1952 through 1959. This shows a steady reduction in median passing distance until 1957. Since the passing distances required by the current economy cars are generally greater than those of the larger, higher powered cars, it may be anticipated that the median passing distance will remain near the 1957 value.

Figure 19 shows passing distance at 20 mph plotted against passing distance at 40 mph with the 1959 cars. In general, cars with relatively short passing distance at 40 mph also have relatively short passing distance at 20 mph, indicating that the single value at 40 mph initial speed may be used to represent comparative traffic flexibility.

In some instances, the time required to accelerate through some arbitrary speed range such as 10–60 mph is more useful than the passing distance as a measure of relative performance.

Figure 20 shows the trend of time to accelerate from 10-60 mph for car models 1933 through 1959. In this chart the cars with the minimum passing distance are shown at the top of the scale. Performance of most cars has increased quite rapidly since World War II. Cars with the lowest performance have required from 25 to 32 seconds to accelerate consistently through this speed range.

Figure 21 shows the trend of rated horsepower 1930 through 1960. The curve of maximum horsepower reached a peak in 1958 and that of the minimum horsepower car increased somewhat from 1946 to 1956 and then started a downward trend.

The trend of the average curve continued the rise indicated since World War II up to 1958; since 1958, the average has decreased. It is probable that current levels will prevail indefinitely.

It is appropriate to discuss again the distribution of horsepower. Figure 22 shows the various aspects of horsepower on one of the larger 1959 cars. The engine of this car had a rated horsepower which we need not discuss here since it was measured under special laboratory conditions. Essentially, these cover a bare engine, which is entirely appropriate because of development and

design considerations. However, with the engine installed in a car and carrying certain accessories such as a fan, generator, and other power-absorbing components, it developed an "as-installed" power of 230 hp, as shown in Figure 22. In the first range of this transmission the 230 hp was developed at about 25 mph; in third gear this was developed at about 65 mph; and in the top gear of the transmission 230 hp would be developed at about 105 mph.

When the power required to accelerate the rotating parts of the power train is taken into account, we find that the horsepower developed at the rear wheels has a maximum value of 172 hp. The power required to overcome wind and rolling resistance, or road load, rises approximately as the cube of the speed and, in this case, reaches approximately 100 hp at 100 mph—nearly the practical maximum speed of the car. At 100 mph, this leaves a residue of 72 hp which is available to accelerate the car. The maximum of 146 hp available to accelerate the car occurs at 47 mph.

Since it is rear-wheel torque rather than horsepower that accelerates the car, it is perhaps more realistic to consider the output of this engine in torque as a function of speed and transmission gear ratio. This is shown in Figure 23. We note four pairs of curves; one pair for each of the gear ranges in the transmission. The upper curve of each pair represents the engine torque transmitted to the rear wheels and the lower represents the residual torque after that required to overcome road load wind and rolling resistance is subtracted. In first gear the effect of road load wind and rolling resistance is almost negligible, as wind resistance is low at low speed. In fourth gear there is considerable difference between the curves amounting to approximately 50 percent of the transmitted engine torque at 100 mph; nearly the practical top speed of this car. Residual torque available for acceleration, as measured on the road, also is shown. This reaches a maximum of 3200 lb-ft at about 11 mph and drops to approximately 300 lb-ft at 100 mph.

Figure 24 shows the acceleration torque in percent of the transmitted engine torque through the speed range and in each of the gear ranges. Seventy-three percent of the torque transmitted to the rear wheels is available for acceleration in first gear at speeds of about 5 mph, but in the upper part of the speed range this falls to something like 35 percent at 95 mph. It is clear that only a small proportion of the engine power is available for acceleration in the upper part of the speed range.

High-powered cars require less passing distance than those of low power but, as suggested in Figures 23 and 24, the relative distance falls off as the horsepower is increased. This has been shown elsewhere[7].

Trends of fuel economy in miles per gallon under constant speed conditions on a level road at 40 mph are shown on Figure 25. This is a somewhat idealized engineering condition. While it may not be realized by the car owner, it is representative of the design characteristics of the automobiles involved. These curves show a rapid increase in fuel economy up to World War II and a slight decrease in the years immediately afterward, followed by a slow but steady increase up to the current period. The average of the group shows, generally speaking, a steady rise in spite of the added number of optional power absorbing accessories carried on many of the cars in this fleet. Fuel economy at 40 mph on the average car has been increased from 15 miles per gallon in 1930 to approximately 22 miles per gallon in 1960. Current smaller economy cars are shown as a special group, and the average of this group was approximately 27 miles per gallon in 1960.

Conditions the owner experiences on cross-country operation are reflected much more accurately in Figure 26. Here are trend data since 1933 measured on a typical highway run on Michigan rural roads covering approximately 300 miles at an average speed of about 45 mph. The route includes some urban and small-town operation.

Cars showing the best economy reached a maximum in 1955. There has been a slight decrease since then largely because of the increased use of power-absorbing accessories. Additional smaller economy cars increased the average in 1960. Cars showing the lowest highway economy have given nearly uniform economy since 1955.

The average of the fleet of cars has increased from about 13.5 miles per gallon in 1933 to approximately 18.5 miles per gallon in 1960. The smaller economy cars, shown separately, have an average highway economy of 23.5 miles per gallon.

Fuel consumption is related closely with the vehicle weight because the energy derived from burning the fuel is used in performing work of moving the weight of the car. Figure 27 shows the trend of curb weights from 1930 to 1960. While we find that the average of the cars in the fleet has increased from about 3500 to 4100 lb, the weight of the heaviest car has fallen since the early

1930's by nearly 500 lb, and the weight of the lightest car, except for the smaller economy cars, has increased about 500 lb. Thus, we find that even though the average curb weight of cars in the fleet has increased more or less steadily through this 30-year period, the constant speed fuel economy average has increased approximately 30 percent and the average highway economy has increased by about 25 percent.

Figure 28 shows the time-distance and time-speed relationships of the car with the lowest performance for the years 1951, 1955, and 1959. There has been only a small increase in performance for cars in this level. For example, at 40 seconds after start, the 1951 car had traveled slightly over 2600 feet, while the 1959 car had traveled approximately 2900 feet. At the same time, the speed attained in the 1951 car was 68 mph, while the 1955 and 1959 cars attained 70 mph.

Figure 29 shows time-distance and time-speed relationships for the best performing car for the same years. The 1951 car attained a speed of 80 mph in 28 seconds while traveling 2250 feet; the 1959 car attained this same speed in 15 seconds and 1120 feet.

These charts can be used to determine approximately the time required and distances required to accelerate from one speed to another or to determine speed change developed and distance traveled through a given length of time of full-throttle acceleration.

No paper on automobile characteristics would be complete without a chart showing the trend of a number of vehicles in operation and the number of miles operated. Figure 30 indicates that by the end of 1960, there will be something like 70 million vehicles on the road and that about 700 billion miles will be traveled during 1960. This is an increase of approximately 40 million vehicles and a yearly rate of travel of nearly 400 billion miles in the last 15 years.

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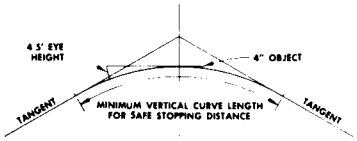

Figure 1 - Heights of eye and object for vertical curves - AASHO Design Policy.

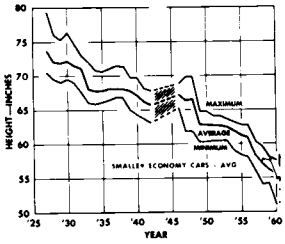

Figure 2 - Trend of car overall height with 5-passenger load for domestic cars (and for foreign cars with 4-passenger load shown for 1960.)

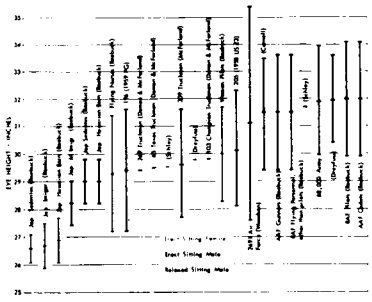

Figure 3 - Data found in the literature on driver eye height above a firm seat.

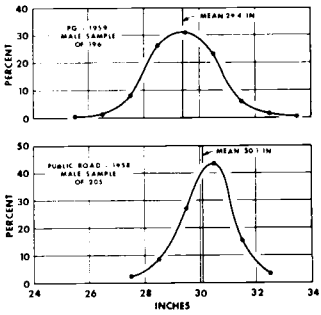

Figure 4 - Percent frequency distribution of driver eye height above a firm seat.

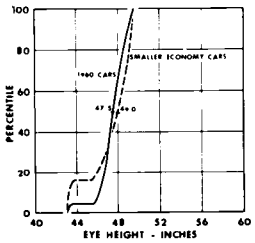

Figure 5 - Percentile distribution of driver eye heights above the ground for 1960 cars.

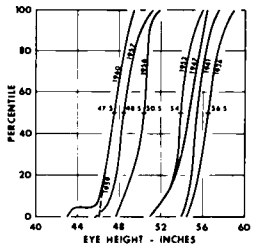

Figure 6 - Percentile distributions of driver eye height above the ground since 1936.

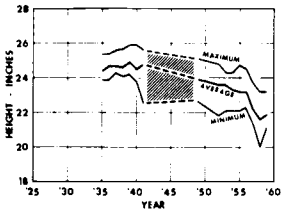

Figure 7 - Trend of center of gravity height of domestic cars from 1935 to 1959.

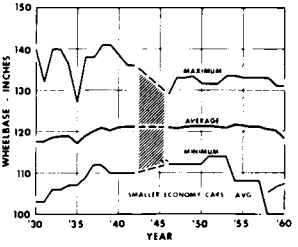

Figure 10 - Trend of wheelbase of domestic cars from 1930 to 1960.

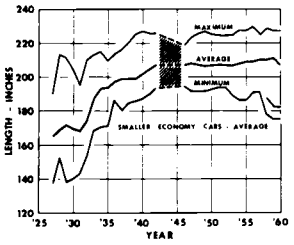

Figure 8 - Trend of overall length of domestic cars from 1927 to 1960.

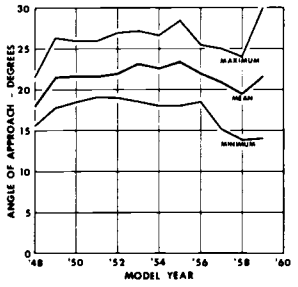

Figure 11 - Trend of the angle of approach of domestic cars from 1948 to 1959.

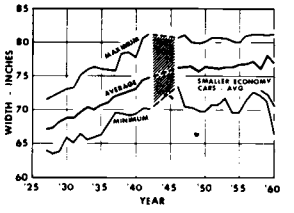

Figure 9 - Trend of overall width of domestic cars from 1927 to 1960.

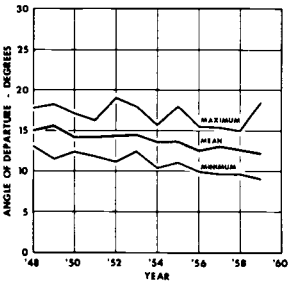

Figure 12 - Trend of the angle of departure of domestic cars from 1948 to 1959.

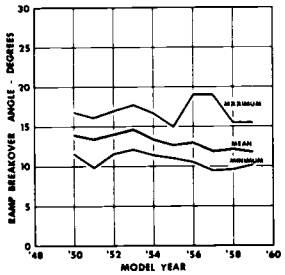

Figure 13 - Trend of the ramp breakover angle of domestic cars from 1948 to 1959.

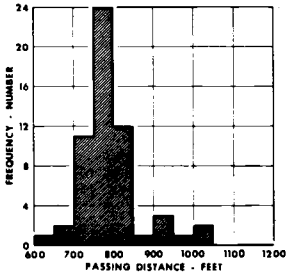

Figure 16 - Frequency distribution of passing distance from a 40-mph start for 1959 domestic cars.

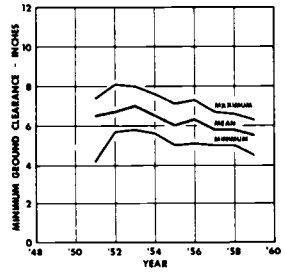

Figure 14 - Trend of the minimum ground clearance of domestic cars from 1951 to 1959.

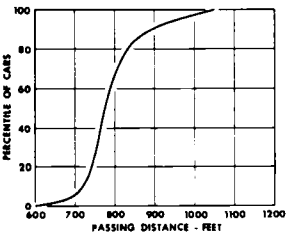

Figure 17 - Percentile distribution of passing distance from a 40-mph start for 1959 domestic cars.

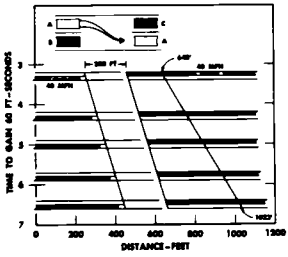

Figure 15 - Range of passing distance from a 40-mph start for 1959 domestic cars.

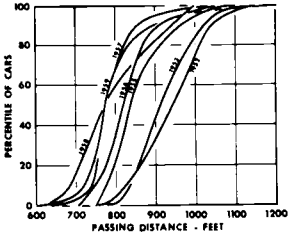

Figure 18 - Percentile distributions of passing distance from a 40-mph start for successive model years from 1952 to 1959.

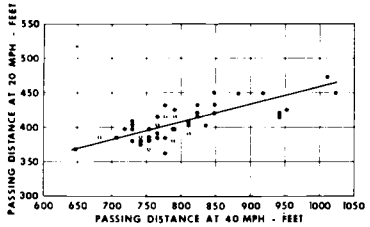

Figure 19 - Comparison of passing distances at 20 mph and 40 mph.

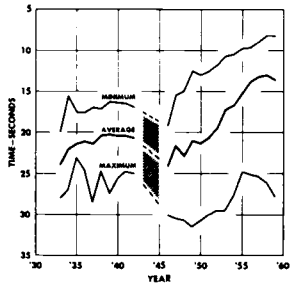

Figure 20 - Trend of time to accelerate from 10 to 60 mph for 1933 through 1959.

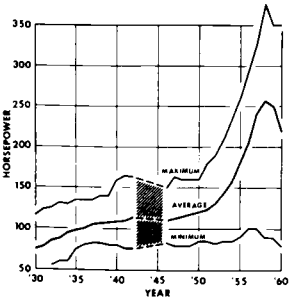

Figure 21 - Trend of rated horsepower for domestic cars from 1930 to 1960.

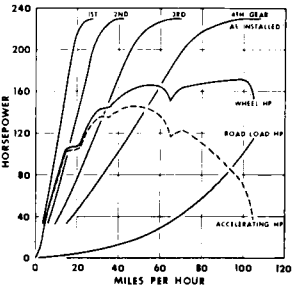

Figure 22 - Comparison of "as installed", road wheel, acceleration, and road load horsepower.

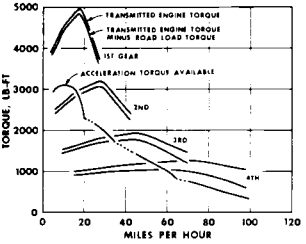

Figure 23 - Comparison of engine torque transmitted to rear wheels and torque available for acceleration.

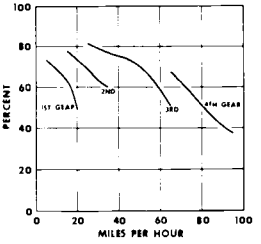

Figure 24 - Acceleration torque in percent of transmitted engine torque for each gear ratio.

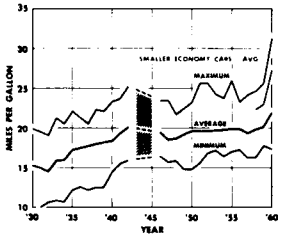

Figure 25 - Trend of level road load fuel economy at 40 mph for domestic cars from 1930 to 1960.

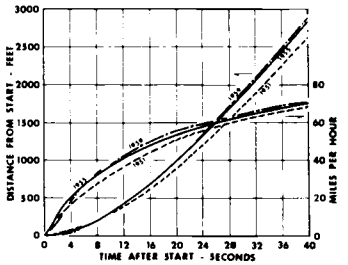

Figure 28 - Time-distance and time-speed comparison of the poorest performing cars for three model years.

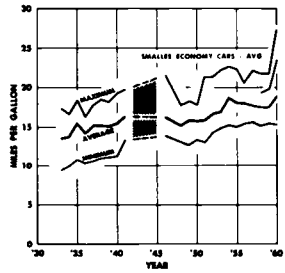

Figure 26 - Trend of highway fuel economy for domestic cars from 1933 to 1960.

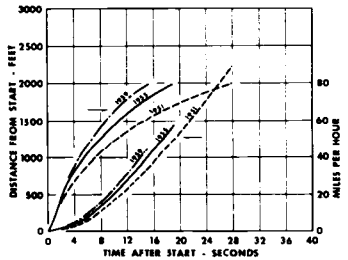

Figure 29 - Time-distance and time-speed comparison of the best performing cars for three model years.

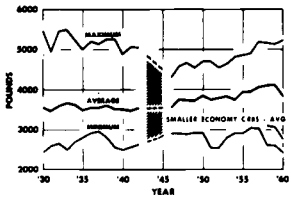

Figure 27 - Trend of curb weight for domestic cars from 1930 to 1960.

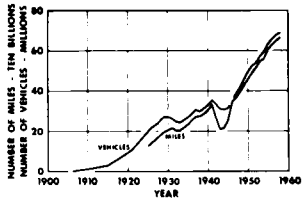

Figure 30 - Trend of number of vehicles on the highway from 1906 to 1958 and number of miles driven each year from 1925 to 1958.

ROADSIDE DESIGN FOR SAFETY

K. A. Stonex

The significance of the roadside in the highway safety problem is apparent from the National Safety Council's statistics. Year after year between 30 and 35 percent of the highway fatalities—12,000 to 13,000—in the country occur in noncollision accidents, most of which involve vehicles leaving the roadway.

This factor is second only to the two-vehicle collision as the most important and deadly. A great deal of engineering design effort is being devoted constructively to reduction and elimination of the two-car collision. Divided highways of the Interstate System, the turnpikes and expressways, grade separations, one-way streets, and signal installations and stop signs on intersections at grade are all attempts to eliminate this type of accident. Intensive driver training, public educational and enforcement programs are corresponding efforts in other fields.

In the policies on geometric design of the Interstate System, recognition is given to the importance of roadside hazards by the adoption of enlightened standards of roadside design with respect to slope, ditch cross sections, and elimination of obstacles. In reconstruction and modernization of existing roads, some attention is given to this problem, but one cannot help but feel that minimum standards are applied all too frequently in construction of portions of the Interstate System; one cannot help but feel that too little emphasis is given to the elimination of roadside hazards on primary and secondary and rural roads, even when they are being reconstructed.

It is the intention of this paper to discuss the problem in general and to give a number of specific examples of roadside hazards drawn in a large part from experience with the Proving Ground road system. It is the further intention to discuss some research results from which specific design criteria for roadside slopes and ditches are derived. Stability factors of passenger cars are related to observed roadside characteristics, especially with respect to the slope of roadsides and the coefficient of friction of roadside surfaces. Some discussion is given of hazards involved in conventional light poles and sign posts, with suggestions as to how this type of hazard may be reduced or eliminated. In addition, further observations on full-scale guardrail impact tests are given to supplement earlier publications on this subject[1]. Particular emphasis is given to guardrail end installations.

Some examples of roadside hazards have been discussed previously. They are repeated here as background and to give appropriate emphasis to the problem[2][3].

Problems of safe roadside design have become of great importance to the management of General Motors Proving Ground, with increasing emphasis placed in General Motors, as in all large industrial organization, on the safety of the employe. Industry has come to recognize that safety is one of the most important of management concerns.

The General Motors Proving Ground was established 35 years ago as an outdoor road test laboratory when a private road system was built for development work by General Motors divisions on their products. From a small operation it was expanded as rapidly as required, and facilities have kept pace with the increasing complexity of automotive design.

Today, the road system includes about 62 miles of all types of surfaces common to those of the public highway. Portions of this system with the highest traffic volume were completed by the middle 1930's. During the past 35 years, over 200 million test miles have been operated, and the current rate is about 40 thousand miles a day, or 10 million miles per year.

At the Proving Ground normal standards of shop safety always have been employed. Thirty-five years ago the attitude about industrial accidents, quite generally, was that accidents were something which would happen and that we had to learn to live with them. The industrial safety engineer has shown that is not so. He has shown that accidents are preventable, and that accidents in the plant usually come about because of some human malfunction. Recognizing that while some accidents are preventable, some will not be prevented, and he provides all safeguards he can imagine for all types of carelessness and inattentiveness which people may show so that the effect of an accident may be minimized.

When, a few short years ago, we began to apply the concepts of the industrial safety engineer in our consideration of the Proving Ground safety program, it became evident that the most serious potential hazards lie in the operation of our vehicles on our road system because both the masses and speeds of cars exceed those of any of the other machines with which we work.

Generally speaking, the Proving Ground road system was quite well developed 20 years ago. In construction, the design standards which prevailed generally at the time of construction were used, and our practices were comparable with those of the state highway departments. Basic elements of highway safety were considered with admirable foresight in the design of the road system at the establishment of the Proving Ground. Limited access and avoidance of intersections of main test roads at grade have always been the policies. Thus, the basic design of the system avoided many of the types of accident which are now causing such great concern in the public transportation system. At the time, this approach was unique in its enlightenment and progressiveness.

As we reviewed our accident statistics we found that during the 6 calendar years 1953-1958, inclusive, covering approximately 65 million test miles, there was a total of 236 accidents of which 72 percent were off-the-road.

Our first and most obvious concern was to determine the reasons why drivers left the road. In many cases the driver went to sleep. In other cases he was obviously inattentive. Educational programs were undertaken, reprimands were given and, in the more flagrant cases, drivers were discharged.

In spite of all this it became evident that drivers do leave the road—infrequently, it is true, but all too often—simply because they are people and suffer normal human fallibilities.

A further consideration led to the conclusion that it was not possible to keep all drivers on the paved surface all of the time. One of the fundamental principles of safety engineering is to anticipate every possible type of accident that may occur because of machine failure or human failure, and then to establish safeguards to minimize the hazards or injury that may result when such a failure occurs.

When we looked at our road system from the same point of view we were considerably disturbed to find that design standards provided little or no safeguard in the event that there should be a failure of some type. Our predecessors had pioneered in safety engineering by taking fundamental steps to avoid accidents, but they did not apply the second concept of the industrial safety engineer to provide all safeguards in the event that an accident occurred because of human fallibility.

When we realized that our roadside design did not incorporate

safety features common to our machine shop, garage, and maintenance tools, we sought to make amends at the earliest possible time by using the experience of other people. We made immediate comparisons with public highways in the adjacent area and found that the public highway system repeated most of the shortcomings of our own road system. We looked at highway construction in other states, at the turnpikes, even the newest components of the Interstate System, and we found even there that there was a lack of safeguards which would not be tolerated in any modern industrial operation. Almost every mile on any of these roads had one or more places where occupants would suffer serious or fatal injury if the vehicle left the road at normal highway speeds.

An approach to the problem of safe roadside design from the attitude of the industrial safety engineer became our primary interest in providing proper safeguards to our employes operating on our own road system. Every roadway accident includes as factors the driver, vehicle, and highway, and these factors were considered properly in our approach to our problem.

Our drivers are adult males in good health; they are selected on the basis of average or above competence and on the characteristics of desirability in an employe; they are all qualified drivers with several years of experience in normal highway driving; and it is fair to assume that they compare with the upper strata of drivers in the traffic stream on the basis of these characteristics.

They drive on a closed road system with favorable geometry, relatively low traffic volumes, controlled access, one-way operation, and under relatively close supervision. Extensive training and educational programs have been conducted. Our minds are not closed to the possibility of more effective ways of improving driver performance. We have exhausted the obvious solutions, and we have tried some which are not obvious. In spite of this, during the last 6 calendar years, we have had 170 off-the-road accidents.

The business at the Proving Ground is the development of automobiles. We are familiar with the scrupulous attention given to safety in design and manufacture, and we are confident that the current automobiles well maintained are practically free from hazardous failures in service.

Our confidence in the quality of vehicles and our experience with the fallibility of the drivers left us with the firm conviction that the major deficiency in our effort to eliminate accidents was

the failure to devote sufficient attention to the road itself. In our case, the concept of the original traffic pattern practically eliminated two-vehicle collisions and confined the problem almost entirely to the roadside.

COMMON ROADSIDE HAZARDS

When one adopts the safety engineer's attitude and concepts, the most dangerous situation perceived immediately is that of obstacles adjacent to the road; that is, close enough to the traveled surface so that the driver who has lost control of his vehicle temporarily will strike the obstacle before he has an opportunity to regain control.

On our road system, and on nearby public highways, the most obvious obstacles are trees. Trees are desirable and beautiful, and in the early days of the Proving Ground we frequently modified the alignment so that a large, beautiful oak might be saved. However, a review of any newspaper shows that trees contribute almost every day to the statistics of injury and death (Figure 1).

Trees have played a part in the more serious Proving Ground accidents (Figure 2). Severity of an impact at normal speeds is indicated in Figure 3. This car was driven by remote control into the tree at 35 mph. It was damaged seriously, and it was evident to anyone who witnessed the accident that occupants of the car would have been seriously injured and probably killed.

To the safety engineer, the immediate conclusion is that trees close to the roadside must be eliminated systematically. Fortunately, with modern equipment this is practical and relatively inexpensive (Figure 4). After the trees are removed and the roadside smoothed with a grader, no possibility of serious accident in this area remains.

This situation has its direct counterpart in the public highway system. On some major highways of relatively modern design there are trees so close to the road as to be lethal obstacles (Figure 5) and, in fact, on some of the newest highways small trees are being planted as part of the landscaping program. As a result, in all too few years the small trees will grow into big ones—significant hazards being cultivated immediately adjacent to the edge of the road.

Beauty is possible without large trees, or with trees well in the background. In exceptional cases, well designed guardrail installations may be used if speed is well regulated. Figure 6 shows how shrubbery can be used.

On many of our city streets, and even some of our rural highways, there are man-made obstacles in the form of utility poles and light poles immediately adjacent to the paved surface (Figure 7), and signs to guide the traveler (Figure 8).

Conventional light poles are self-supporting structures normally erected on a concrete base and designed to withstand winds of hurricane velocity. Unfortunately, they become roadside obstacles of important dimensions. As a compromise we have proposed use of a tripod structure constructed of light tubular material with shear mounts flush with the base. Figure 9 shows such a pole in contrast with a conventional pole in our parking lot.

This was evaluated in a full-scale test. Figure 10 shows three frames from the motion picture record of this test. The car passed through beneath the pole with negligible impact and only superficial damage. One leg, whipping during the collision, would have injured occupants of a convertible, but the design can be modified to control this.

Standard roadside signs, mounted at 42 inches above the pavement, are also a hazard. Figure 11 shows that in a collision at 40 mph, a sign of this type pierces the windshield partially and showers the front passenger compartment with glass. At higher speeds the sign would not drop so far and occupants would find themselves running into a 25-lb sign at whatever speed the car was traveling. When the sign is mounted at 60 inches, the car passes beneath harmlessly (Figure 12). Roadsigns at the Proving Ground are being relocated at 66 inches.

DITCHES

In all parts of the United States it is necessary to provide some type of drainage system along the road to carry off surface water. These ditches are effective for carrying off water, but they may present a very serious hazard.

Figure 13 shows a typical situation on many miles of rural road. It does not take a safety engineer to recognize the seriousness of the inevitable accident when some driver becomes inattentive or falls asleep and leaves the road at this point.

Unfortunately, these practices are carried over to new roads (Figure 14). Sharp V-ditches are still being graded almost immediately adjacent to the traveled path of roads being built according to the Interstate System's standards.

In some cases, careless inspection procedures or lack of detail in construction leaves a mound unnecessarily (Figure 15). On rural roads additional right-of-way must be procured or agreements made with abutting landowners to abolish such ditches and banks. However, on portions of a modern road system where adequate right-of-way is available, such construction is intolerable to the safety engineer.

Severity of ditch impacts is indicated by Figure 16, which shows a remotely controlled car driven off a road through a ditch with a 2:1 backslope. The car was severely damaged, and it is evident that the occupants would have suffered serious injury, at least.

Figure 17 shows a much milder degree of severity when the backslope is 4:1. In this case the car climbed the bank with a rather minor impact, and the injury and damage would have been negligible.

Desirability of ditches with flat bottoms and smooth contours and flat slopes has been discussed before, but no design criteria have been given. Some preliminary experimentation showed that a car could be driven through a flat ditch with a wide, rounded bottom at 60 mph with ease and comfort (Figure 18).

DITCH TESTS

In the test above it was not clear whether the value of the slope and backslope, width of ditch bottom, or depth of ditch contributed most significantly to the severity of operation. We made a series of tests to evaluate the severity of crossing a ditch as a function of speed and ditch cross-section elements. In the initial series of tests a ditch was dug in conformity with the Michigan State Highway Department standards for a median ditch on a divided road. Cars were driven through the ditch at moderate speeds, the driver noted the subjective severity as speed was increased, and measurements of "vertical" accelerations were made so that the numerical values could be correlated with the driver's sensations up to the point where the operation became so severe it was unsafe. Remotely controlled tests were continued at increasing speeds through the point of minor to severe damage to the automobile. By

extrapolation, some estimate may be made of where serious or fatal injury may be produced.

Intuition suggests that a ditch cross section should be of some curved form to minimize impact. Because the suspension system deflects under impact, the unsprung mass of the car will follow a curved path. If the transition from the side slope to the bottom of the ditch is gentle enough that the bumper does not dig in, the unsprung weight and the sprung mass of the car should have a continuous, curvilinear motion. The simplest to consider would be a circular motion, as indicated schematically in Figure 19.

If the ditch cross section is circular with radius r, the projection on the path at which the car may run through the ditch becomes elliptical in form. The path will make some angle with the axis of the road, possibly up to 20 degrees or more. The projection of a circular cross section on a path at angle $90° - \phi$ from the axis of the road has this mathematical form

$$\frac{t^2}{r^2/\cos^2\phi} + \frac{y^2}{r^2} = 1$$

which is an ellipse in the y-t plane, with major axis - $r/\cos\phi$, minor axis - r, where $90° - \phi$ = angle between path of car and axis of ditch. The derivation is given in the Appendix, and Figures 20 and 21 indicate how this projection is made.

With a given ditch cross section, the radius of curvature may be estimated graphically, and with the speed arbitrary the value of the radial acceleration can be computed.

In order to verify the analysis and to develop values of radial acceleration or severity which could be tolerated, three test ditch sections were constructed as shown in Figure 22. Two sections with a 4:1 slope are taken from the Michigan State Highway Department standards for a median ditch. These have ditch slopes of 4:1 with varying width of bottom and varying depth to provide longitudinal drainage. Section 3 has the slope and backslope of 6:1 and depth varying from 4-1/4 to 4-3/4 feet, with an 8-foot bottom width.

Typical values of normal or vertical accelerations were computed from the test sections of 6:1 slope, which are shown in Figure 23.

Tests were conducted by laying out angles between the car path and axis of the ditch of 10, 15, and 20 degrees and by driving

the car through the ditch at increasing increments of speed. During each test recordings were made of the normal acceleration, and the driver's opinion of the severity was noted. Tests were conducted up to the point of extreme discomfort and an estimate was made of the tolerable value of normal acceleration.

It should be noted here that considerable training was involved, and the test engineer developed a considerable resistance to this type of operation. This is an experience of considerable severity at the higher speeds, and it may be anticipated that the unwary driver will suffer severe psychological damage before he suffers physical injury. Because of his natural alarm he is apt to lose control of the car and precipitate an even more serious accident. Figures 24 and 25 show typical test scenes.

After the practical limit of driver tolerances have been reached, test cars equipped with remote control devices were operated in a limited series of tests to determine, if possible, the severity at which structural damage began to appear. It was intended to continue the tests up to the point where we assumed that serious injury would result to the passengers. A limited number of tests were made, but these were not considered to be significant because there should be no serious interest in a ditch section where the severity is beyond the driver's tolerance.

Test data consisted of the values of acceleration measured by a transducer carried on the car such that it measured the accelerations approximately normal to the longitudinal axis of the car and recorded them on an oscillograph. Car speed was recorded simultaneously.

Figure 26 is a typical oscillogram from these tests. The upper trace indicates car speed—in this test it was 50 mph. The second trace from the top shows an indication of the time during which the car was passing through the ditch as noted by the driver. This is indicated by the slightly elevated portion of the second line from the top extending across the middle two-thirds of the chart.

The bottom trace shows the acceleration recorded. As the car enters the ditch the acceleration is slightly above the zero line, or negative, probably from the effect of going over the vertical curve. The acceleration increases fairly rapidly, and during the most severe portion of the passage through the ditch has a fairly high level which persists for approximately 0.2 seconds. The mean value indicated during this portion of the passage through the ditch was approximately 0.75 g.

The value calculated by assuming the reasonable path of curvature from the projected cross section of the ditch was 0.32 g.

This relationship between the calculated value and the typical value measured is representative of the conditions found on most of these tests. This chart indicates that during such tests we observe values in the range of those calculated, but we also observe values persisting for an appreciable length of time that are considerably higher than those calculated. In the severe cases, of which this is an example, the observed values are nearly twice the calculated values.

This is easy to understand. The suspension system of an automobile will bottom under the values of vertical acceleration which are relatively mild in the framework of reference of these tests. When the suspension system bottoms, vertical forces are transmitted through the rubber bumpers, which have a much higher rate than the car springs and a rate which may increase considerably as the deflection is increased. Consequently, an impact severe enough to bottom the suspension system will introduce nonlinearities for which no provision is made in the calculations and, indeed, which would be difficult or impossible to compute directly by simple means.

Figures 27 and 28 show the comparison of calculated and measured values on Ditch Sections 3 and 1, respectively, as a function of speed for an angle of attack of 20 degrees.

It will be noted that at the relatively mild conditions at 10 mph, there is reasonably close agreement between the observed and calculated values, but that the difference between them increases rapidly as the speed and, consequently, severity of the test increases. It may be noted also that the values of both the computed and measured decelerations increase as the angle of attack increases; thus a 20 degree angle of attack at 50 mph where the computed value is approximately 0.56 g, the observed value is approximately 1.1 g on the tests on Ditch Section 3 (Figure 27).

Somewhat comparable results are shown in Figure 28 in the tests on Ditch Section 1. The differences between the observed and computed values are even greater. Observed severity of tests was somewhat greater on Ditch Section 1 and the limiting speed was approximately 40 mph, compared with approximately 50 mph on Ditch Section 3. Values are tabulated in Figure 29. Data indicate that observed severity is approximately twice that of the calculated value under the more severe conditions.

Thus, it is apparent that none of the three ditch sections tested would be acceptable for a primary road or a road where speeds above 50 mph might be anticipated.

The ditch section shown under test in Figure 18 was re-evaluated more carefully to provide a better estimate of its capacity by using a remotely controlled car at elevated speeds. The cross section is shown in Figure 30.

Driving experience at moderate speeds indicates that the severity of impact begins to become uncomfortable at approximately the point where the suspension bottoms, and it approaches the intolerable level when the bumper strikes the ground. At higher speeds it would be expected that even minor contact with the ground would be injury-producing. Therefore, this is a condition which the ditch design should avoid. There is some evidence that suspension systems will bottom heavily under normal vertical accelerations in the order of 0.5 g, which appears to be in the range in which the calculated severity of operation is a first approximation to the average values observed.

Design criteria might therefore be based upon the development of ditch cross sections which, when projected at reasonable angles of attack, would yield path profiles such that curvature of the path of the center of gravity could be estimated reasonably accurately and first order approximation to vertical acceleration computed. Conservative design criteria should provide that calculated values of vertical accelerations should not exceed 0.5 g for a car passing through a ditch at an angle of 15 degrees under the anticipated speeds of operation. This would assure reasonably comfortable operation at the design speed and provide a slight margin of safety for the driver who may have been unwise enough to exceed the design speed and unfortunate enough to leave the paved surface at 15 degrees or even some higher angle.

The most important element of the ditch section design in controlling the severity is the length of the vertical curve between the side slopes and the ditch bottom. Obviously, the radius of curvature is the controlling element. For design purposes, however, it is much simpler to use a circular vertical curve and employ criteria based on vertical curve length.

Figure 31 defines the elements which are considered in the development of criteria.

Figure 32 shows the relation between vertical curve length

and the ditch slope for the arbitrary conditions of the speed of 65 mph and angle of attack of 15 degrees, which will provide a severity or normal acceleration of 0.5 g. To be noted is the rapid increase in required length of vertical curve as the slope increases.

Figure 33 shows the influence of the angle of attack on vertical curve length for the arbitrary conditions of speed of 65 mph and a ditch slope of 6:1 which will produce a severity or minimum acceleration of 0.5 g. From this it will be noted that the severity increases much more rapidly than the angle of attack.

Importance of the vertical curve as a design element of the ditch section is emphasized by Figure 34, which shows variation in severity with vertical curve length. Conditions assumed are 15-degree angle of impact, 65 mph, and 6:1 side slope. The vertical curve cannot be left to chance in design, construction, or maintenance.

This concept of roadside safety for highways at current operating speeds provides that obstacles are cleared for a reasonable distance from the edge of the pavement to provide maneuver room for the driver who leaves the pavement, and that the roadside is traversable so he can maneuver satisfactorily. Obviously, the driver will be unable to control his car if the roadside is so severe that the car is damaged or if he is injured or even severely shaken up or alarmed.

ROADSIDE SLOPES

There are little data upon which to base design criteria of the value of the side slopes on fill sections. In some cases it is obvious (Figure 35) that the slope is too steep, or that the transition from side slope to natural grade was too abrupt. In many cases we find on relatively flat, gentle slopes that the car slides rather than rolls over (Figure 36), and in certain cases the car may roll over (Figure 37).

Force and moment systems on a car sliding down a side slope are indicated in Figure 38. Here W equals the weight of the car, T is the tread, H the center of gravity height, θ the angle of inclination of the slope, and F the sum of the gravitational component and ground reaction or impact reaction against an obstacle at the point where the weight on the upper wheel, W_u, approaches zero. The equilibrium of force components parallel to the slope of the plane are given in Equation 1, the equilibrium of normal force components by Equation 2, and the equilibrium of moments by

Equation 3.

$$\Sigma F_x = F - (ma + W \sin \theta) = 0 \quad (1)$$

$$\Sigma F_y = W_1 - W \cos \theta \quad (2)$$

$$\Sigma M_o = \frac{T}{2} W \cos \theta - H (ma + W \sin \theta) = 0 \quad (3)$$

From (1)

$$F = ma + W \sin \theta \quad (4)$$

From (4) and (3)

$$\frac{T}{2} W \cos \theta - HF = 0 \quad (5)$$

$$F = \frac{T}{2H} W \cos \theta \quad (6)$$

$$f = \frac{F}{W} = \frac{T}{2H} \quad (7)$$

where $\theta = 0$, and where f = the coefficient of friction or coefficient of ground reaction.

Thus, on a level road the coefficient of ground reaction which will balance the car about the reacting wheel is equal to the ratio T/2H, where T = tread width and H is center of gravity height.

Equation 6 shows that on a car sliding down a slope, the ground reaction force necessary to tip it over is proportional to the cosine of the angle of inclination of the slope, and that consequently the reaction force against the wheel required to tip the car over decreases as the angle of inclination of the slope increases. It should be noted further that the ratio of the horizontal and normal forces, F/W, may be a coefficient of friction or a coefficient of ground reaction required to give this equilibrium of overturning moments and that the value of this reaction is dependent upon the tread width and the center of gravity height as expressed in Equation 7. On a level road, for example, the car will overturn when the coefficient of friction exceeds the ratio of the tread and twice the center of gravity height.

The value of the deceleration which must be provided by the friction or ground reaction on the side slope to overturn the vehicle

may be determined from the relations above.

Solution for the deceleration, a, gives

$$ma = \frac{T}{2H} W \cos \theta - W \sin \theta \quad (8)$$

$$\frac{W}{g} a = \frac{T}{2H} W \cos \theta - W \sin \theta \quad (9)$$

$$\frac{a}{g} = \frac{T}{2H} \cos \theta - \sin \theta \quad (10)$$

where a/g is the deceleration in gravity units or "g's." It is in the same units and magnitude as f in the equation

$$f = \frac{T}{2H} \quad (7)$$

The effect of roadside slope on the deceleration provided by the friction or ground reaction on the deceleration required to trip the car is shown on Figure 39 for an arbitrary angle of attack of 25 degrees, where a value of T/2H representative of current automobiles is considered. It shows, for example, that deceleration provided by ground reaction and coefficient of friction of the slope required to tip the car over is reduced by about 6 percent below that required on a level road on a slope of 6:1. On a roadside slope of 4:1, tripping deceleration required to overturn the car is reduced by 9 percent; on a 3:1 slope by 13 percent; and on a 2:1 slope by 18 percent. Figure 39 means, then, that it is easier to tip over a car on a steep slope than on a relatively flat slope.

As computed approximately for static conditions, current automobiles have an average stability factor of about 1.4, with some small variations related to different design approaches.

Effect on the stability factor, T/2H, of variation in T and H, the tread width and center of gravity height, respectively, is shown on Figure 40 for all treads in the practical range and a range in center of gravity height from 18 inches to 24 inches. Effect of lowering the height of the center of gravity is of more importance on this variation than is the effect of changing the tread. Figures 41 and 42 show the rates of change of f with T and H, respectively. The derivative of this function with respect to T, $df/dT = 1/2H$ is independent of T, indicating that f decreases as the reciprocal of H of all values of T. On the other hand, the derivative of f with respect to H, $df/dH = -T/2H^2$, is inversely propor-

tional to the square of H, the center of gravity height, so that the contribution of H to the stability index varies as the negative reciprocal of H^2.

Relative stability of current cars has been achieved largely by virtue of low center of gravity height. In passing, it should be noted that reduction in the center of gravity height means inevitably that the driver's position in the car will be lowered and, consequently, that the driver's eye height also is lowered.

In other papers, some on this program, the trend in driver's eye height and its relation to crest vertical curve passing distance is discussed (4)(5)(6).

It should be clear, however, that reduction in eye height occurs somewhat in proportion to the decrease in center of gravity height and that stability of the car is increased approximately as the inverse square of the reduction in driver's eye height; that is, as the square of the decrease in height of the center of gravity.

Significance of the stability factor, T/2H, is that this factor is equal to the coefficient of friction of the surface on which the car will overturn when it is sliding sideways, or "coefficient" of ground reaction. Units of stability factor are the same as those of coefficient of friction.

In order to determine significance of the values of the stability, T/2H, or the tripping deceleration rate which must be provided by ground reaction or coefficient of friction of the ground surface, a car was dragged sideways on several types of surface. The method is shown in Figure 43 and oscillograms of the results are shown on Figures 44 and 45. Figure 44A shows recorded test results measured over a range of low speeds on a dry, firm, grass surface. This surface is that of the typical mowed grass in a field, and it is believed to be representative of sodded roadside surfaces in Michigan. Ground was firm and dry, representative of typical summer conditions. Tests were repeated in late October when fall rains had moistened the ground thoroughly, and results of this test are shown in Figure 46. Differences between dry and firm and wet sod are not large and are generally less than the effects of local variations or protuberances during each of the tests.

The side force ground reaction on dry sod, shown in Figure 44A, ranges primarily between 1.0 and 1.2 as expressed in units of coefficient of friction with local variations which may be taken as indicative of the effect of small local protuberances. While the

range of speed was low, there is little variation in the value of "coefficient" with speed. Although this factor is expressed as if it were a coefficient of friction, it is probably not a true coefficient, and values are probably dependent on surface irregularities.

Figure 44B shows values developed on a bituminous concrete surface. At lower speeds, coefficient of friction also falls in the range between 1.0 and 1.2, and at speeds of approximately 10 mph, the coefficient falls below 1.0; that is, in this case, we observe a decrease of coefficient with an increase of speed.

Figure 45A shows results of tests made on a gravel road surface. Coefficient of friction varies between 0.6 and 0.8, and with a typical value of possibly 0.7. Very little effect is shown over speed range of approximately 11 mph to nearly 0 mph.

Figure 45B shows results of tests made on a dirt surface. Typical values of speeds of the order of 4 mph or less are, generally speaking, below 0.8, although the coefficient reaches 1.0 locally. Effect of speed over a range up to approximately 5 mph appears to be negligible.

Figure 45C shows the coefficient of friction measured by dragging a car sideways on a Portland cement concrete road surface. For speeds of approximately 10 mph, the coefficient is somewhat below 0.8. At lower speeds, 8 mph or lower, the coefficient rises above 0.8 and exceeds 1.0 at creeping speeds.

On paved surfaces the coefficient develops higher values at lower speeds, but this condition is apparently not found on sod, gravel, or dirt surfaces.

Figure 47 is a summary of average values of lateral coefficient of friction or ground reaction shown on the oscillograms in Figures 44, 45, and 46.

While it was not possible on this series of tests to observe values of ground reaction at practical road speeds, the oscillograms made in the range from 0-12 mph do not suggest there is an important variation in speed on either wet or dry sod. The values on wet and dry sod are essentially the same.

It seems obvious that the maximum practical values of coefficient of friction or ground reaction on a side slope with firm, dry sod will occur when there are irregularities in the surface, protuberances or ruts which the car wheel may strike so that

relatively high values of impact resistance occur which may trip the car, or when the ground is soft enough that the lower wheel can dig in and develop a relatively large shear force against the edge of the groove in the ground.

In view of the relatively small reserve of stability provided by current automobiles with low center of gravity height, careful design and construction of the roadside is a matter of great significance in the design of roadside safety. This leads to the suggestion that more sophisticated design and construction practices for roadside surfaces should provide for compact, smooth surfaces and that maintenance practices should give much more emphasis to preserving this smoothness. Importance of smooth, firm, low coefficient roadside surfaces can hardly be overemphasized in the consideration of roadside safety.

Effect of roadside slope in reducing the tripping deceleration level is of first order of significance. The 6 to 18 percent reductions noted on Figure 39 when the car is sliding down the slopes of 6:1 and 2:1 at a 25 degree angle may indeed be of great significance.

Value of slope also has secondary effects since the steeper the slope the longer the velocity of the car will be maintained and, thus, the greater will be the possibility of striking some protuberance which will trip it. Furthermore, the steeper the slope, the greater is the weight transfer from the upper to lower wheel and the greater the indentation into the ground will be and the larger the shear forces may be.

It must be concluded that for safe roadside design the slopes must be as flat as possible; not steeper than 6:1 and preferably flatter. They must be as smooth and firm as possible and provide the lowest possible reaction against a car sliding sideways down them.

Unfortunately, there is no manner of adequately specifying roadside smoothness. Tentatively, it may be said that slopes should be free from stumps, firmly embedded stones, and erosion channels, and smooth enough to be mowed comfortably. The apparent margin of stability factor of even the current automobiles with low center of gravity height is such that relatively small improvements in the flatness and smoothness of the roadside slopes will make significant reduction in roadside hazards.

GUARDRAILS

Under some circumstances it will be impossible to eliminate obstacles from beside the road. Bridge piers must be relatively close, and in mountainous terrain it would be impossible to have side slopes constructed according to the ideal which we have discussed. In other cases, on high fill, the slope of the natural ground will be such that it will be impossible to build a flat, gentle side slope, and a steep fill will be required. In these cases some use of guardrail must be made to protect against the more serious obstacles.

At the last meeting of the Highway Research Board, Messrs. Lundstrom and Skeels reported on a series of full-scale guardrail tests conducted at the Proving Ground[7]. A major conclusion of their paper was that there was no such thing as a perfect guardrail, that a guardrail was a last resort, and that it should be used only when no other solution was possible. Mr. Beaton of California is reporting this year on a series of tests of median barrier installations which are comparable with guardrails, and thus we have a great deal more information that we had two years ago[8]. However, since Messrs. Lundstrom's and Skeels' report was incomplete, we have conducted some additional tests with particular reference to the design of the end installation.

Figure 48 shows results of a full-scale impact of a car against the end of a guardrail installed according to the standard installation. This produces a shocking direct collision with an obstacle, and it is a completely undesirable installation. We sought to improve on this by ramping the end sections down to the ground to allow the car to slide upward, and Figure 49 shows a car striking the end of such a ramped section at 50 mph. Impacts were rather moderate, and this approach appeared to be rather promising.

A second test was made at 60 mph on an installation having a somewhat longer ramp (Figure 50). In this case, it is obvious that the ramp was too steep and the car was pitched violently up in the air. A third installation was made with a still longer ramp and with closely spaced posts extending 6 inches above the rail (Figure 51). Results were somewhat more favorable, but the impact was severe.

There may be other and better solutions to this problem. Figure 52 shows probably a nearly ideal condition where the back slope of the ditch was approximately 30 inches above the pavement surface and the guardrail was taken across the ditch and started at

approximately the top of the bank so that the end is protected completely. This solution can be applied to equal advantage where the back slope extends well above the level of the pavement, provided there is a shallow ditch of good design.

In locations where there is no convenient ditch and back slope, a long, low earth mound ahead of the end of the guardrail, as depicted in Figure 53, would appear to have great advantage. As shown in this figure, provision is made that one or the other of the wheels might run up on the bank, and when the car reaches the guardrail it will simply slide along the top. If the car strikes the approach ramp dead center, it will simply slide up the long, gentle ramp with very low impact values.

A variation of this design might be to build a somewhat wider ramp, falling away more slowly as the end of the guardrail is reached, so that the whole car would drive up the ramp and the flat departure slope of the ramp would allow the car to settle down on top of the guardrail gently.

We have not had an opportunity to evaluate the design suggested by Figure 53. One is left with the intuitive impression that it should be a satisfactory solution to the problem for most installations. It seems clear that almost anything is better than no end treatment at all.

As noted also in the Lundstrom-Skeels paper, there is still uncertainty as to the type of installation which will produce minimum hazard to occupants of the car. There is some question about the compromise between minimum hazard to occupants and to other travelers on the highway. There is some question remaining about the optimum type of guardrail, whether it be a beam, cable-type, net-type, or some fixed impassable barrier. More information is needed on the best type of material, which may be steel, aluminum, fiberglass, or wood. There is some question still about the optimum size of posts, their spacing, and the material of which they are made. There are still some questions about the best way of mounting the guardrail, whether it should be mounted directly to the post, mounted with a spring connection, or with a solid block.

While it appears that there is a great deal not known about guardrail design, it is clear that hitting a guardrail is an accident, and that installation of guardrails should be avoided wherever possible.

IDEAL EXAMPLE

Figure 54 shows how we have applied these concepts of safe roadside design. This is our latest road, built in 1958. There are no obstacles within 100 feet of the pavement, all slopes are gradual, and all ditch bottoms are wide and gently rounded. Cost of construction was only about $9500 per mile above what the cost of standard highway design would have been. Terrain was favorable, but part of the area was heavily wooded and drainage requirements were unusually expensive.

Figure 55 shows a typical scene on our Hill Road, part of which was completed in 1927. This road has a sharply curved alignment as indicated in Figure 56. It covers a total distance of 2.37 miles over fairly rough country, it has numerous short, steep grades, and a total rise and fall of 6.10 feet per 100 feet. It was constructed originally according to 1926 standards. The typical cross section is shown in Figure 57. For comparative purposes the somewhat improved cross section designated as the 1940 standard is shown in Figure 58. The section is possibly typical of many of the rural roads now being constructed, particularly of secondary roads. Primary differences are that the shoulder width has been increased from 3 to 6 feet and the ditch slope has been flattened from 1.5:1 to 3:1.

The typical section which would be required by our 1960 standard is shown in Figure 59. Differences here are that the lane width has been increased to 12 feet, shoulder width has been increased to 10 feet, maximum slopes have been decreased to 6:1, 6.5-foot vertical curves are incorporated in ditch bottoms, and obstacles are cleared from each side of the center line to a minimum distance of 100 feet.

Cost details according to the three standards are compared in Figure 60 and summarized in Figure 61.

Relative costs of construction estimated at current unit prices are: For the 1926 standard, $48,800 per mile; for the 1940 standard, $54,000 per mile; and for the 1960 standard, $75,000 per mile. Thus, the difference in cost per mile between the 1960 and 1926 standards is only approximately $26,000 per mile. This means that for $26,000 per mile we can transform this primitive one-way rural road into a highway with roadside design standards surpassing those of the New York Thruway. We think this will be a good investment.

SUMMARY

Roadside hazards are a significant part of the highway accident problem. These hazards can and should be reduced significantly by eliminating obstacles adjacent to the roadside, including trees, light poles, and sign posts.

Ditch sections should be shallow and wide. A ditch with a 4:1 slope and back slope and an 8-foot bottom will produce vertical accelerations exceeding 1.0 g at 40 mph. Maximum intensity of operation short of driver injury is approximately 2.0 g, which occur in a ditch of this type at an angle of attack of 20 degrees at a speed of approximately 50 mph. Vertical or normal accelerations produced can be estimated by calculation under rather mild conditions up to the point where the suspension system bottoms at values of normal accelerations of possibly 0.5 g. Beyond these values the nonlinearities of the suspension system make it impossible to calculate normal accelerations by simple, direct methods. For high-type roads where practical speeds above 65 mph may be anticipated, a ditch section having slopes of 6:1, bottom width of at least 6.5 feet, with vertical curves 6.5 feet long on each side, is the most severe that should be used for desirable standards of roadside safety. This section will give computed values of normal acceleration of 0.5 g at 15 degree angle of "attack."

Side slopes have a first-order influence on the probability of the car rolling over. Stability factors of even current automobiles with low center of gravity height have a margin of reserve beyond the frictional reaction of smooth, firm, sodded slopes such that even small losses in effective stability may be significant. These losses may be produced by steep roadside slopes or roughness of the surface. On the other hand, even the rather small numerical improvement achieved by reducing the roadside slope and smoothing the irregularities of the roadside surface would make significant gains in roadside safety. The slope should be no steeper —and preferably flatter—than 6:1; the roadside should be smooth and clear of small obstacles and protuberances; and it should be constructed of firm material.

Guardrails should be eliminated wherever possible. Conventional end installations are serious man-made obstacles, and improvements in design of these installations have been suggested. A straight ramp reduces hazards materially. Where possible the end may be buried in the ditch back slope, or a long, low artificial mound may be built to cover the end.

Cost of construction according to the 1960 roadside standard over the primitive 1926 standard is approximately $9000 per mile on level terrain and $26,000 per mile in hilly, wooded country on specific portions of the Proving Ground road system.

ACKNOWLEDGMENT

Contributions of the many participants in this project are acknowledged gratefully. Of particular value have been those of (Mrs.) Arline Marshall, Professor A. H. Easton during 1959 summer employment, and A. H. Kelly, Jr, for their analytical work, and P. C. Skeels and his staff who conducted the tests.

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2. Lundstrom, L.C., "Safety Aspects of Vehicle-Road Relationships," Paper 66B, SAE Summer Meeting (June 1958).

3. Stonex, K.A., "Engineering and Regulatory Standards in Highway Construction and Traffic Control," Proceedings 10th Annual Conference on Standards, American Standards Assn (1959).

4. Stonex, K.A., D.W. Loutzenheiser, and E.R. Haile, Jr, "Driver Eye Height and Vehicle Performance in Relation To Crest Sight Distance and Length of No-Passing Zones," Highway Research Board Bulletin 195 (1958).

5. Lee, C.E., "Driver Eye Height and Related Highway Design Features," presented at 39th Annual Meeting of Highway Research Board (1960).

6. Stonex, K.A., "Review of Vehicle Dimensions and Performance Characteristics," presented at 39th Annual Meeting of High-Way Research Board (1960).

7. Lundstrom, L.C. and P.C. Skeels, "Full-Scale Appraisals of Guardrail Installations by Car Impact Tests," Proceedings of Highway Research Board, Vol. 38 (1959).

8. Beaton, J.L. and R.N. Field, "Dynamic Full-Scale Tests of Median Barriers," presented at 39th Annual Meeting of Highway Research Board (1960).

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Pontiac Driver Hits Tree, Dies

Lloyd Irwin Killed as Car Misses Curve on Bald Mountain Road

A Pontiac man was killed last night when his car apparently missed a curve on Bald Mountain road, a half-mile south of Silver Bell road, in Orion Township.

Oakland Highway Toll in '58
26

Lloyd V. Irwin, 39, of 695 Sterling Ave., was dead on arrival at Pontiac General Hospital. His car hit a tree on the left side of the road as he was driving south.

Irwin, who was unemployed, lived with his parents, Mr. and Mrs. Len Irwin.

The Oakland County Sheriff's Dept. was informed of the accident at 8 a.m. today, but it apparently occurred during the night. The car light switch was on and the dash clock was stopped at 4.

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Figure 1 - Typical newspaper story.

Figure 2 - Proving Ground car-tree accident.

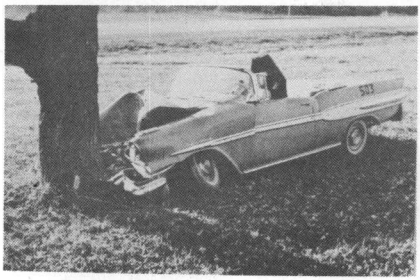


Figure 3 - 35 mph car-tree impact - remote control.

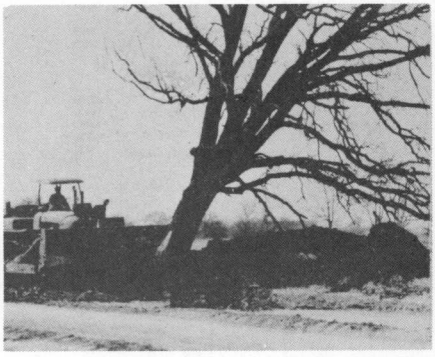


Figure 4 - Tree removal with modern equipment.

Figure 5 - Trees adjacent to modern road.

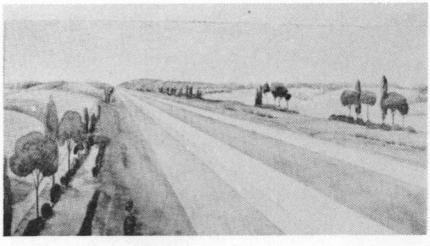


Figure 6 - Artist's concept of safe roadside.

Figure 7 - Man-made roadside obstacle.

Figure 8 - Roadside sign.

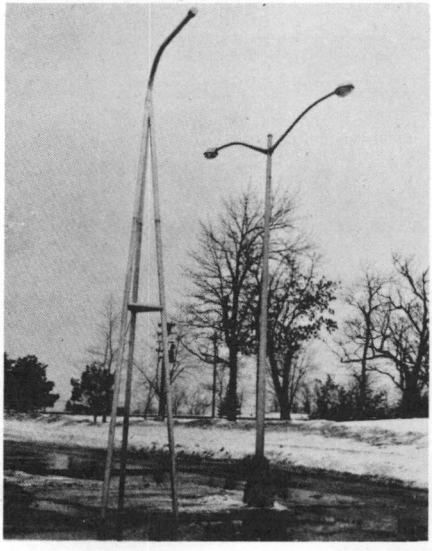


Figure 9 - Comparison of low-impact and conventional light pole.

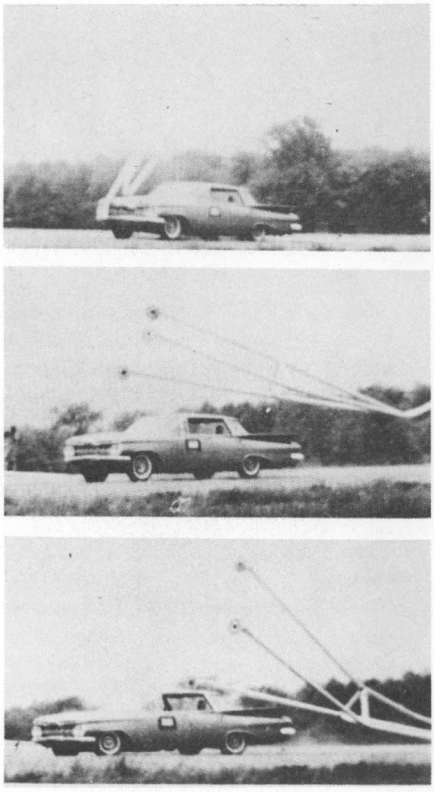


Figure 10 - Full scale test of low-impact pole.

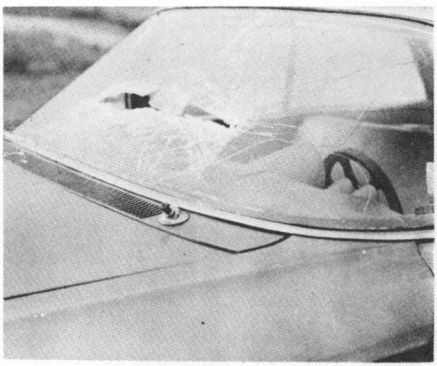


Figure 11 - Damage from collision at 40 mph with traffic sign mounted at 42 inches; car runs into sign detached from post by impact.

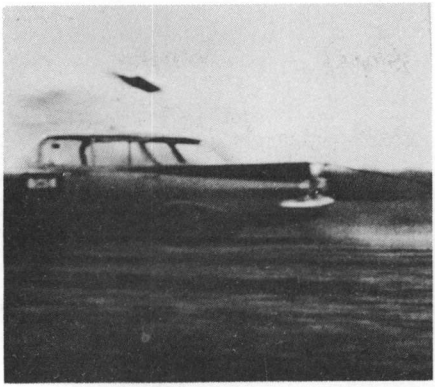


Figure 12 - Full scale test at 40 mph; traffic sign mounted 60 inches above pavement allows car to run beneath harmlessly.

Figure 13 - Typical ditch on secondary road.

Figure 14 - Sharp V-ditch on modern super highway.

Figure 15 - Abrupt unnecessary roadside mound.

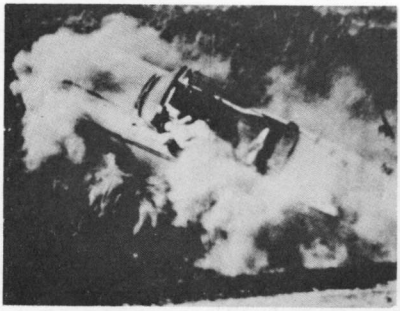


Figure 16 - Impact test - ditch with 2:1 backslope.

Figure 17 - Impact test - ditch with 4:1 backslope.

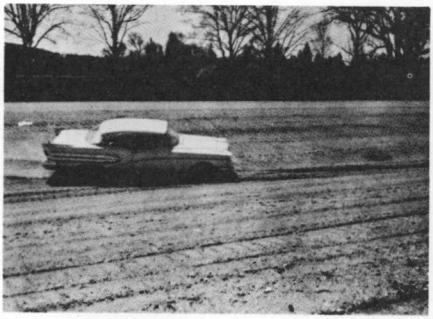


Figure 18 - 60 mph test - driving through flat-bottom ditch.

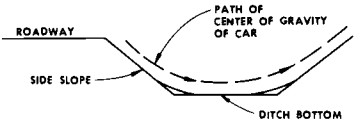


Figure 19 - Schematic - path of car center of gravity through ditch.

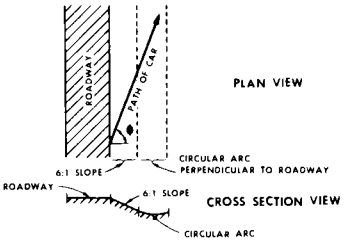


Figure 20 - Plan and Section - ditch test.

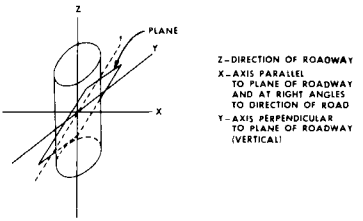


Figure 21 - Projection of circular cross section on car path through ditch.

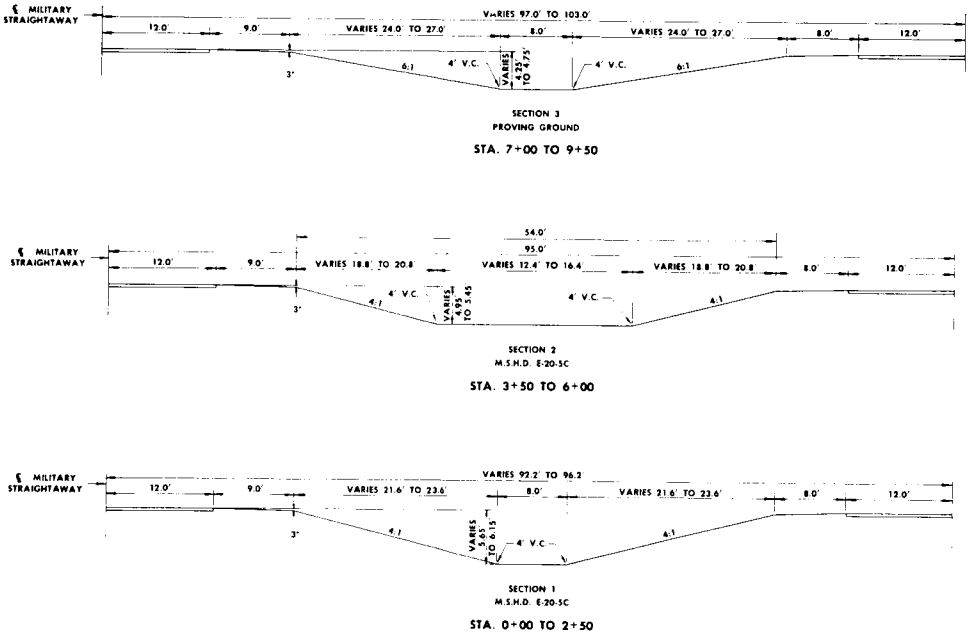


Figure 22 - Test ditch cross sections.

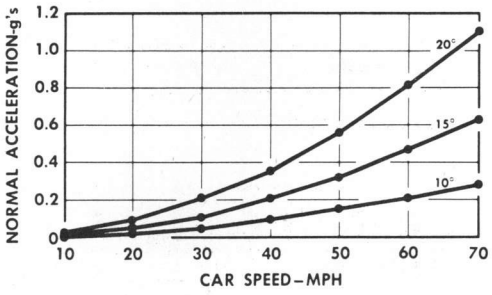


Figure 23 - Normal ("vertical") acceleration computed for Ditch Section 3 with 6:1 slopes and 8 ft bottom.

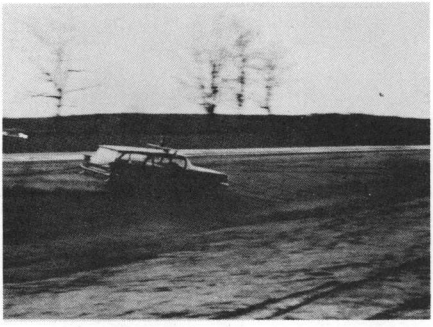


Figure 24 - Car entering ditch on test.

Figure 25 - Car passing through ditch; bumper strikes ground here.

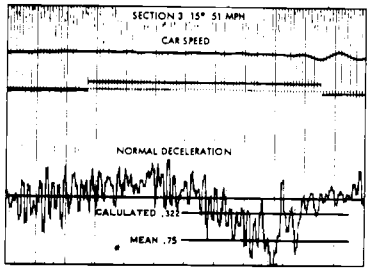


Figure 26 - Oscillogram showing ditch test results.

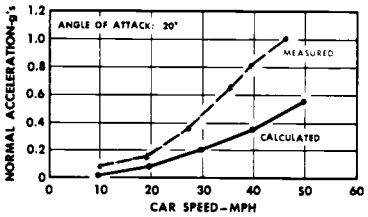


Figure 27 - Comparison of calculated and measured accelerations on Ditch Section 3 with 6:1 slopes and 8 ft bottom.

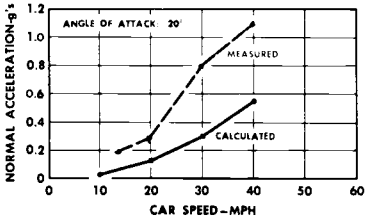


Figure 28 - Comparison of calculated and measured accelerations on Ditch Section 1 with 4:1 slopes and 8 ft bottom.

Section 1

Angle	10 mph Measured	10 mph Calculated	10 mph $\frac{c}{m} \times 100$	20 mph Measured	20 mph Calculated	20 mph $\frac{c}{m} \times 100$
10°	.09	.009	10%	.14	.036	26%
15°	.07	.020	29%	.15	.079	53%
20°	.14	.034	24%	.30	.137	46%
	30 mph			40 mph		
10°	.25	.081	32%	.39	.143	37%
15°	.36	.178	50%	.54	.316	59%
20°	.80	.309	39%	1.10	.548	50%

Section 3

Angle	10 mph Measured	10 mph Calculated	10 mph $\frac{c}{m} \times 100$	20 mph Measured	20 mph Calculated	20 mph $\frac{c}{m} \times 100$
10°	.05	.006	12%	.10	.023	23%
15°	.05	.013	26%	.14	.052	37%
20°	.07	.025	28%	.15	.100	67%
	30 mph			40 mph		
10°	.16	.052	32%	.19	.096	50%
15°	.30	.116	39%	.39	.205	53%
20°	.42	.224	53%	.80	.398	50%
	50 mph					
10°	.25	.145	58%			
15°	.71	.322	45%			
20°	1.10	.645	59%			

Figure 29 - Tabulation of calculated and measured values, ditch section 1 and 3.

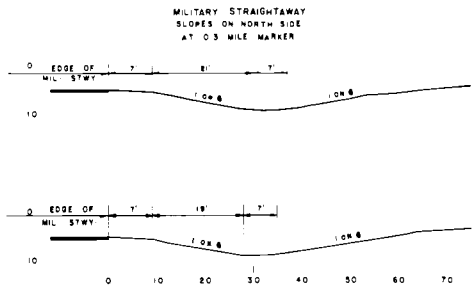


Figure 30 - Test at 75 mph in first experimental ditch.

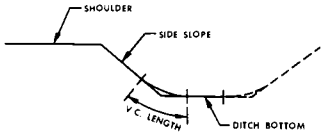


Figure 31 - Schematic - elements considered in the development of criteria.

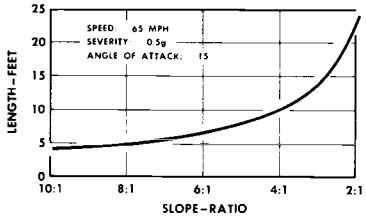


Figure 32 - Vertical curve length as a function of ditch slope for severity of 0.5 g's at an angle of attack of 15°.

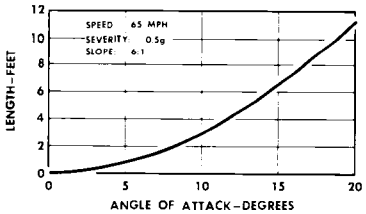


Figure 33 - Vertical curve length as a function of angle of attack for severity of 0.5 g's on a slope of 6:1.

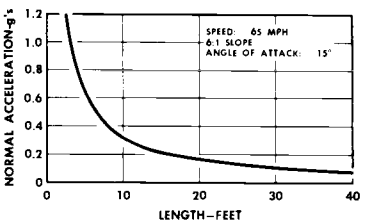


Figure 34 - Variation in severity with ditch vertical curve length.

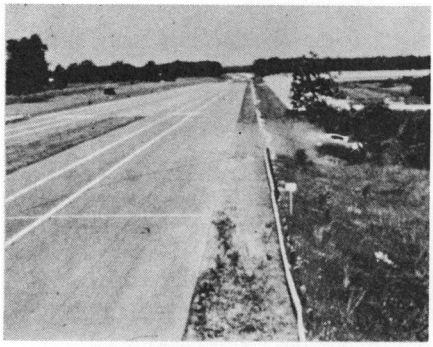


Figure 35 - Car on test at 65 mph rolls over at toe of 4:1 slope.

Figure 36 - Car slides on 6:1 slope.

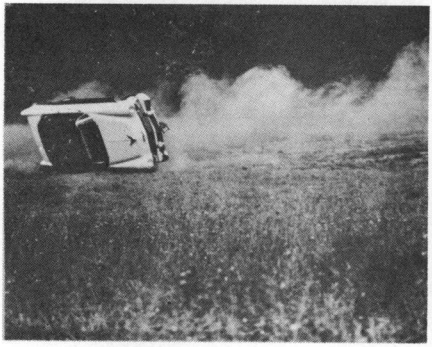


Figure 37 - Car rolls over on side slope.

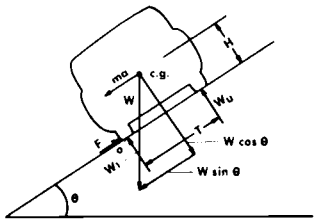


Figure 38 - Force and moment relations when car sliding down side slope is decelerated.

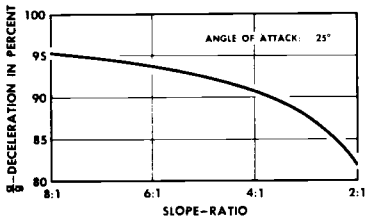


Figure 39 - Effect of roadside slope on "tripping" deceleration.

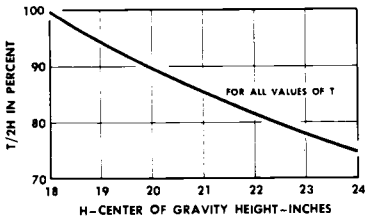


Figure 40 - T/2H as function of H and T.

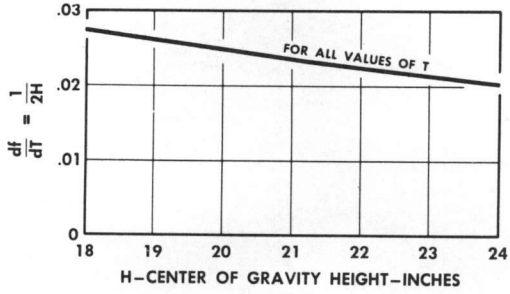


Figure 41 - Rate of change of f with respect to T.

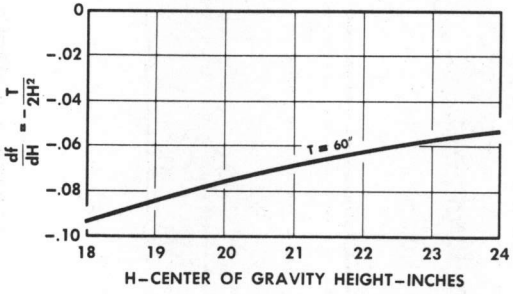


Figure 42 - Rate of change of f with respect to H.

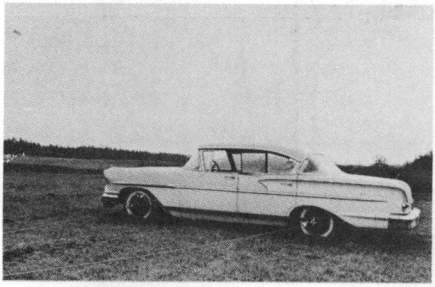


Figure 43 - Method of measuring lateral ground reaction.

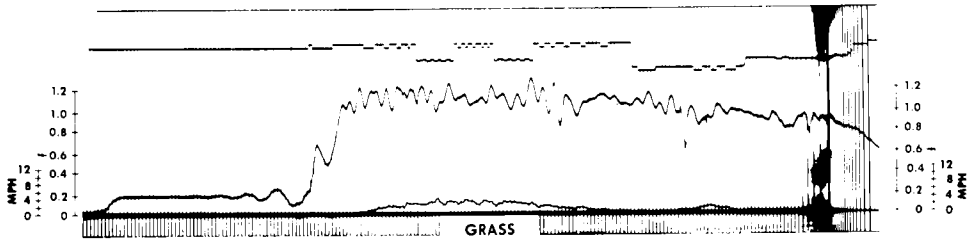


Figure 44A - Coefficient of lateral ground reaction - dry sod.

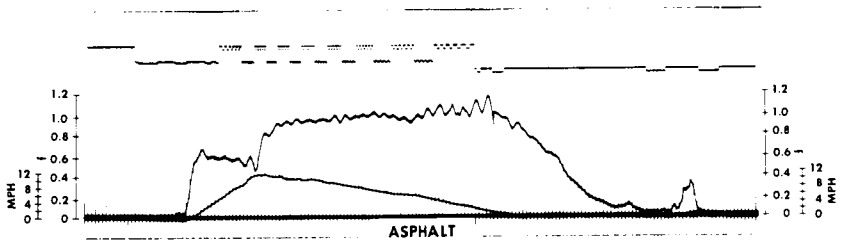


Figure 44B - Coefficient of lateral friction - bituminous concrete.

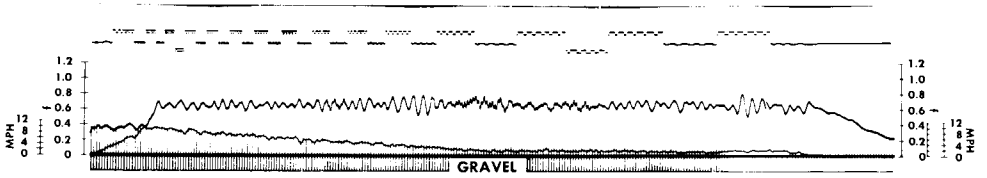


Figure 45A - Coefficient of lateral friction - gravel road.

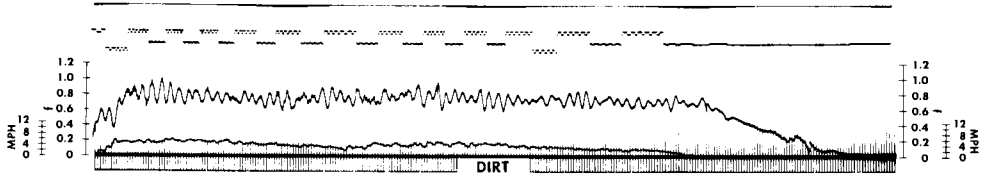


Figure 45B - Coefficient of lateral friction - dirt road.

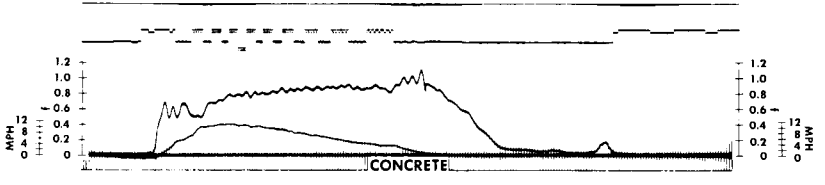


Figure 45C - Coefficient of lateral friction - Portland Cement concrete.

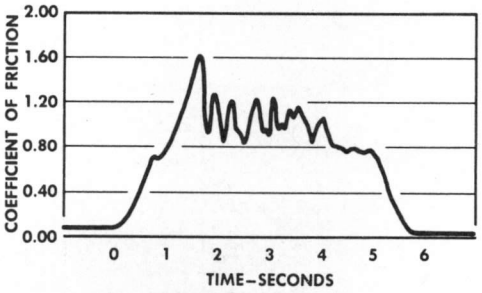


Figure 46 - Coefficient of lateral ground reaction - wet sod.

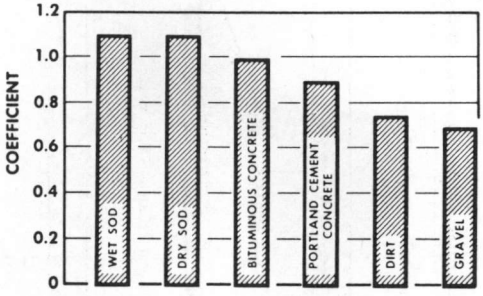


Figure 47 - Summary of average values of lateral coefficient of friction in the speed range of 0-12 mph.

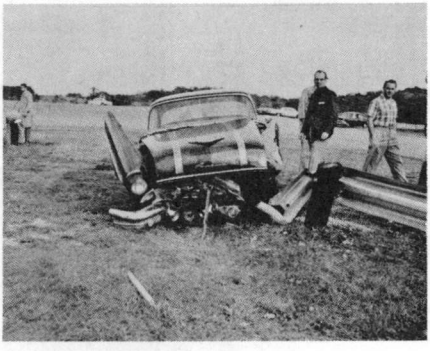


Figure 48 - Collision with standard guardrail end installation.

Figure 49 - Test of twenty-five foot ramp end installation - 50 mph.

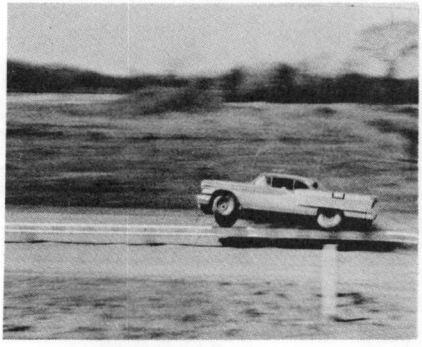


Figure 50 - 60 mph test of 37.5 ft ramp end installation.

Figure 51 - Test of guardrail end ramp with 6-inch post exposed.

Figure 52 - Guardrail end installation in ditch back slope.

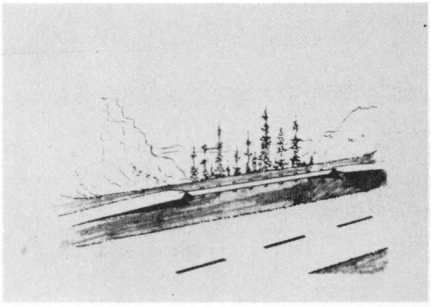


Figure 53 - Artist's concept of buried guardrail end installation.

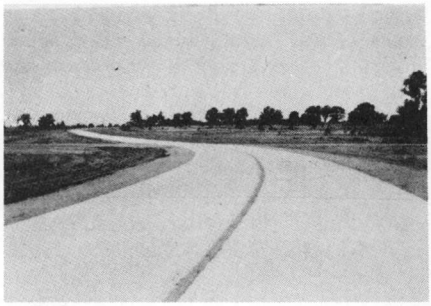


Figure 54 - "Ideal" roadside design - Proving Ground R and H Loop.

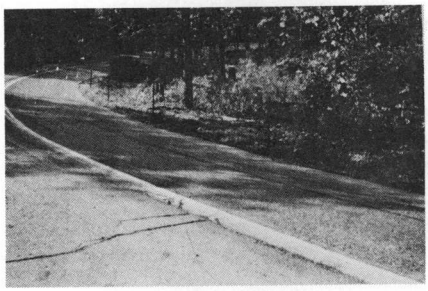


Figure 55 - Typical scene on Proving Ground Hill Road - 1926 standard.

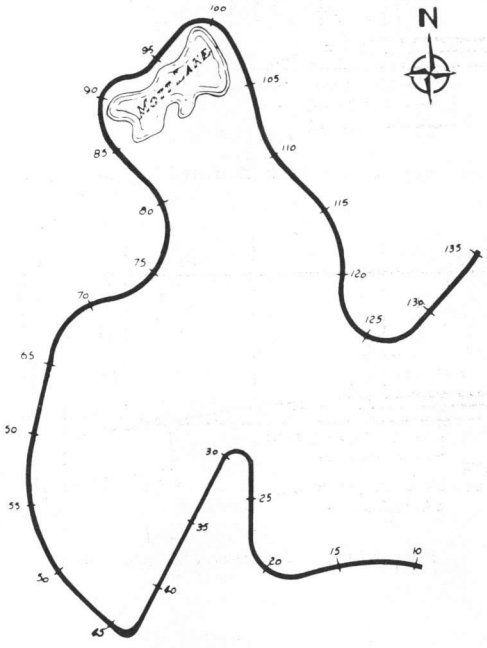


Figure 56 - Hill Road layout.

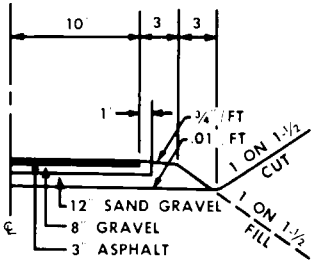


Figure 57 - 1926 standard cross-section.

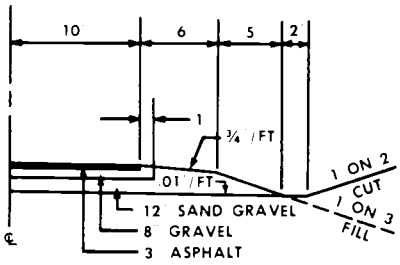


Figure 58 - 1940 standard cross-section.

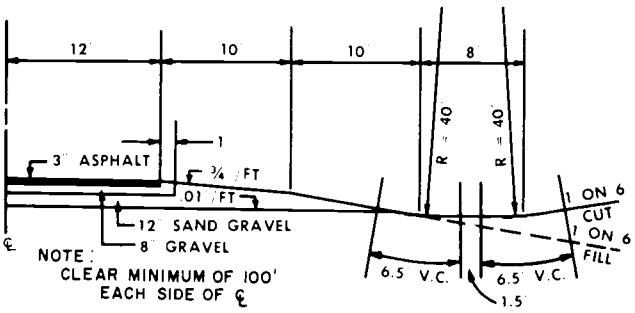


Figure 59 - 1960 standard cross-section.

2.37 Miles of Hill Road

	Items of Work	Units	Unit Price	Quantities 1926 Std.	Quantities 1940 Std.	Quantities 1960 Std.	Cost 1926 Std.	Cost 1940 Std.	Cost 1960 Std.	Cost Difference 1940 Minus 1926	Cost Difference 1960 Minus 1926	Percent Increase Above 1926 1940	Percent Increase Above 1926 1960
1	Clearing	Acre	$500.00	2.5	3.5	10.5	$ 1,250	$ 1,750	$ 5,250	$ 500	$ 4,000	+0.43	+3.46
2	Tree Removal	Tree	50.00	20	45	120	1,000	2,250	6,000	+1,250	+5,000	+1.08	+4.33
3	Excavation	cu. yd.	0.35	45,000	62,500	123,200	15,750	21,875	43,200	+6,125	+27,450	+5.30	+23.75
3a	Overhaul	c.c.y.m.	0.15	1,600	3,500	13,000	240	525	1,950	+285	+1,710	+0.25	+1.48
4	Sand Sub-base	cu. yd.	0.45	16,250	23,200	30,000	7,320	10,440	13,500	+3,120	+6,180	+2.70	+5.35
5	Gravel	cu. yd.	0.75	6,800	6,800	8,100	5,100	5,100	6,075	0	+975	0.00	+0.84
6	Purchase Gravel	cu. yd.	1.50	8,500	8,500	10,000	12,750	12,750	15,000	0	+2,250	0.00	+1.95
7	Drainage		Varies				5,066	5,500	7,630	434	+2,564	0.38	+2.21
8	Asphalt	Ton	12.50	4,375	4,375	5,250	54,700	54,700	65,600	0	+10,900	0.00	+9.43
9	Topsoil	cu. yd.	0.50	1,600	2,600	5,900	800	1,300	2,950	500	+2,150	0.43	+1.86
10	Seeding	Acre	100.00	4	6.5	14.5	400	650	1,450	250	+1,050	0.22	+0.91
11	Guardrail	L.F.	3.50	3,200	3,200	2,500	11,200	11,200	8,750	0	-2,450	0.00	-2.12
	Totals						115,576	128,040	177,355	12,464	61,779	+10.78	+53.45

Figure 60 - Hill Road construction cost estimates.

A. Cost Per Mile			B. Differences in Cost Per Mile		
1926	Standard	$48,800	1940-1926	Standards	$5,200
1940	Standard	$54,000	1960-1940	Standards	$21,000
1960	Standard	$75,000	1960-1926	Standards	$26,200

Figure 61 - Hill Road cost summary - comparison of 1926, 1940, and 1960 standards.

APPENDIX

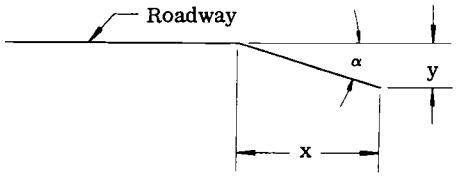
If a car leaves the road at some angle ϕ, as shown in Figure 20 of the text, and travels along the side slope and curvilinear ditch at this angle, then the slope and vertical curve of the path of travel depend on this angle ϕ and the cross section of the side slope and ditch.

A. Uniform Side Slope

Along the uniform side slope section, let the side slope equal tan α cos ϕ as shown below.

Let α = angle of side slope
ϕ = angle at which car leaves roadway
θ = angle of grade of path of travel

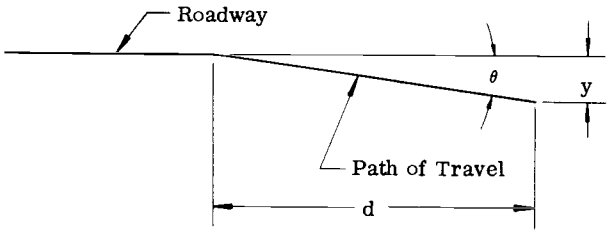
Side slope is represented in the following cross-section diagram



At a distance of x feet from the roadway, the ground has dropped y feet and

$$\tan \alpha = y/x \qquad (1)$$

The grade of the path of travel is represented below



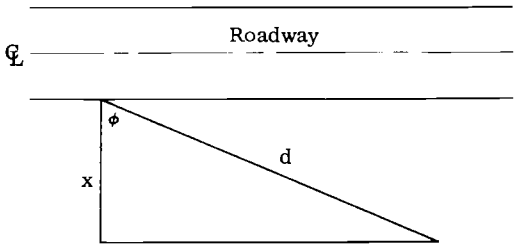
d and y are horizontal and vertical projections of car's path, and

$$\tan \theta = y/d \qquad (2)$$

The "y" in the two equations is the same. Solving simultaneously

$$\tan \theta = \frac{x}{d} \tan \alpha \qquad (3)$$

Viewing x and d in the horizontal plane



$$\cos \phi = x/d \qquad (4)$$

Substituting (4) in (3)

$$\tan \theta = \tan \alpha \cos \phi$$

B. Circular Ditch Bottoms

Figure 20 of the text represents a road with a 6:1 side slope and a ditch bottom formed like the arc of a circle. If a car leaves the road at some angle ϕ, then the slope it travels is less than 6:1 based on cos ϕ, and the curve it goes through is something other than a circular arc.

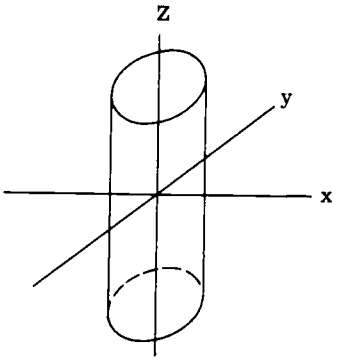
The path corresponds to the curve formed by the intersection of a plane with a cylinder.

In Figure 21 of the text, the plane has one line in common with the y-axis and rotates about the y-axis making an angle ϕ with the x-axis. This angle corresponds to ϕ in Figure 20. Let t represent the second axis of the plane. The equation for the curve where the plane and cylinder intersect will be in the y-t plane, and is the result of treating the equations for the cylinder and the plane as simultaneous equations.

The equation for the cylinder is

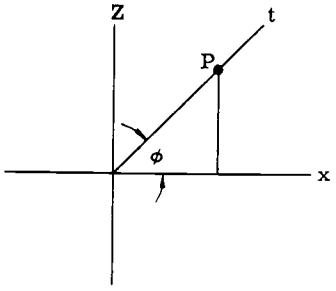
$$x^2 + y^2 = r^2 \qquad (1)$$

r = radius



The equation for the plane is

$$Z = x \tan \phi \qquad (2)$$



A point P on the plane has a distance from the y-axis of

$$t = \sqrt{Z^2 + x^2}$$

$$t^2 = Z^2 + x^2$$

$$t^2 = x^2 \tan^2 \phi + x^2 = x^2 (\tan^2 \phi + 1) = x^2/\cos^2 \phi \qquad (3)$$

Rewriting (1)

$$x^2 = r^2 - y^2$$

Substituting in (3)

$$t^2 = (r^2 - y^2)/\cos^2 \phi$$

$$\frac{t^2}{1/\cos^2 \phi} = r^2 - y^2$$

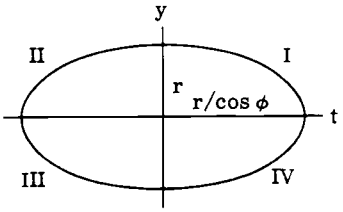
$$\frac{t^2}{1/\cos^2\phi} + y^2 = r^2$$

$$\frac{t^2}{r^2/\cos^2\phi} + \frac{y^2}{r^2} = 1 \qquad (4)$$

Equation (4) is an ellipse in the plane y-t.

Major axis = $\pm$ r/cos ϕ

Minor axis = $\pm$ r



The portion of the ellipse usable for this problem lies in quadrants III and IV, symmetrical about the y-axis and limited by slope of cos ϕ times the side slope of the road from Section A of this Appendix.

For the ellipse in Equation (4), solve for y, y', y'', and radius of curvature. This is the vertical radius that the car would travel along its path.

$$\frac{t^2}{r^2/\cos^2\phi} + \frac{y^2}{r^2} = 1 \qquad (4)$$

$$t^2 \cos^2\phi + y^2 = r^2$$

$$y^2 = r^2 - t^2 \cos^2\phi$$

$$y = \sqrt{r^2 - t^2 \cos^2\phi}$$

Differentiating y with respect to t

$$y' = \frac{dy}{dt} = 1/2(r^2 - t^2 \cos^2\phi)^{-1/2} (-2t \cos^2\phi)$$

$$y' = \frac{dy}{dt} = (r^2 - t^2 \cos^2\phi)^{-1/2} (-t \cos^2\phi)$$

$$y'' = \frac{d^2y}{dt^2} = (r^2 - t^2\cos^2\phi)^{-1/2}(-\cos^2\phi)$$

$$+ (-t\cos^2\phi)\left[-1/2(r^2 - t^2\cos^2\phi)^{-3/2}(-2t\cos^2\phi)\right]$$

$$y = (r^2 - t^2\cos^2\phi)^{1/2}$$

$$y' = \frac{-t\cos^2\phi}{(r^2 - t^2\cos^2\phi)^{1/2}}$$

$$y'' = \frac{-\cos^2\phi}{(r^2 - t^2\cos^2\phi)^{1/2}} - \frac{(t\cos^2\phi)(t\cos^2\phi)}{(r^2 - t^2\cos^2\phi)^{3/2}}$$

The radius of curvature is

$$R = \frac{\left[1 + (y')^2\right]^{3/2}}{y''}$$

$$R = \left[1 + \frac{t^2\cos^4\phi}{r^2 - t^2\cos^2\phi}\right]^{3/2} \Bigg/ \frac{(-\cos^2\phi)(r^2 - t^2\cos^2\phi) - t^2\cos^4\phi}{(r^2 - t^2\cos^2\phi)^{3/2}}$$

$$R = \frac{\left[r^2 - t^2\cos^2\phi) + t^2\cos^4\phi\right]^{3/2}}{(-\cos^2\phi)(r^2 - t^2\cos^2\phi) - t^2\cos^4\phi} \qquad (5)$$

Maximum radius is at t = 0

$$R = \pm\left[\frac{r^3}{-r^2\cos^2\phi}\right] = \frac{\pm r}{\cos^2\phi}$$

Minimum radius is at t = r/cos ϕ

$$R = \frac{(r^2\cos^2\phi)^{3/2}}{-r^2\cos^2\phi} = \frac{\pm(r^3\cos^3\phi)}{-r^2\cos^2\phi} = \pm r\cos\phi$$

For the general case, where tan α = slope, the limiting slope of the ellipse is tan $\alpha \cos \phi$

$$y' = \tan \alpha \cos \phi = \frac{- t \cos^2 \phi}{(r^2 - t^2 \cos^2 \phi)^{1/2}}$$

Find t and solve equation (5) for R

$$\frac{- t \cos \phi}{(r^2 - t^2 \cos^2 \phi)^{1/2}} = \tan \alpha$$

$$t^2 \cos^2 \phi = \tan^2 \alpha (r^2 - t^2 \cos^2 \phi)$$

$$= r^2 \tan^2 \alpha - \tan^2 \alpha (t^2 \cos^2 \phi)$$

$$t^2 \cos^2 \phi (1 + \tan^2 \alpha) = r^2 \tan^2 \alpha$$

$$t^2 \cos^2 \phi = \frac{r^2 \tan^2 \alpha}{1 + \tan^2 \alpha} = r^2 \tan^2 \alpha \cos^2 \alpha$$

$$t = \frac{r \tan \alpha \cos \alpha}{\cos \phi} \qquad (6)$$

$$R = \frac{\left[(r^2 - t^2 \cos^2 \phi) + t^2 \cos^4 \phi\right]^{3/2}}{(- \cos^2 \phi)(r^2 - t^2 \cos^2 \phi) - t^2 \cos^4 \phi} \qquad (5)$$

Substituting (6) in (5)

$$R = \frac{\left[(r^2 - r^2 \tan^2 \alpha \cos^2 \alpha) + r^2 \tan^2 \alpha \cos^2 \alpha \cos^2 \phi\right]^{3/2}}{(- \cos^2 \phi)(r^2 - r^2 \tan^2 \alpha \cos^2 \alpha) - r^2 \tan^2 \alpha \cos^2 \alpha \cos^2 \phi}$$

$$R = \frac{\left[r^2 - r^2 \tan^2 \alpha \cos^2 \alpha (1 - \cos^2 \phi)\right]^{3/2}}{- r^2 \cos^2 \phi}$$

$$R = \frac{\left[r^2 (1 - \tan^2 \alpha \cos^2 \alpha \sin^2 \phi)\right]^{3/2}}{- r^2 \cos^2 \phi}$$

$$R = \frac{\pm r(1 - \tan^2 \alpha \cos^2 \alpha \sin^2 \phi)^{3/2}}{-\cos^2 \phi} \qquad (7)$$

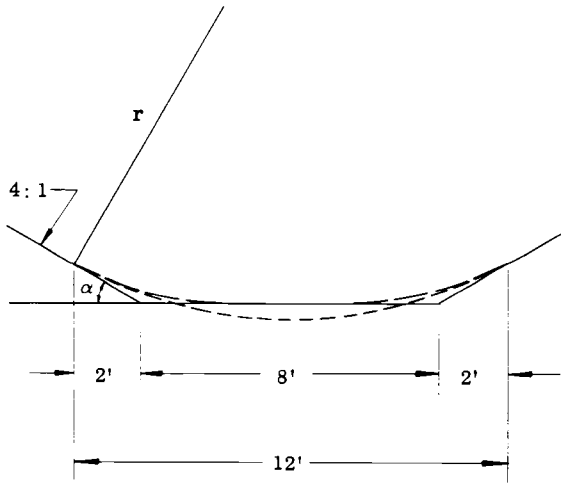
C. Sample Calculation

Calculate accelerations through the ditch bottom along path of travel for

$\phi = 80°$; $90 - \phi = 10°$
$\phi = 75°$; $90 - \phi = 15°$
$\phi = 70°$; $90 - \phi = 20°$

and V = 30 mph and 40 mph on Section 1.

Section 1



$\tan \alpha = 0.25$
$\sin \alpha = 0.24254$
$\cos \alpha = 0.97014$

$2r \sin \alpha = 12$
$r \sin \alpha = 6$
$r = 24.74'$

Radius of curvature of path of travel

$$R = \frac{r(1 - \tan^2 \alpha \cos^2 \alpha \sin^2 \phi)^{3/2}}{\cos^2 \phi}$$

$$R = \frac{24.74\left[1 - (0.25)^2(0.097014)^2 \sin^2 \phi\right]^{3/2}}{\cos^2 \phi}$$

$$R = \frac{24.74(1 - 0.05882 \sin^2 \phi)^{3/2}}{\cos^2 \phi}$$

Calculate radius of curvature for paths of 10°, 15°, and 20°.

	ϕ	80°	75°	70°	
	$\sin \phi$	0.98481	0.96593	0.93969	
	$\sin^2 \phi$	0.96985	0.93302	0.88302	
	$0.05882 \sin^2 \phi$	0.05705	0.05488	0.05194	
	$1 - 0.05882 \sin^2 \phi$	0.94295	0.94512	0.94806	
	$(1 - 0.05882 \sin^2 \phi)^3$	0.83842	0.84423	0.85212	
	$(1 - 0.05882 \sin^2 \phi)^{3/2}$	0.91565	0.91882	0.92311	
	$24.74(1 - 0.05882 \sin^2 \phi)^{3/2}$	22.653	22.732	22.838	(1)
	$\cos \phi$	0.17365	0.25882	0.34202	
	$\cos^2 \phi$	0.03015	0.06699	0.11698	(2)
(1) ÷ (2)	R	751.34	339.33	195.23	
	$\tan \alpha \cos \phi = \tan \theta$	0.04341	0.06470	0.08550	
	$\cos \theta$	0.99906	0.99792	0.99637	
	$\sin \theta$	0.04337	0.06456	0.08519	

Calculate acceleration a/g for these paths at 30 mph and 40 mph.

	$V = 30$ mph $V^2 = (44)^2$ $V^2 = 1936$			$V = 40$ mph $V^2 = (58.667)^2$ $V^2 = 3441.82$		
ϕ	80°	75°	70°	80°	75°	70°
R	751.34	339.33	195.23	751.34	339.33	195.34
$a = V^2/R$	2.577	5.705	9.916	4.581	10.143	17.620
a/g	0.08	0.18	0.30	0.14	0.32	0.54

D. Practical Design Approach

Assume $V = 65$ mph
$A = 0.5\ g = 16.08\ ft/sec^2$
$\phi = 75° = 90° - 15°$

$\sin \phi = 0.96593$
$\cos \phi = 0.25882$

$$\frac{V^2}{R} = 16.08$$

$$R = \frac{(65)^2(2.1511)}{16.08}$$

$$R = \frac{9088.44}{16.08}$$

$$R = 565.2 \text{ ft}$$

Using R = 565.2 and equation (7) from Section B of this Appendix

$$R = \frac{r(1 - \tan^2 \alpha \cos^2 \alpha \sin^2 \phi)^{3/2}}{\cos^2 \phi}$$

$$565.2 = \frac{r\left[1 - \tan^2 \alpha \cos^2 \alpha\ (0.93302)\right]^{3/2}}{0.06699}$$

By assuming a value of tan α which is the side slope, the radius of curvature, r, of the ditch bottom and the length of the vertical curve needed can be calculated. Two examples are shown.

6:1 Slope

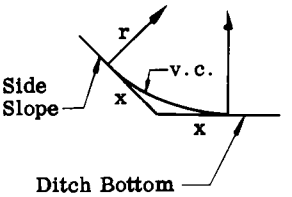
Let $\tan \alpha = 0.16667$
$\sin \alpha = 0.16440$
$\cos \alpha = 0.98639$

Then

$$565 = \frac{r\left[1 - (0.16667)^2(0.98639)^2(0.93302)\right]^{3/2}}{0.06699}$$

$$r = \frac{565(0.06699)}{0.96241} = 39.33 \text{ ft}$$

$\tan 1/2\ \alpha = 0.08247 = x/r$; $x = 0.08247(39.33) = 3.24$ ft



4:1 Slope

Let $\tan \alpha = 0.25$

$\sin \alpha = 0.24254$

$\cos \alpha = 0.97014$

$$565 = \frac{r\left[1 - (0.25)^2(0.97014)^2(0.93302)\right]^{3/2}}{0.06699}$$

$$r = \frac{565(0.06699)}{0.91882} = 41.19 \text{ ft}$$

$\tan 1/2\ \alpha = 0.12310 = x/r$; $x = 0.12310(41.19) = 5.07$ ft

SIGNING AND UNIFORMITY

Robert D. Conklin

It is a pleasure and an honor to be able to talk to you gentlemen about signing and uniform signing practice. About two years ago the Oregon State Highway Department prepared a manual on Uniform Traffic Control Devices for Streets and Highways. Copies of this manual were distributed to all counties and incorporated cities in the State. The response we have received from most of the counties and cities regarding their efforts to install uniform signs according to this manual is very gratifying. They should be congratulated for doing an excellent job in promoting the use of uniform signs.

The matter of proper and uniform signs is a difficult and never-ending job because of the pressure brought to bear from civic leaders, city councils, PTA's, mothers-in-law, and barbers, each of whom has his own ideas on size, shape, color, legend, and placement of signs. They undoubtedly have good intentions, but have questionable ability in the technique of proper signing.

I might mention that according to State law, the Oregon State Highway Department not only has the authority but also the responsibility of establishing uniform signing practice to be used on all public roads in the State. Now that motorists are traveling so many more miles on longer trips over roads of many jurisdictions, it is essential that they have confidence in knowing that a particular sign means one particular thing.

Several years ago it was an easy matter to drive a few miles and find dozens of examples of nonstandard signs, poor signing practices, and multitudes of different signs for the same conditions. Recently, however, there are fewer and fewer cases in Oregon where there are numerous different signs covering the same condition or the same sign being used to cover numerous different conditions.

As an example, one county used to install a so-called "STOP" sign which consisted of a 12-inch board, diamond-shaped, with a white nonreflectorized background and the word "STOP" stenciled in black, using about 2-inch letters. The only thing that was standard about this sign was that they spelled "STOP" the same way the manual does. During the past couple of years, however, this county has done an excellent job of replacing all of these signs with the standard octagon shaped red "STOP" sign.

Following are photographs of both good and bad signing which I think you will find interesting.

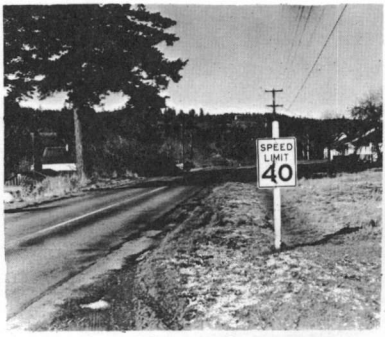


Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

By far the most common nonstandard sign still in place today is the speed regulation sign with the word "limit" in the legend. Examples of such signs are shown on the preceding page. Oregon does not have an absolute speed limit, but a prima facie speed, so consequently we feel the word "limit" is the wrong nomenclature. I think there is a question as to the legality of these speed limit signs.

Figure 6.

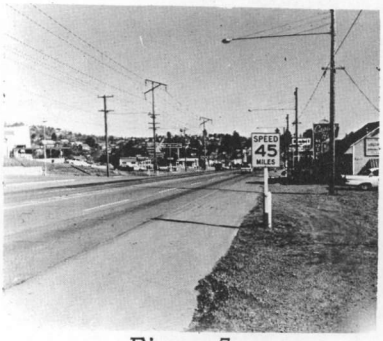


Figure 7.

Figures 6 and 7 show good examples of the standard speed signs. As all of you know, this is a regulatory type sign and, therefore, has the rectangular shape with black letters on a white reflectorized background.

Figure 8.

In Figure 8, the "SPEED 12 MILES" sign is posted on the main street of a small town. The sign in the foreground is standard except for the numerical value of the indicated speed. The statutory indicated speed for a business district is 20 mph, and only the

State Speed Control Board has authority to change that value. I think that using a numerical value other than an even 5 mph increment is splitting hairs. I recently read a report from some city back East where they changed some 35 mph speeds to 34 mph, and also some 40 mph to 39 mph. They thought that having an unusual indicated speed might be more effective because it would be more noticeable. Speed checks taken "before" and "after" the change, however, indicated no significant change in vehicle speeds. You will notice in the picture that there is also a yellow diamond-shaped sign with the legend of "12 MILES PER HOUR 12." You will also notice that both of these signs are on the left and that there are no signs on the customary righthand side of the street.

Figure 9.

Figure 10.

Figures 9 and 10 show a couple more of the nonstandard speed limit signs with the addition of "enforced" in the legend. A number of years ago we used to use this "enforced" rider on some of our signs, but we found that the cities that used them or wanted them were the cities that did not have any enforcement, so the enforce angle proved ineffective.

Another common type of nonstandard signs we still see quite frequently are signs for schools and school crossings. The following pictures illustrate some nonstandard signs on the same post. One sign is another example of the speed limit sign. Figure 12 shows a white, round "SCHOOL GO SLOW" sign which is about as nonstandard as you can get. This goes back to one of the basic principles of signing of using a yellow diamond shape for warning signs, rectangular white for regulatory, round for railroad, and octagon for stop. By sticking to this shape and color code, a motorist knows a lot about the condition even without the legend.

Figure 11.

Figure 12.

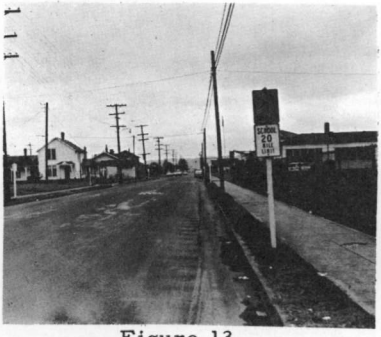


Figure 13.

Figure 14.

Figures 13 and 14 show further nonstandard signs on the same post. Highway Department standard sign used to be "SCHOOL ZONE BE CAREFUL." Other than the word "SCHOOL" the rest of the legend is just so much garbage.

The following three pictures illustrate some good "SCHOOL' sign installations. With the new "SCHOOL" sign, we are able to use much larger letters on the same sized board for better visibility and we have not lost anything because the "be careful" portion is self-evident.

Figure 15.

Figure 16.

Figure 17.

Figure 18 is an example of a good "SCHOOL CROSSING" sign installation. The sign is a very visible one and properly placed. You also can notice the "SCHOOL CROSSING" stencil on the pavement.

Figure 19 is another nonstandard sign that falls in the school classification, "CAUTION SCHOOL BUS LOADING ZONE." I have made some calculations and have found that a school bus would be in the act of loading or unloading only 0.05 of 1 percent of the time on a yearly basis, which includes acceleration and deceleration time for the school bus. It is very doubtful in my mind that a sign that has no meaning for 99.95 percent of the time would be effective. We get a number of requests for this type of sign on our highways, but we never use them. We feel that a big yellow school bus with two big flashing red lights offers much more protection to the school children than this sign ever would.

Figure 18.

Figure 19.

Figure 20.

Whenever I see the above picture, I feel sorry for Mr. John Q. Motorist. No matter what he does he violates one of the signs. If he stops for the "STOP" sign, he violates the "NO STOPPING OR NO PARKING" sign, or vice versa. This particular situation could easily be corrected by moving the "NO STOPPING OR PARKING" sign a short distance down the highway where it belongs and not have it facing the side road traffic as it does now.

Figure 21 shows a sign with a red legend on a white background, and Figure 22 has a white legend on a red background. A city on the coast recently installed these new signs. This "NO U TURNS ENFORCED" sign is located in the middle of the block in front of the Police Station on a fairly narrow street. This sign is nonuniform due to shape, color, legend, and location—which covers about everything.

Figure 21.

Figure 22.

Figure 23.

In the above picture the "NO LEFT TURN" sign is a standard sign, but it is certainly in a poor location. The no left turn restriction is for the sideroad, but the highway also turns to the left.

Figure 24.

Figure 25.

"YIELD RIGHT OF WAY" signs are shown in Figures 24 and 25. This sign has cropped up from time to time during the past few years, particularly in some of the small cities. An Oregon law, which you all know, states that a motorist shall yield the right of way to approaching traffic on his right. The "YIELD RIGHT OF WAY" sign, however, makes motorists yield the right of way in every direction, and our "legal beagles" tell us that such a sign is illegal because it is contrary to this law. Portland uses some of them on their one-way streets where the traffic is approaching only from the motorist's right, which makes it legal. This sign is not in our Manual because of this State law, but due to the fact that the population of Portland is over 50,000, they are permitted to deviate from the Manual, although they normally follow the Manual very closely.

Figure 26.

There is some talk about changing the State law which would legalize this sign. There is a lot of strong feeling both pro and con regarding the use of the "YIELD RIGHT OF WAY" sign. I have read reports from other states where studies were conducted which seemed to indicate the sign is valuable and other reports to the contrary. If the sign were legalized and included in the Manual, it would definitely have the advantage of discouraging indiscriminate use of the sign, such as in one city in Eastern Oregon which put up the sign on all four legs of a four-way intersection. I wonder what would happen if cars approached the intersection from all four directions simultaneously. They would have a choice of sitting there all day or violating the sign.

Figures 27, 28, and 29 show several examples of nonuniform signs with long and complicated legends. A motorist almost has to stop to be able to read them.

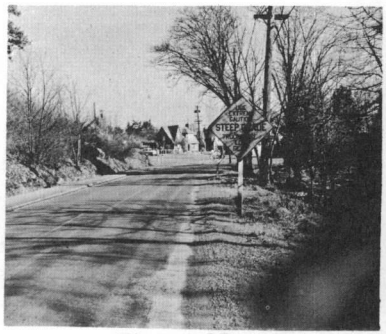


Figure 27.

Figure 28.

Figure 29.

Following are five examples of signs with unusual shapes and legends. Figures 30 and 31 are examples of the octagon shape being used for something other than a "STOP" sign.

Figure 30.

Figure 31.

Figure 32.

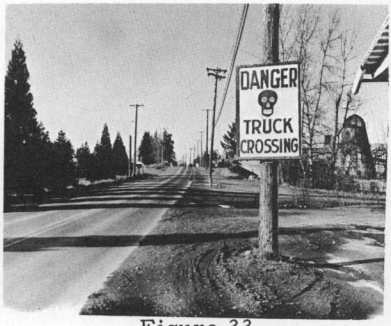


Figure 33.

Figure 34.

Figure 32 is a cartoon type sign for a school. The "DANGER TRUCK CROSSING" sign in Figure 33 uses the threat of death for emphasis. I doubt whether this threat is very effective. I have driven on the road where this sign is installed dozens of times, and I have yet to see a truck crossing the road.

The five pictures on the following page show where the sign itself is standard but, due to its placement, there is some confusion. Figure 35 shows a standard "SPEED 40 MILES" sign with a "STOP AHEAD" located just past the sign. It would be difficult at this point to drive 40 mph and still be able to stop for the "STOP" sign. Figure 36 is where a motorist first sees a "SPEED ZONE AHEAD" sign coming into this small town, then this old standard sign "SCHOOL ZONE BE CAREFUL" with a "20 MPH CROSSING HOURS" rider, followed by a "SPEED 35 MILES" sign. The two speed indications so close together are confusing to many motorists. Figure 37 shows a "STOP" sign placed on the far

side of the intersection. There is no place to put the "STOP" sign on the near side because of another intersecting road on the right. I think the existing flashing red beacon and the rubber "STOP" flap would give adequate warning to the local type traffic without the confusing farsided "STOP" sign.

Figure 38 shows a pet peeve of mine, and that is when a sign unintentionally faces the wrong direction. Here the "STOP" sign could be twisted or shielded so it would not face the arterial street. Figure 39 shows the old standard "SCHOOL ZONE BE CAREFUL" sign. The sign is located exactly 1/4 mile away from the school, which is much too far to be effective or even remembered by the motorist.

Figure 35.

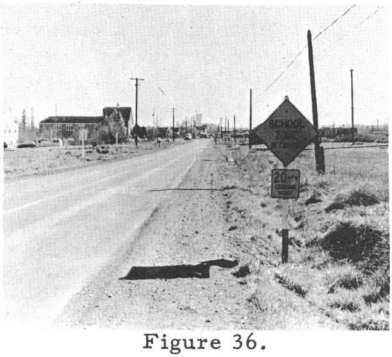


Figure 36.

Figure 37.

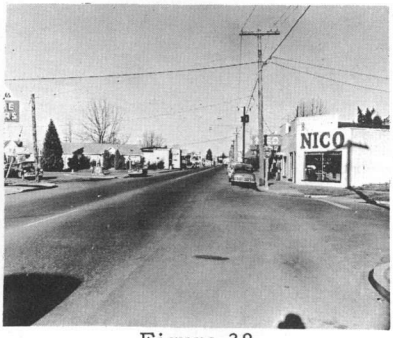


Figure 38.

Figure 39.

Figure 40 shows a nonstandard sign which I feel is good. I might add that when the Manual was written none of us expected it to take care of every situation that you might run into. I do feel that the Manual would take care of about 98 percent of signing problems, and the other 2 percent will have to be treated as special cases, which I feel this one is. This location is on a rural country road that makes a curve to the right, and there is another relatively major road intersecting on the outside of a curve. The only standard sign we have that comes close to fitting this condition is a side road symbol sign, but I think this existing sign is better.

Figure 40.

Figure 41 shows a midblock "STOP" sign for a school crossing. The legend of the "STOP" sign is "SCHOOL STOP LANE." Someone almost ran into the rear end of my car when I stopped for this sign. I don't think the local citizens pay any attention to it. A part-time "STOP" sign such as this just does not seem to work.

Figure 42 shows an 18-inch yellow "STOP" sign. We still see a lot of yellow "STOP" signs around, although the changeover

to the red color has been very good in most places.

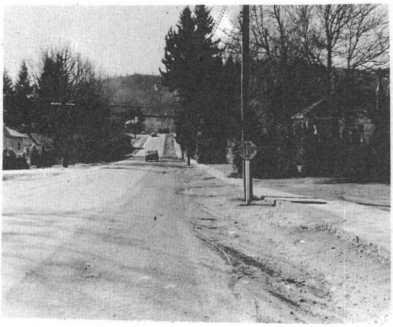


Figure 41.

Figure 42.

Figure 43.

Figure 43 shows a portable battery-operated traffic signal that school officials roll out into the middle of the road for a school crossing. Fortunately, it is on a very minor city street or some tourist probably would have knocked it to kingdom come some time ago. It has a 60-second cycle and turns from green to amber to red in fine shape, but then goes back to amber and then green. Notice the pavement stencil which says, "STOP ON RED LIGHT." This reads coming toward you instead of away from you. When I first read it I thought it said, "light on red stop."

I think Oregon is fortunate in being one of the best states I have seen for having standard traffic signal locations; always span wire mounted on the far side of the intersection. Traveling in some other cities or states, you never know where to look for the traffic signal. Fortunately, we do not have very many exceptions to our rule.

Figure 44.

This is an unusual parking restriction sign. I have read the message a number of times, and I still cannot figure out what it means.

Figure 45 is an example of a nonstandard loading zone sign which I like. This is located at a large department store in Salem. A lot of motorists stop here to pick up persons who have been shopping in the store. A parking limit of 5 minutes, or some other type of loading zone sign, would be ineffective in my opinion because it would be so difficult to enforce. There is a large turnover of cars at this location. I think it is very efficient and convenient. There is very little violation to the stipulation that a driver must remain at the wheel.

Figure 45.

We get a number of requests for signs prohibiting passing or no-passing zone stripes. I think one of the reasons we get so many of these is because a no-passing zone stripe is one of the most effective traffic control devices we have. One of the reasons

it is so effective is that we do not use it indiscriminately. We only stripe a no-passing zone when there is a sight distance restriction caused by a crest vertical curve or in advance of physical channelization, in which case we supplement the stripe with a "NO PASSING NEXT 1000 FEET" sign. We do not stripe no-passing zones for intersections, horizontal curves, or school crossings.

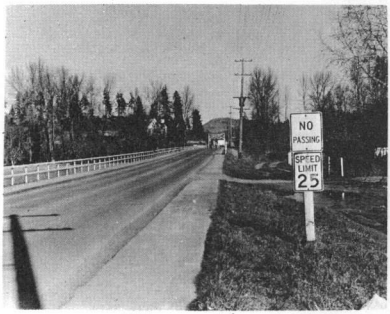


Figure 46.

Figure 47.

The following are photographs of signs that have seen better days. They not only have lost their effectiveness, but are also eye-sores, in my opinion.

In closing, I would like to state that these nonuniform signs I have shown are certainly the exception, not the rule. As a whole, I think cities, counties, and state highways are very well signed.

Figure 48.

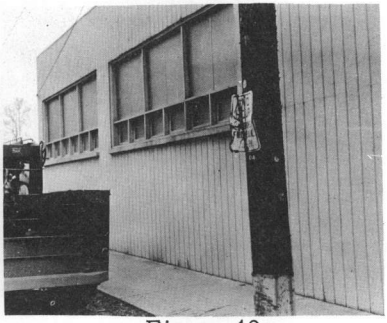


Figure 49.

MONTANA'S CHANGEABLE COPY SIGN

Maurice Richey

Montana has problems peculiar to Montana. One of our problems in signing for weigh stations in the Interstate System has been to provide adequate advance signing for truck weigh stations. Most states, usually those with ton-mile or weight-distance revenue measures, operate port-of-entry stations on a 24-hour basis. In Montana, where we are operating on a gross vehicle weight and other types of revenue collecting bases, the weigh stations are usually manned for only an 8- or 10-hour period during the day. Thus, we have the problem of providing directions to truckers as to when a weigh station is open or closed. To avoid expensive electrical installations, we have developed manually-operated changeable copy signs for our truck weigh stations.

The legend decided upon was "WEIGH STATION (with an arrow pointing in the direction of exit) ALL TRUCKS MUST ENTER." When the station was not in operation, the sign would read, "WEIGH STATION CLOSED." Eight-inch white reflectorized removable legend was used for all copy except "CLOSED," which was 12 inches. A green reflectorized background was used for nighttime target value.

Due to the height (7 feet to bottom of sign) and size of sign (7 by 9 feet), it would be impossible for the station attendant to change the copy without some mechanical help, so it was decided to split the sign in the middle and let the bottom section rotate from one side to the other.

The bottom section was made as a double-faced sign with 4- by 4-inch framework. A 1-inch diameter lineshaft was installed through the center of the bottom section with bearings (split-journal type, babbit and case iron construction) on both ends. A 2-foot angle iron arm was attached in the right side of the shaft with a rope to the ground so attendant could change the face of the sign. To aid in changing and to hold the sign face in place, a spring providing a pull of 75 pounds with a stretch of 12 inches was used. Stops were used to keep the bottom section from rotating too far in one direction.

The top section used 4- by 4-inch framework bolted directly to the two structure posts. Five-eighths inch high density overlay plywood faces, attached to the framework with 2-inch galvanized wood screws countersunk at 18-inch centers, were used.

Structure posts were 8- by 8-inch full length pressure-treated, wooden posts. A-7 carbon steel hardware was used throughout the sign structure. Framework and all metal parts were painted to match the green background color of the sign.

When this sign had been built and installed, tests were run to see if the sign did the job it was intended for. The short message could be read at a glance, and the enlarged copy could be read 400 to 500 feet in advance (day or night). Due to the contrasting color of white on green, the sign could be seen for a distance of 800 to 1000 feet in advance. The changeable bottom section worked easily and without use of unhandy fastening devices.

We also have a problem at some weigh stations where up to as many as six of these changeable copy signs have to be used. This creates a problem as to how one man can change six of these signs (some as far as 1 mile away) within a reasonable time.

Because of the necessity in Montana of signing for icy highways and closed passes, we are considering the use of these manually-operated signs to indicate road conditions in mountainous areas in required locations where power is not usually readily available. Where power is available, we are considering adopting and adapting devices similar to those the California Highway Department is using on Donner Pass—radio-controlled changeable copy signs denoting road conditions ahead.

CANADA'S UNIFORM MANUAL—SIGN VARIATIONS

R. C. Boyes

In 1956, work was commenced on preparation of a Canadian Manual on Uniform Traffic Control Devices. This project was sponsored by the Canadian Good Roads Association in conjunction with the Canadian Section of the Institute of Traffic Engineers, with the prime purpose of producing standard traffic signs, signals, and pavement markings for installation and operation on roads and streets throughout Canada.

There was representation on this project from every province and from eleven major municipalities, from industry and from major national organizations. A joint manual committee was established with separate subcommittees for signs, signals, and pavement markings. The City of Vancouver was represented on all of the committees.

In May of last year the joint committee approved the final draft of the manual, and it was formally presented at the Annual Canadian Good Roads Association Convention in Vancouver in September.

In general, the standards follow those set out in the U.S. Manual on Uniform Traffic Control Devices, and these practices are presently being followed in most provinces and cities throughout Canada. You will appreciate that in a project of this type it was not possible to obtain unanimous agreement on all points. Accordingly, it was felt desirable to abide by the majority decision with the view to producing one standard manual and thereby to achieve the desired goal of uniformity across Canada.

For the purpose of my brief talk today, I will confine my comments to the Signs chapter of the manual and mention only those signs in our manual that deviate from U.S. Manual standards.

One of the first aspects that confronted the Signs subcommittee was the bilingual situation that exists in Canada. While the French speaking population is generally confined to eastern Canada, both languages are officially recognized and, therefore, deserve equal consideration in the manual.

It was felt that this difficulty could be overcome to some extent by symbolizing the legend message of as many signs as possible. Furthermore, if certain signs could be symbolized in a satisfactory

manner the resultant increased visibility would be desirable. With this in mind, the United Nations system of "Interdiction" symbol signs was examined. It was found, however, that the legibility of many of these signs was not entirely satisfactory, and the symbols themselves were subject to misinterpretation. After much checking, testing, and discussing, it was agreed that the following signs would be symbolized:

1. Turn prohibition series
2. Pedestrian signs
3. Other individual signs that are readily adaptable to symbolization

1. Turn prohibition series. The following pictures illustrate signs for left turn prohibition. First, the legend message sign (which is the previously accepted standard), and next the U. N. interdiction symbol sign with the red circle and red bar through the prohibited movement and, finally, the positive symbol sign adopted in the Canadian manual. This last sign is referred to as a positive symbol sign because, as you can see, it shows the movements that are permitted by directional arrows within a green circle—in this case a straight through and right-turn movement are permitted but not a left turn. The circle is green in color, indicating the permitted or positive movements as opposed to the red circle or the interdiction symbols.

Figure 1.

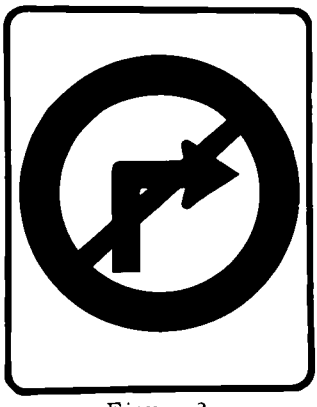


Figure 2.

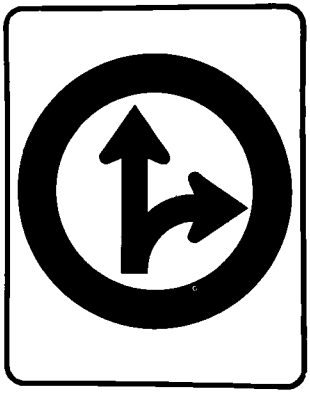


Figure 3.

The manual suggests for an introductory educational period of two to three years that the legend message, in relatively small letters, should also appear on the sign. Signs for other turn prohibitions—no right turn, no turn, no entry—are on the same principle as this sign, with merely the appropriate directional arrows shown for the permitted movements.

Figure 4.

Design and tests in connection with these turn prohibition signs were carried out by traffic officials in the City of Montreal. In that city and some other eastern cities they have had such signs up for a year or two with quite satisfactory results.

In Vancouver, where we have quite a high percentage of part-time turn prohibitions (i.e., 7-9 a.m. and 4-6 a.m.), and

also a one-way street system in the C. B. D., we had certain reservations in connection with these signs. We felt that with the signs being of a positive type; i. e., showing permitted movements, they might prove to be somewhat confusing to the motorists, particularly when there was a mixture of part-time and full-time prohibitions.

A problem is also presented in adequately signing the termination of a one-way street. Our present arrangement is to place "DO NOT ENTER" signs at the entrance to the street at an angle of approximately 45 degrees so that these serve the three remaining approaches to the intersection. Replacing these signs with the new positive type symbol sign, however, would indicate to the motorist on the cross street that he should enter the one-way street which, of course, is exactly what we do not want. One solution is to prohibit turns from the cross street into the one-way street, but at such locations we already had a part-time prohibition for the other turning movement and, therefore, we would only confuse the motorist further by such an arrangement. It appears that the use of more elaborate "blank-out" or "blind-type" signs at such locations may be the answer.

As I mentioned earlier, it was not possible to obtain unanimous agreement on all points and, therefore, having had an opportunity to express our views, we were prepared to abide by the majority decision in order to achieve uniformity. We are currently attempting to overcome these difficulties of applying the new turn prohibition signs and hope to start a conversion program to implement these new turn prohibition signs within the next year.

2. Pedestrian signs. I think you all will agree that the problem of meeting demands for the protection of children and other pedestrians is complex and difficult. You are aware of the great public pressure from parent and teacher groups and from other civic organizations for installation of signs, signals, and markings. Demands made upon civic officials are frequently economically and technically impossible to meet. As a result of this situation there has been a wide range in regulations and school signing practices throughout North America.

While some may feel that the advance school sign should conform to the standard for advance warning signs, the Signs subcommittee for the Canadian manual felt that in view of past history and experience school crossings present a special situation. A comparable situation of the special nature is the case of the railway crossing advance signs, where the special shape (round) was felt justified even though it was not consistent with the yellow diamond shape recommended for warning signs.

In the case of the advance school sign, a new and distinctive shape and color was adopted for the Canadian manual. This sign (Figure 5) is a pentagon-shaped schoolhouse with a white symbol on a blue background (minimum size 24 by 24 inches). This sign is used in advance of a marked crosswalk or to warn of the presence of a school.

Figure 5.

In the pedestrian warning series we have two other signs. First, the pedestrian crossing advance sign shown in Figure 6, which is a standard warning sign in shape and color, but has the message replaced with a symbol. This sign may be used in advance of a marked pedestrian crosswalk.

Second, the playground advance sign, which is on the same principle as the pedestrian warning sign; i.e., yellow diamond with symbol of a child running. This sign may be used in advance of a marked playground crosswalk or to warn of the presence of a playground.

Signs marking pedestrian crosswalks also have been symbolized and the next photograph (Figure 7) shows the sign to be used in designating a school crosswalk. Signs for pedestrian and playground crosswalks are the same, with the exception of the word which is changed for the appropriate application.

Figure 6.

Figure 7.

Last fall in Vancouver we installed these new school crosswalk signs at all locations where we have school crosswalks, and in each case a schooling sign was placed 150 to 200 feet in advance of the crosswalk. The next two photographs (Figure 8) show the particular sign we are using, and you will note that in the case of the crosswalk sign an additional legend message has been added. This is merely the result of a particular school regulation that is applicable only in the Vancouver area. It might be worth mentioning that we have received very favorable comments from the School Board and parent-teacher groups.

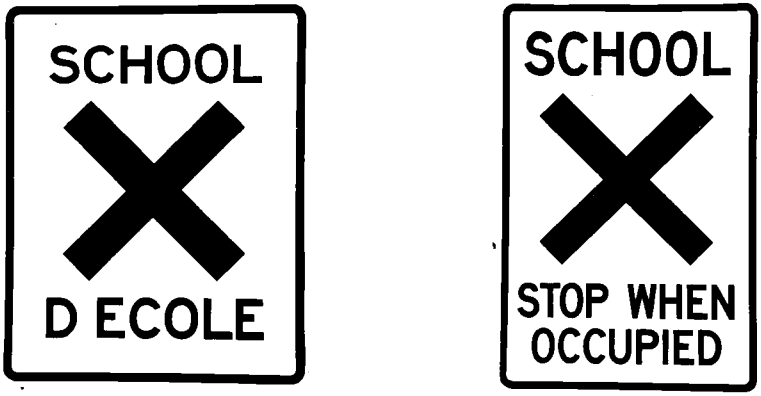


Figure 8.

3. Other symbolized signs. In addition to the two series of signs I have mentioned (turn prohibition and pedestrian series), there are a few individual signs that have been modified. The "KEEP RIGHT" sign is entirely symbolized by depicting a plan view of the end of a channelization island with a directional arrow diverting to the right of the island (black symbols on white background).

A slight modification has been made to the parking series signs in an attempt to give more emphasis to "NO STOPPING" regulations. All "NO STOPPING" signs contain a red band across the sign with the applicable time period stated within this red band.

Speed limit signs in the Canadian manual read "MAXIMUM SPEED" instead of "SPEED LIMIT." One of the reasons for a departure from the U.S. manual in this case was the fact that the word "maximum" is the same in both French and English. A further reason was the future use of "MINIMUM SPEED" signs.

These signs that I have mentioned and illustrated are those that are included in the Canadian manual and that deviate from the U.S. manual. I can assure you that these deviations were not made just to have something different from the U.S. manual. In all the studies one essential requirement was evident; any substantial deviation from the American standard would, in itself, create a hazard because of the large volume of American motorists and truckers who travel throughout the year on Canadian roads.

It was felt, however, that the preparation of this new manual was an opportunity to improve on standards that have long been used and unimproved on the North American Continent. Consequently, departures from AASHO signs have been introduced only where the departure was considered to be a genuine improvement. This was particularly so in the use of the graphic symbols in signs which will be more quickly and easily understood by the motorist.

I think it would be worth mentioning that the membership of the Canadian Good Roads Association who sponsored the manual comprises the attorney generals of all provinces in Canada. Therefore, with the manual now approved in principle, it is hoped that within a year or two its use will be made mandatory.

PARKING METER THEFT WARNING DEVICE

Don Bergstrom

During the past several years the number of parking meter thefts in the City of Portland has shown a sharp increase. These thefts follow somewhat of a pattern in that they generally occur during the slack employment season; in the months of November, December, January, and February. Also, the thefts are usually confined to fringe areas and poorly lighted sidestreet locations.

Basically, there are two different methods used to open the meter. In one of the methods the coin box door is pried off and then the lock is used to make a key. In the other method the coin box door is jimmied by using either a large screwdriver and a hammer or a sharp-edged pry bar.

The following table shows the number of meters that have been opened and the loss to the City of Portland during the past two years. It should be noted from this table that when a key is used to open the meter, the actual loss is only the nickels, which average $1.75 per meter. When the coin box door is forced open, however, the door, lock, and often times the entire housing is damaged beyond repair. Damage loss has averaged $9.50 per meter in addition to the $1.75 loss of nickels.

PARKING METER THEFTS IN PORTLAND, OREGON

Year	1958	1959	2-yr total
No. of meters opened by picking lock	70	51	121
No. of meters opened by force	637	468	1,105
Est cash loss	1237.25	908.25	2,145.50
Est damage to meters	6013.75	4444.20	10,457.95
Est total loss	7251.00	5352.45	12,603.45
Average cash loss per meter:			$1.75
Average damage loss per meter:			$9.50

In an attempt to reduce these losses we first tried to purchase some type of warning device and found that none was available on the commercial market. Our Meter Repair Division then made some experiments with several types of devices before selecting the horn type, as shown in Figure 1.

This device has three basic parts:

1. A buzzer or horn of the type used on bicycles
2. A pen light type, dry cell battery (not shown in photo)
3. A pressure switch

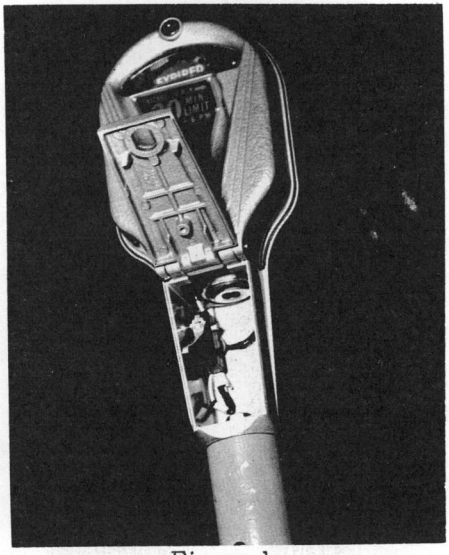


Figure 1.

The device can easily be mounted in the lower portion of the parking meter housing so that when the coin box door is closed, the circuit between the horn and battery is broken, and when the coin door is opened the circuit is completed and horn begins to blow. Tests by our shop indicate that the horn will blow approximately 30 minutes before the battery runs down. Total cost of this warning device is about $2.50 per meter.

Next fall when the meter thefts begin, we plan to install approximately 150 meters equipped with this warning device in the affected areas. It is our hope that when the coin box is opened, that either the police will be able to apprehend the individual immediately or the buzzing horn, which will sound twice as loud in the middle of the night, will shake up the individual to the point that he will figure "there must be an easier way to make a buck."

ALUMINUM GUARDRAIL

Brian R. Tibbot

The original concept of this product was initiated some 9 years ago due to the inquiries from highway engineers throughout the country. At that time it was found, through research and polling, that the cost ratio of aluminum guardrail to other materials available would not make it advantageous to enter this field in 1947.

In 1957, interest in this product was renewed with the entry of the Interstate Highway Bill. Again, we contacted state and federal engineers in regard to initial cost versus maintenance cost. The advent of the 90-10 money brought home the long-range maintenance cost on thousands of highway miles which will be constructed during the next century.

At this point, the Aluminum Company of America, through strength, corrosion, and appearance studies, found an alloy from which guardrail could be constructed. Alclad 2024-T3 alloy was chosen.

The standardization of AASHO on the "W" cross section type guardrail has likewise been adopted for aluminum and is available in three thicknesses which are interchangeable with present steel rail. They are:

0.105 inch giving 65,000 psi joint strength
0.125 inch giving 80,000 psi joint strength
0.156 inch giving 100,000 psi joint strength

The thickness then is governed by the joint strength requirement of the owner.

The major advantage of the aluminum rail is found in the maintenance saved by eliminating painting requirements. It was found that the state highway departments were establishing a 2- or 3-year painting cycle. Cost of repainting the guardrail ran between $0.12 and $0.31 per foot. This included cleaning rail, masking post, and one coat of paint. It is easy to see that it would take just one or two paintings to offset the difference in the initial cost of aluminum compared to painted steel rail. Likewise, over a period of 30 to 50 years, a sizable saving is afforded the owner.

It is also worth noting that because of the high mortality rate of this product, scrap value comparison between steel and aluminum is truly amazing. Average scrap value of steel is approximately $0.02 per pound (rail weight 8 lb per ft), equaling

$0.16 per foot. Aluminum scrap value is approximately $0.18 per pound (rail weight 3 lb per ft), equaling $0.54 per foot, or a difference in favor of aluminum of $0.36 per foot.

We hope the advantages of aluminum guardrail as described above will offer you or your state a method of saving on the ever-mounting maintenance costs.

INFRARED SIGNAL DETECTOR

Harlan Baxter

Magnetic and pressure type vehicle detectors of the past are giving way to detectors of new design. We all know the shortcomings of the pressure type detector: short life of pad, vulnerability to ice, snow, and snowplows, and poor contact closure at high vehicle speeds. Pavement must be broken if one is to be installed in an existing roadway. We know the shortcomings of the magnetic detector, also. They include loss of calls, inability to detect a very slow or stopped vehicle, false calls from 60-cycle interference, and electronic troubles in the d-c amplifier.

Modern detectors that have been built in the last few years have been designed to overcome these difficulties. Each new type of detection system, however, generates its own type of problem which, in turn, must be solved before the detector finds widespread use.

The infrared detector has an elliptical pattern which approximates the area described by a 6-foot pressure type detector. Major axis of the ellipse is approximately 60 inches and extends across the highway lane. The minor axis is approximately 18 inches and extends in the direction of traffic movement. Thus, a small foreign car cannot elude the detector even if it skirts the lane edge.

With increased use of volume density controllers and traffic volume computers with master controllers, the trend is to employ a detector over each lane so that adequate traffic information is available. A detector which sees only a single lane is required for this new and growing use. Only the infrared detectors easily restrict their field to a single lane for this purpose.

ADVANTAGES OF INFRARED

The infrared detector recently placed on the market has all the advantages of other types of overhead mounted units and avoids most of their disadvantages. The device has the advantages of simplicity, ease of installation, and ease of maintenance. It can detect vehicles traveling from 0 to 80 miles per hour. Its response time is short and thus will not miscount vehicles moving bumper to bumper. It has no tubes, requires no FCC license, and is absolutely safe to handle. It does not radiate radio frequency energy or high frequency sound. Further, it can be located above a crosswalk to act as a pedestrian detector, thus reducing the need for pedestrian pushbuttons. In a modified housing it can be mounted on a post at the side of a roadway, thus eliminating the need for a

mast arm. It is envisioned that future models possibly will be installed under the signal head and directed toward the traffic lane they are detecting Future designs appear to be suitable for a height detection device also, although some work must be done to develop the concept

OPERATION

The principle of operation is simple. Infrared energy is modulated and projected toward an area on the pavement. A pair of infrared detector cells are aimed at an adjacent area. When a vehicle moves through the area it reflects infrared energy into the detector cells. Change is sensed by the cells, amplified, and employed to energize a relay which signals the controller or counting device.

Source of radiation is a sealed beam head lamp. Modulation of the output of the bulb is obtained with a drum type fan blade. Drum is driven by a long-life synchronous motor at a speed to provide 450 modulations per second. A lens system concentrates the energy from the bulb onto a selected area of pavement. Type or color of pavement makes no difference because the detector disregards the pavement. Likewise, ice and snow on the ground have no effect on the detector. During heavy rain or snowfall some of the energy is dissipated, but sufficient energy remains to retain the output well within the range required.

The receiver is equally simple. It consists of two small detector cells mounted back to back at the focal point within another sealed unit. Resistance of the cells changes with incident radiation. This change is detected in a 7-transistor amplifier. The amplifier is tuned sharply to admit only modulations at 450 cycles per second. Thus, the shimmering of sunlight on the pavement is disregarded by the detector. Fluctuation of street lighting powered by alternating current is also disregarded.

Having explained the function of the unit, I now will describe its components in greater detail.

The infrared source is a ruggedized headlight unit designed for mine locomotive use. Rated 150 watts at 115 volts, it is operated at reduced voltage to give it extended life. A life of from 2 to 5 years is expected. When failure does occur it will probably result from fracture of the filament due to vibration rather than burnout. By operating the filament at less than rated voltage, a second benefit accrues—its output is enriched in the infrared wave length region. Its light output is reduced somewhat, but since the wave length of light is shorter than infrared, this is not a detriment.

The lamp slips into a socket and can be replaced without the use of tools.

Modulation of the infrared is obtained with a 4-inch diameter aluminum drum mounted directly to the output shaft of a totally enclosed synchronous motor. The motor drives the drum at 1800 rpm, or 30 revolutions per second. There are 15 slots in the surface of the drum. Fifteen slots passing by at 30 revolutions per second give 450 cycles per second modulation.

The synchronous motor contains sealed-in lubrication and will operate continuously for at least 5 years without any maintenance. Motor and drum assembly can be removed by removing three cap screws.

Between the source and modulator are two large light-concentrating lenses. Their function is to collect the radiation from the bulb and focus it into a narrow beam which passes through one side of the chopper, is reflected by a gold mirror mounted at a 45-degree angle, and passes through the bottom of the chopper and down toward the roadway. A third lens located on the door widens the beam to give it its elliptical pattern.

Infrared detection apparatus consists of only two components; the detector cell enclosure and the amplifier. Two lead sulfate detector cells are mounted back to back at the focal point of a sealed headlamp unit. In manufacture, the same glass components utilized in a sealed beamlamp are used, except that the detector cells are mounted in place of the normal lamp filament. The unit is not evacuated. Cells are wired in parallel and are connected to the input circuit of the amplifier through a shielded conductor. A balancing resistor is connected to the 90-volt power supply in series with the two detector cells.

The amplifier is enclosed in a sealed but unevacuated metal container. It consists of seven transistors and three diodes, and is designed for long, trouble-free service.

The amplifier circuit employs one of the transistors in the input circuit as an emitter follower. Next, two MacIntosh type amplifiers each utilize two transistors. A bridge T filter network in a feedback circuit in each stage passes the desired frequency and cancels other frequencies. A final stage utilizes two transistors as a one-shot multivibrator.

The amplifier unit is supplied with 90 volts a-c and contains its own rectifier and filter circuit. A separate power supply is employed to polarize the detector head. The output of the amplifier is available at a terminal for use in energizing an output relay

external to the amplifier container.

The entire unit is contained in a quality cast aluminum housing. A one-piece cast aluminum door unclamps easily and hinges down for observation in the field. The unit is self-disconnecting when open to avoid electrical exposure. Amplifier and detector head are mounted on the door. A spare door would offer immediate repair should the need arise. Head-producing elements are mounted in the top of the case housing. Amplifier and detector elements are mounted on the door, which has cooling ribs. Chimney effect is employed to cool the unit.

Housing mounts to the end of a 2-inch mast arm with three set screws. A hole is provided for a 1/2-inch through bolt through the mast arm. Housing contains a large ball and socket swivel joint which permits aiming the device at any angle up to 20 degrees from horizontal. A total swing of 40 degrees is thus obtained. A mast arm which is as much as 20 degrees off horizontal can be compensated for. Also, a sharply sloping road surface can be accommodated.

The output relay is located within the housing and externally to the sealed amplifier and is energized by the amplifier while a vehicle is in the detected area. Closure of the relay contacts energizes the detector relay in the controller.

POLE FRAME STRUCTURES FOR UTILITY BUILDINGS

Paul D. Christerson

Although unfamiliar to many persons in the Pacific Northwest, pole-type or rigid wood post-type construction is not new. In fact, its history begins over a century ago when the settlers erected their buildings using the straight, naturally-resistant timber which was then in plentiful supply. As this timber became unavailable, the life span of the poles diminished, depreciation costs soared, and the pole-type building lost its favor.

With the advent of modern pressure-treating practices which permit wood to be classified as a permanent construction material even though used in contact with the ground, a rebirth of pole buildings occurred. Simplicity of this method of construction permits unusual flexibility and economy.

Pressure-preserved round poles or sawn timbers are placed vertically, usually in drilled holes. Since it is necessary that adequate soil bearing be obtained to support both the deal load and the live load of the building, it is often necessary to pour in the bottom of the hole a concrete footing adequate to distribute the expected loads. This is usually the case when clearspan construction is utilized. When soil conditions are unsuitable, vertical pressure-treated members may be driven as piling.

From these columns, the roof and walls provide a structure that is tied to the ground and therefore particularly suited to withstand lateral loading such as that created by wind pressure as well as vertical loading created by snow, wind, weight of building, plus occupancy load.

Industry, which started looking at pole buildings about 1952, has found a widespread use for warehousing and processing facilities erected in this manner, and I hope you can be shown how, with sensible designs, good, sound and inexpensive buildings can be erected to protect your equipment and to provide shops for its maintenance.

We are pleased that there is a practical example for you to see while you are here; a building erected for Benton County at their shops near Avery Park. Having a clearspan of 60 feet in width and 160 feet in length and containing a 6-inch reinforced concrete slab floor through 7/8 of its interior, this building was erected for less than $1.70 per square foot. Roofing and siding are 26-gauge galvanized sheet steel custom-rolled to the full length

required. Plastic skylights in the roof provide natural lighting for the interior and, in addition to this, transluscent plastic was installed at one end to add additional light for the paint shop to be completed within the building. You will note that double rolling doors provide easy access to the closed side.

Another building erected for Benton County is an 80- by 180-foot arena located at their new fairgrounds west of Corvallis. By utilizing 80-foot bowstring trusses, an interior free of any columns was provided. Again, 26-gauge galvanized sheet steel was used for roofing and siding and plastic skylights were installed in the roof. Siding was then applied only to the center 100 feet of each side since additions are to be erected as more funds become available to complete an arena and display building that will be H-shape in configuration. Construction price, which included heavier foundations to accommodate the later additions, but no floor, was $1.36 per square foot. Those of you who have an opportunity to inspect this building can visualize how well suited it could be for your storage purposes by enclosing the balance of the building and installing an asphalt or concrete floor.

Where equipment must also be housed in strategic locations throughout a large area, small units such as 24- by 30-foot or 40- by 60-foot utility buildings are practical. These generally can be erected for costs varying from $1.00 to $2.00 per square foot, depending upon the particular design.

When a building can be provided that is designed to your specific needs, soundly constructed for 40 to 50 years life expectancy at a nominal cost, one cannot afford to leave expensive equipment exposed to the elements. We hope that you will consider this a solution to your storage and maintenance problems.

WINDLOADINGS AND POLE DEVELOPMENT

G. W. Kolling

I believe the situation I want to discuss with you today is one that has crept up on us without our being particularly aware of it.

Forty years ago the entire steel pole market consisted of the little gem in Figure 1. This pole or standard averaged about 15 feet in height, and all five of the lamps and globes combined weighed about 25 pounds, which imposed no particular load on the pole. A few years later we progressed to the type of pole which was a few feet higher, but the luminaire weight decreased, as in this case, or at least did not change (Figure 2).

Figure 1.

Figure 2.

By 1940 we were up to 25 feet in height and mounting 20-pound luminaries on 4- or 6-foot mast arms. The following photograph of part of our display yard shows some of these (Figure 3).

It was about this time that some sort of design load standard was required. The National Electric Safety Code had what seemed to be the answer, and the following phrase with very little variation was and still is being used. "Strength shall be adequate to withstand 101.6 mph wind in accordance with the National Electric Safety Code Handbook."

Obviously, this did not say much, but it seemed adequate at the time. Then, after the war, the highway program really burst forth and the pole industry was out to stay with it.

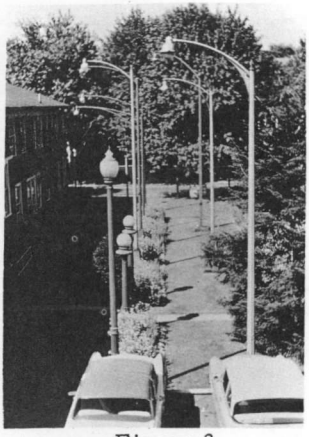


Figure 3.

Figure 4.

The aluminum pole came into being and we had steel and aluminum poles similar to the one in Figure 4. This had a 35-foot mounting height and twin arms each 12 feet long mounting fluorescent luminaires having a combined total weight of 156 pounds and mounted 24 feet apart. This was just the beginning.

Figure 5 was taken in our display yard of one of 75 steel poles now located on State Street in Chicago. This is 45 feet high, having various davit arm lengths carrying four fluorescent luminaires with a total weight of 328 pounds. A far cry from the 20-pound luminaire mounted at 25 feet on this same street 21 years ago.

Figure 5.

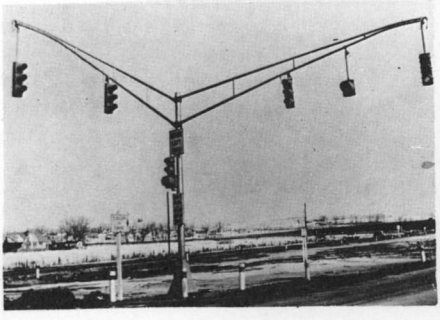


Figure 6.

Figure 6 shows another example of what has developed. Here is an 18-foot aluminum pole with twin arms each 24 feet long and carrying miscellaneous signal equipment weighing about 219 pounds.

I am not trying to say that we have gone beyond the limits of the pole industry. Far from it. The following illustrations are some examples of what advanced engineering techniques have permitted us to do. Shown are 110-foot floodlighting towers, each carrying 32 floodlights. Figure 8 is the latest; a 300-foot continuously tapered, self-supporting antenna pole. There are no guy wires.

Figure 7.

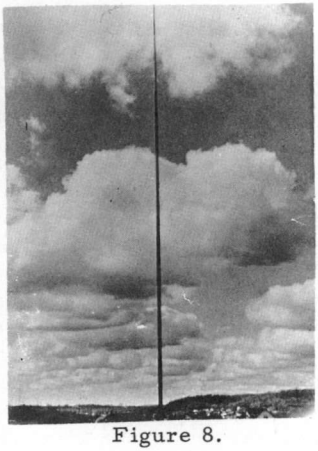


Figure 8.

Structural engineering alone would be sufficient if these products were located indoors. Instead, we have absolutely no control over their location. We must mount them at an intersection, whether it is on a mountainside or in a gorge, and regardless of continuously changing wind and weather conditions. Yet, we have specifically said that these poles shall withstand 101.6 mph.

The only criteria for determining wind velocity are the U.S. Weather Bureau stations located at major cities throughout the country, usually at an airport. These stations are at known altitudes, and for standardization purposes, their wind measuring devices are located exactly 20 feet above this level. It would help if all poles were 20 feet high and located at airports, but even then our problem would not be solved because the Bureau's method of measuring this wind is not applicable to this problem. The Weather Bureau determines a fundamental wind speed, additional speed of occasional gusts, and the general direction of the wind; this being

the only available basis for our current standards. However, this is not the cause of our problem. There is not a pole standing today that would be affected by a steady wind of continuous velocity from one direction.

We have all seen cones of sand or snow, sometimes called whirlwinds, or clouds of dust or sand swirling in various directions with changing speeds and shapes. These are indications of the secondary winds that contribute to this problem.

The fundamental wind creates a load on a pole in varying intensities and gusts, and at the same time affects other movements of a traffic signal or luminaire on a long arm. Because of the difference in shape between the pole shaft and the arm and luminaire, the movements are different, and many stresses are created at various points on the pole and arm.

On a bridge in Michigan, the sockets in luminaires were breaking for no apparent reason. Winds were not creating any particular movement of the pole. It was found, however, that the wind caused a slight back and forth deflection at the top of just a few inches. This, in turn, was causing harmonic vibration of several hundred cycles per second that were transmitted out the arm to the luminaire where these harmonics were measured at an even greater rate. This vibration was in turn destroying the sockets. At the stadium of the Air Force Academy in Colorado Springs, they were concerned about excessive deflection in the flood-lighting poles until they found that because concentrations of freak winds through the gorges of the mountains were so intense that standard latches were not sufficient to keep the doors closed, and heavy duty glass had to be installed in windows facing south because standard glass kept blowing in.

An interesting sidelight involves a utility here in Oregon whose specifications had previously called for the standard 101.6 mph wind velocity. When they experienced some wind loading problems with some poles, they changed the specifications to require 150 mph wind velocity. I often wonder how they know that the new poles they receive meet this requirement.

A lot of work has been done toward the solution of this problem. NARTB, the National Association of Radio and Television Broadcasters, has done much advanced work and written volumes on wind loadings on radio and TV transmission towers. Some later work that is even more directly related to the problem has been done by the Highway Research Board, and I am sure all of you traffic engineers are familiar with their Circular 355, which applies to traffic and overhead sign support structures. Work done in preparing their bulletin has contributed a great deal toward the

answer we are seeking. However, until a new set of nationally accepted standards are developed to specifically control this problem as we know it, you, as the customer, must rely to a great extent on the manufacturer. Individual traffic engineers or even highway departments cannot be expected to develop these specifications alone.

For the last 5 years or so our research and development department has been concentrating on this problem; consulting with aircraft industry engineers, Bureau of Public Roads, research departments of MIT and Carnegie Institute of Technology, and conducting wind tunnel and field tests. In addition, they have absorbed everything available that has been written which even remotely approaches the subject.

As a final result we have just released a new catalog for which we redesigned every pole product we manufacture, not with the old design criteria of 101 mph wind, but for any and all conditions, and then classified each item as to maximum weight and projected area of the luminaire or signal equipment it is designed to carry. This permits you to choose a product based on its application, not the wind loading to which it may be subjected.

RECENT DEVELOPMENTS IN CONCRETE FORM AND TRAFFIC CONTROL SIGN MATERIALS FOR HIGHWAY CONSTRUCTION

Harry W. Berry

On behalf of the fir plywood industry, we appreciate the opportunity to present latest developments that may be of great interest to you who are currently engaged in highway design and construction.

At this time there are three fairly recent developments that we feel are appropriate to bring up. One is in the field of concrete form work, and the other two are in the field of highway signing.

CONCRETE FORMS

I think we all are pretty familiar with the current use of regular plywood for concrete form work. This pertains particularly to bridges, aqueducts, as well as to highway department buildings. A development in the field of concrete form sheathing, which actually is not new but has relatively recently come into common use, is use of a plastic type surface applied to plywood faces for concrete form sheathing. This product, which is called high density overlaid plywood, provides a phenolic resin impregnated fiber which eliminates grain rise and face checking. You might be interested to know that the first overlaid surface for plywood was fabricated of groundup surplus helmet liners during the war, at which time the resin coating was extracted from the helmet liners themselves.

The smooth surface provides an excellent face for concrete form work so that sacking and touching up is kept to a minimum. It has especially paid off, however, through the greater number of reuses provided for each panel so that overall economics can be realized. Where regular wood surfaces will provide 20 to 25 reuses per panel, engineers have reported 75 to 100 reuses per side for the high density overlay. Forms are easily stripped with a minimum of damage to the concrete surface.

A recent example is shown through the use of high density overlaid concrete forms for the Nimitz Freeway viaduct through Oakland, California. A box girder type of construction was utilized with hollow voids under the roadway to reduce weight. High density overlaid form work was used for the inside of the boxes as well as the outside to entirely eliminate sacking. The contractor reused each panel 50 times, and most of the panels were salvaged for additional use on other jobs. The engineers found that even though

the insides of the boxes were not visible to the public, the number of reuses justified the overlaid plywood cost. In areas where the smooth concrete surface was visible to the public, however, the public reaction was highly favorable and justified the extra expense in these areas.

TRAFFIC CONTROL SIGNS

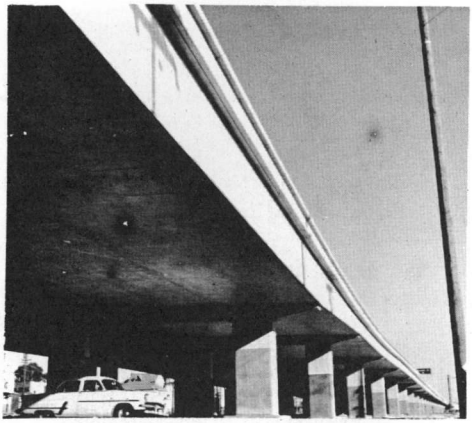
Developments within the sign field have been toward a reanalysis of the basic product. As a log is peeled (as you would an apple) and reassembled with cross-laminated veneers, an extremely strong material results which is greatly resistant to damage and provides tremendous bridging strength.

Recognizing the need for high quality effective signs because of the current higher speeds and public interest, development has been in the direction of improving designs so that framing members can be eliminated or minimized. Panels were developed to provide self-supporting signs that could be fabricated out of large panels out of inventory, and any size or shape could be cut and easily worked. Improvements in factory applied finishes have been made so that colorfast prefinished surfaces are now available also. This, therefore, combines the inherent strength of the plywood with a superior factory applied colorfast surface. For signs, therefore, all that need be applied to the surface is the application of a legend, which may be either reflectorized or nonreflectorized.

These finishes are readily adaptable to small signs as well as large signs, and can be obtained in either green or white. In many cases counties, cities, and state agencies are utilizing the white or green for the back of the sign, then applying reflectorized sheeting to the other side. The surface provides an acrylic coating, which is colorfast, and testsshow that there is no change in color over a 10-year period.

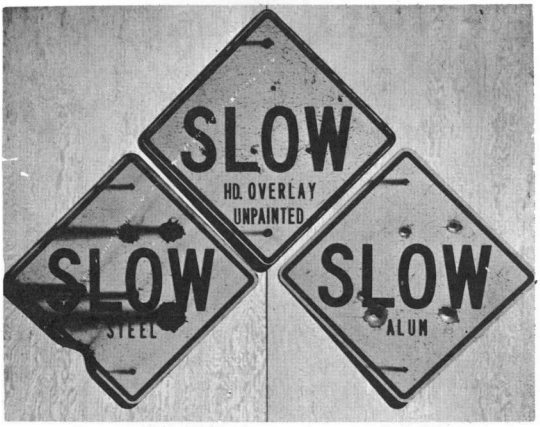
Along with recognizing the need for high quality permanent signs, a new attachment method has been developed in which the plywood panels may be fastened to the backs of the signs so that the face is free of bolts and hardware. These clips are fabricated of aluminum and are attached to the back of the sign through use of a blind fastener which acts as a wood rivet. The particular advantage of these signs is to allow these panels to be slipped in place on the horizontal framing members so that the sign can be completely assembled either in the shop or on the site. All panels are placed vertically so that horizontal joints are eliminated. If necessary, individual panels can be removed without affecting the

remainder of the sign. This means that the section of the sign most susceptible to damage immediately adjacent to the roadway can be readily replaced without affecting the rest of the sign.



High density concrete forms.
Nimitz Freeway, Oakland, California.

Pennsylvania Turnpike highway signs.
Medium density - overlaid plywood signs.



Bullet holes after five years' weathering.
High density overlay highway signs.

High density overlaid plywood signs. Wisconsin and New Mexico

TRAFFIC PAINTING, HEATING, AND APPLICATION

W. O. Widdows

The Oregon State Highway Department has been interested in the heating of traffic paint for a number of years, but it was not until the fall of 1955 that we hit upon a successful method to accomplish this. We knew that heating paint would speed up application, cut down drying time, give better adherence to the pavement, and lengthen out the striping season.

Traffic paint is very volatile, and it was deemed advisable to separate the heating unit from the supply tank. Under this system it would be necessary to heat only the paint about to be applied to the road and not the entire tank.

Under our plan we depart from the conventional method of pressure tanks that force the paint by air pressure from the supply vessel to the spray guns by using a paint pump similar in principle to the method that gas is supplied to the carburetor of your car.

The paint tanks are rectangular in shape and mounted transversely to the truck. The load is always balanced whether the tank is empty or full. Use of a paint pump over air pressure tanks has reduced the tank dead load by one-half.

Pump capacity is over twice the spray guns' capacity, so no surging action results. Paint is pumped from the supply tank to the heaters and then through a small filter tank and out to the spray guns. If not immediately utilized by the spray guns it returns to the supply tank.

Heating elements consist of two 3000-watt elements similar to a waffleiron in design. Current is supplied to a 7-1/2 kva generator. Heating capacity is 65 gallons per hour to a temperature of 150-160 degrees F. Heaters are thermostatically controlled, and as the paint is constantly circulating there is no danger of explosion.

Other advantages of the hot spray striping system include less time needed for cleaning the tank since tanks and heaters do not require any special cleaning at the end of the day's run. There is no down-time for pressure adjustment. In cold weather the crew can start heating the paint on the way to the job, thus warming the paint to proper viscosity for spraying when the job is reached. Stripes are brighter, and penetration on asphaltic concrete is much better.

Oregon uses a nine-man crew in its striping operations. The crew does its own centerline spotting. A pilot truck with roto-beam light precedes the striping unit and a third truck follows to pick up wet paint cones and carry extra paint and supplies.

The striping cart is attached to the front of the truck by means of a floating pin to the slotted bumper, which enables the car operator to yield the right-of-way in either traffic lane, thus occupying only 2 feet of the chosen lane. The cart is free to float in either direction from the truck up to the limits of the bumper width. This permits traffic to continue around the striping machine, even on narrow roads. Oregon has used the pusher type striping cart for more than 25 years which permits painting the centerline with a minimum amount of advance spotting and, we believe, results in painting a straighter line.

Use of the hot-spray striping method has made the operation a year around possibility except it is not recommended as a standard procedure when surface moisture is present. The overall application speed increased by more than 30 percent. Using cold spray, the average was between 6 and 7 miles per hour under adverse weather conditions. With hot spray, application speed has been increased to 11 and 12 miles per hour.

As a rule, drying time has been decreased by 50 percent. Since heated solvents evaporate faster (and most solvents disappear between the gun and the stripe), naturally there is a faster dry with hot spray. This means that cones are out a much shorter distance behind the truck and there is less tracking.

This past four-year experience has shown that we increased the mileage 50 percent in cold weather, and that average increased mileage gained with hot spray is approximately 30 percent over the entire season.

There is no down-time for pressure adjustment. When the crew leaves the shop in cold weather, the heaters are turned on and the recirculated material is hot and ready to spray when they reach the target area. There is no lost time since viscosity of the material stays the same and no adjustments are necessary.

Stripes are brighter and penetration is better because hot-sprayed stripes dry faster. We know that the stripes have a much longer life, but this cannot be stated percentage-wise because of the variance in pavement texture and temperature range when trying to compare cold and hot spray.

Because of the additional weight of equipment necessary to hot-spray paint, it does not appear feasible to apply this principle to the small one-man striping machines.

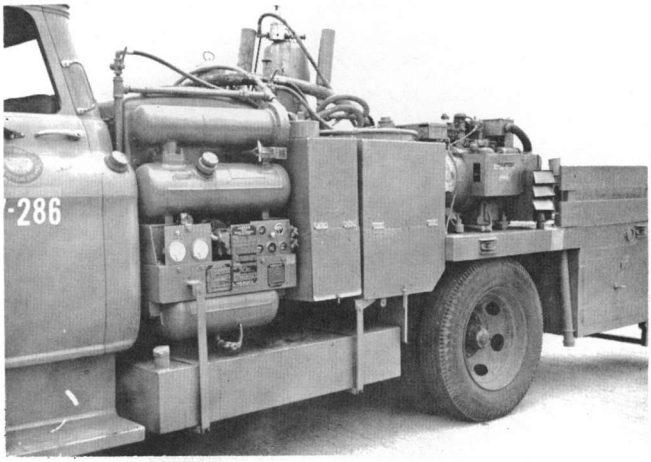


Figure 1.

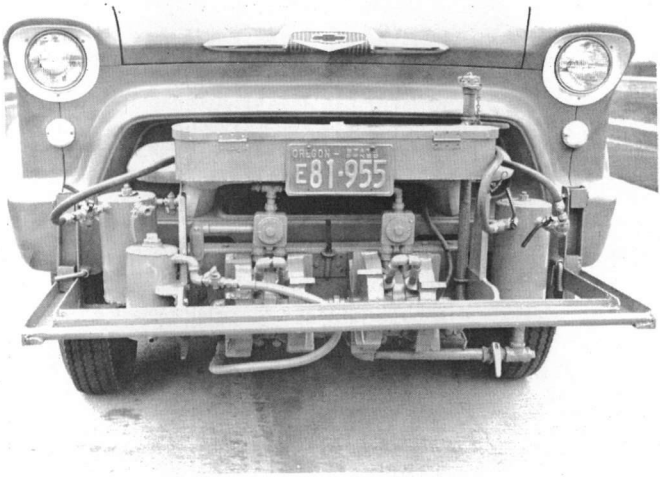


Figure 2.

Figure 3.

Figure 4.

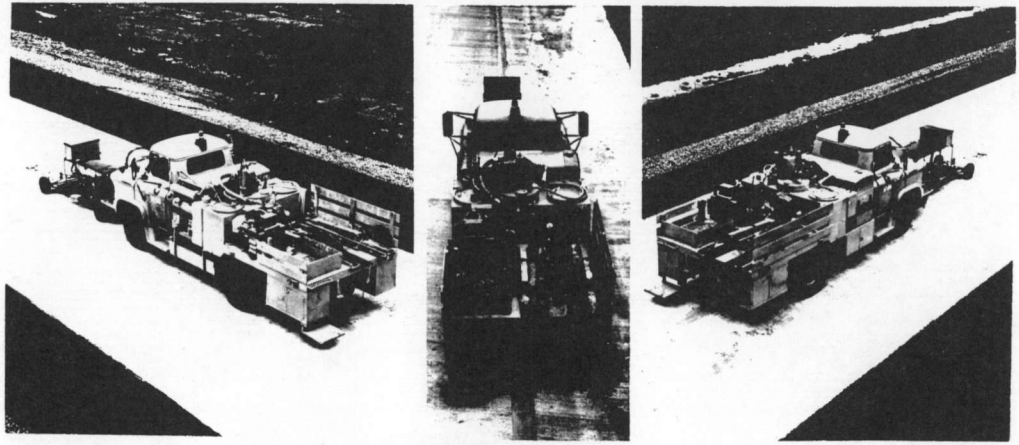


Figure 5.

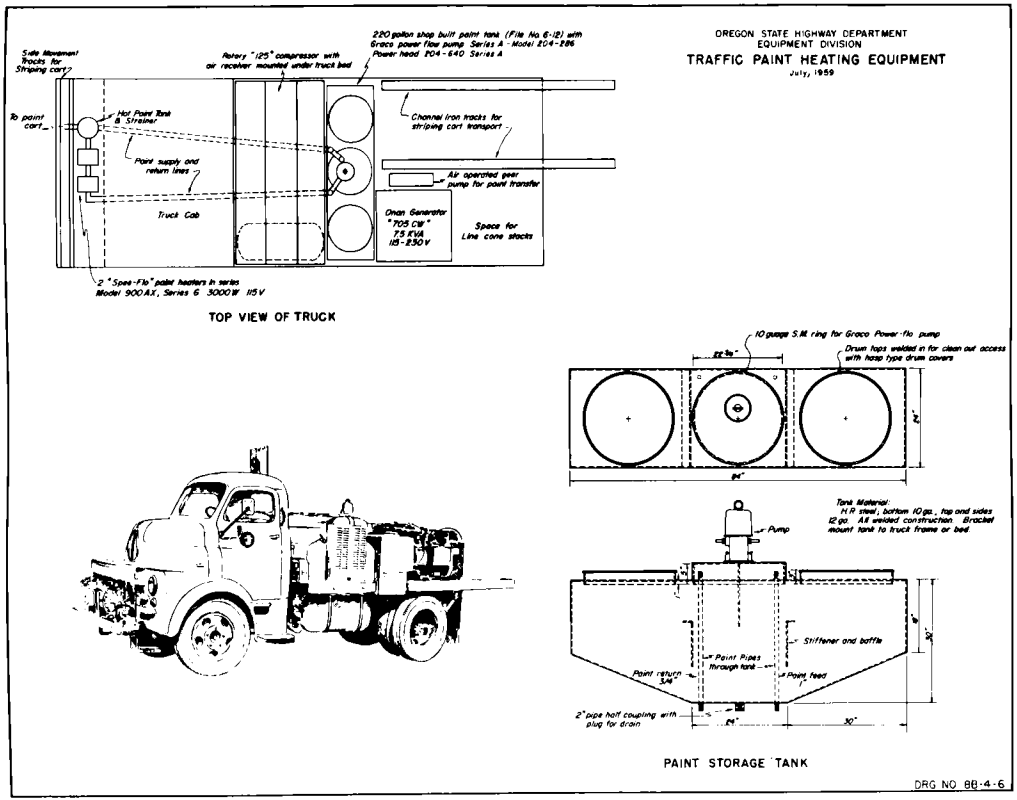

OREGON STATE HIGHWAY DEPARTMENT
EQUIPMENT DIVISION
TRAFFIC PAINT HEATING EQUIPMENT
July, 1959
Safe Movement Tracks for Striping cart
Rotary "125" compressor with air receiver mounted under truck bed
220 gallon shop built paint tank. (File No. 6-12) with Graco power flow pump Series A - Model 204-286 Power head 204-640 Series A
To paint cart
Hot Paint Tank & Strainer
Paint supply and return lines
Channel iron tracks for striping cart transport
Air operated gear pump for paint transfer
Truck Cab
Onan Generator "705 CW" 7.5 KVA 115-230 V
Space for Line cone stacks
2 "Spee-Flo" paint heaters in series Model 900 AX, Series 6 3000 W 115 V
TOP VIEW OF TRUCK
10 gauge S.M. ring for Graco Power-flo pump
Drum tops welded in for clean out access with hasp type drum covers
Tank Material H.R. steel; bottom 10 ga., top and sides 12 ga. All welded construction. Bracket mount tank to truck frame or bed.
Pump
Stiffener and baffle
Paint Pipes through tank
Paint return 3/4"
Paint feed
2" pipe half coupling with plug for drain
PAINT STORAGE TANK
DRG NO. 88-4-6

Figure 6.

REGISTRATION LIST

NAME	ADDRESS	ORGANIZATION
Adams, Donald R.	Salem, Oregon	Oregon State Hwy Dept
Allen, Donald	Eugene, Oregon	Dept of Public Works
Allingham, Roy	Bend, Oregon	Deschutes County
Anderson, John	Salem, Oregon	Marion County
Anderson, W.E.	Tillamook, Oreg	Tillamook County
Joseph Andreotti	Yakima, Wash.	Yakima County
Archibald, A.E.	Salem, Oregon	Oregon State Hwy Dept
Asburry, R.D.	Salem, Oregon	Oregon State Hwy Dept
Baldwin, E.A.	Eugene, Oregon	Lane County
Barkus, E.H.	Salem, Oregon	Bureau of Public Roads
Bartley, J.M.	Tacoma, Wash.	Refinery Sales Co
Baxter, Harlan E.	Seattle, Wash.	Eagle Signal Co
Beaty, R.W.	Olympia, Wash.	Dept of Highways
Beecroft, G.W.	Corvallis, Oreg	Oregon State College
Beuker, Gus	Portland, Oreg	Shell Oil Co
Bell, James R.	Eugene, Oreg	Bureau of Mun Research
Bergstrom, D.	Portland, Oreg	City of Portland
Berry, H.W.	Tacoma, Wash.	Douglas Fir Plywood
Beyersdorf, Guy	Seattle, Wash.	Charles R. Watts Co
Blee, K.R.	Portland, Oreg	Shell Oil Co
Blensly, R.C.	Salem, Oregon	Oregon State Hwy Dept
Bokholt, J.P.	Edmonds, Wash.	Minnesota Mining & Mfg
Bond, W.R.	Portland, Oreg	Amer Wood Preservers
Bowes, W.A.	Portland, Oreg	City of Portland
Boyes, R.C.	Vancouver, BC	City of Vancouver
Brooks, G.R.	Salem, Oregon	Bureau of Public Roads
Buggee, William	Olympia, Wash.	Wash. Dept of Highways
Burghardt, C.R.	Vancouver, Wash.	Bureau of Public Roads
Canutt, John L.	Portland, Oreg	Ross Island Sand & Gravel
Cameron, James	Portland, Oreg	Bureau of Public Roads
Campbell, D.E.	Spokane, Wash.	Wash. Dept of Highways
Carnegie, O.A.	Albany, Oreg	Linn County
Carstensen, R.J.	Medford, Oreg	Jackson County
Casey, Robert	Grants Pass, Oreg	City of Grants Pass
Chapman, Archie	Salem, Oregon	Salem Engr Dept
Chevron, C.F.	Odell, Oregon	Hood River County
Christerson, P.D.	Portland, Oreg	Western Structures, Inc
Clark, Glen L.	Salem, Oregon	Oregon State Hwy Dept
Coffey, V.H.	Salem, Oregon	Oregon State Hwy Dept
Coghill, Richard	Eugene, Oregon	Lane County
Conklin, R.D.	Salem, Oregon	Oregon State Hwy Dept
Cook, B.L.	Seattle, Wash.	City of Seattle

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Cooper, Forrest	Salem, Oregon	Oregon State Hwy Dept
Coopey, Martin P.	Corvallis, Oreg	Oregon State College
Cox, H.S.	Salem, Oregon	Oregon State Hwy Dept
Crandall, F.B.	Salem, Oregon	Oregon State Hwy Dept
Culver, Bruce R.	Seattle, Wash.	City of Seattle
Dana, Marshall	Portland, Oreg	U.S. National Bank
Daniels, Douglas	Corvallis, Oreg	Oregon State College
Davis, J.H.	Salem, Oregon	City of Salem
Decker, G.L.	Salem, Oregon	Oregon State Hwy Dept
DeYoung, W.E.	Los Angeles, Cal	Automatic Signal Div
Dillard, David	Corvallis, Oregon	Oregon State College
Drake, G.L.	San Franicisco, Cal	Wilbur Smith & Assoc
Duggan, C.W.	Salem, Oregon	Bureau of Public Rds
Dunbar, William	Portland, Oreg	Bureau of Public Rds
Dungey, Ron	Coquille, Oreg	City of Coquille
Dunn, R.E.	Olympia, Wash.	Wash. Dept of Hwys
Edick, Tom	Corvallis, Oreg	Oregon State College
Eison, L.T.	Springfield, Oreg	City of Springfield
Ekse, Martin	Seattle, Wash.	Univ of Washington
Face, Glenn S.	Tacoma, Wash.	Douglas Fir Plywood
Failmezger, R.W.	Salem, Oregon	Oregon State Hwy Dept
Fowler, F.T.	Portland, Oreg	City of Portland
French, B.M.	Portland, Oreg	Bur of Public Roads
Gallagher, D.A.	Corvallis, Oreg	Corv Sand & Gravel
Gilbert, Ralph	Portland, Oreg	Oreg Portland Cement
Gillmouthe, R.L.	Hood River, Oreg	City of Hood River
Gilman, Don	Eugene, Oregon	City of Eugene
Goodnight, V.L.	Corvallis, Oreg	City of Corvallis
Grafe, Willis R.	Salem, Oregon	Bur of Public Roads
Greene, Ed	Tulelake, Cal	Oreg Agri Chemicals
Hagemann, J.F.	Salem, Oregon	Oregon State Hwy Dept
Hague, George	Salem, Oregon	Amer Bit. & Asphalt
Hallvik, G.C.	Boise, Idaho	Bur of Public Roads
Hamilton, H.E.	Sweet Home, Oreg	City of Sweet Home
Hanson, C.C.	Corvallis, Oreg	Benton County
Hanson, G.K.	Independence, Oreg	Oregon State Hwy Dept
Hardie, J.A.	Salem, Oregon	Oregon State Hwy Dept
Hayes, F.B.	Pendleton, Oreg	Umatilla County
Head, J.Al	Salem, Oregon	Oregon State Hwy Dept
Hector, Wally	Portland, Oreg	Douglas Oil Co
Higgins, B.L.	Bend, Oregon	Retired
Higgins, Herb	Olympia, Wash.	Asphalt Institute

NAME	ADDRESS	ORGANIZATION
Hoey, W.E,	Eugene, Oregon	Bur of Municipal Res
Holcomb, G.W.	Corvallis, Oreg	Oregon State College
Howland, J.C.	Corvallis, Oregon	Cornell, Howland, Hayes & Merryfield
Huddleston, Mike	Newport, Oregon	Lincoln County
Hutchens, C.W.	Rigby, Idaho	Jefferson County
Irwin, A.W.	Portland, Oreg	J.H. Baxter Co
Jacob, Glenn	McMinnville, Oreg	Yamhill County
Jamison, M.W.	Klamath Falls	USAF
Jess, Arthur L.	Anchorage, Alaska	District Corps of Engineers
Johnson, B.M.	Pullman, Wash.	Highway Res, WSU
Johnson, D.E.	Seattle, Wash.	Baxter-Wyckoff Co
Johnson, H.C.	Corvallis, Oreg	Oregon State Hwy Dept
Johnson, V.P.	Salem, Oregon	Oregon State Hwy Dept
Jones, Byron	Portland, Oreg	Portland Cement Assn
Jorgenson, R.E.	Washington, DC	Nat'l Hwy Users Conf
Juve, Maurice	Salem, Oregon	Oregon State Hwy Dept
Kalinsoki, J.R.	Klamath Falls	Klamath County
Keeley, J.H.	Beavercreek, Oreg	Clackamas County
Kinder, C.D.	Vancouver, Wash.	Clark County
Kistner, K.L.	Coquille, Oreg	Coos County
Kjelstad, Nels	Bellevue, Wash.	City of Bellevue
Koch, A.S.	Santa Ana, Calif	Orange County
Koenig, C.M.	Salem, Oregon	Oregon State Hwy Dept
Kolling, G.W.	Portland, Oreg	Union Metal Mfg Co
Kuehn, K.H.	Corvallis, Oreg	Oregon State College
Lacey, F.T.	Salem, Oregon	Oregon State Hwy Dept
Lamb, G.E.	Salem, Oregon	Oregon State Hwy Dept
Larson, C.S.	Portland, Oreg	Asphalt Institute
Larson, Don	Salem, Oregon	Minnesota Min. & Mfg
Larson, W.W.	Albany, Oregon	Linn County
Leedom, Hal	Coos Bay, Oregon	City of Coos Bay
Leland, E.J.	Spokane, Wash.	City of Spokane
Liedlich, W.G.	Los Alamitos, Calif	A'G'A'
Lincoln, P.A.	Vancouver, Wash.	Bur of Public Roads
Littlefield, L.A.	Portland, Oreg	Arrow Trans. Co
Maloney, Avery	Portland, Oreg	Bur of Public Roads
Manning, Lynn	Seattle, Wash.	Union Oil Co
Marker, Vaughn	Berkeley, Calif	Asphalt Institute
Marsh, B.W.	Washington, DC	Amer Auto Assn
Mathes, E.L.	Boise, Idaho	Idaho Dept of Hwys

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Martell, C.J.	North Bend, Oreg	Coos County
Matthews, A.T.	Seattle, Wash.	Econolite Corp
May, Al H.	Roseburg, Oreg	Douglas County
Maytin, Iury L.	Pullman, Wash.	Highway Res, WSU
Miller, J.N.	Portland, Oreg	Bur of Public Roads
Millcorn, Isom	Prineville, Oreg	Crook County
Miner, Asberry	Tillamook, Oreg	Tillamook County
Morrill, H.C.	Roseburg, Oreg	Douglas County
Murray, Ray A.	Portland, Oreg	Ideal Cement Co
McInerny, John	Coalfax, Wash.	Whitman County
McKillop, R.L.	San Francisco, Calif	U.S. Steel Corp
McKinstry, E.N.	Hillsboro, Oregon	Washington County
McLane, H.R.	Salem, Oregon	Bur of Public Roads
Nelson, R.W.	Portland, Oreg	Traffic Safety Supply
Newton, J.M.	Portland, Oreg	Bur of Public Roads
Norling, L.T.	Chicago, Ill.	Portland Cement Assn
Oakes, J.R.	Salem, Oregon	Oregon State Hwy Dept
O'Hearne, James	Portland, Oregon	Bur of Public Roads
Olson, Adrian	Silverton, Oregon	Oregon State Hwy Dept
Olson, R.F.	Eugene, Oregon	Eug Conc Pipe & Prod
Orth, L.M.	Salem, Oregon	Oregon State Hwy Dept
Owens, A.L.	Idaho Falls, Idaho	Bonneville County
Page, E.B.	Salem, Oregon	Central Paving Co
Painter, J.E.	Idaho Falls, Idaho	Bonneville County
Palmateer, J.C.	Seattle, Wash.	King County
Palmer, Gene	Pendleton, Oreg	Umatilla County
Palmer, Mel	Coos Bay, Oreg	City of Coos Bay
Penton, H.V.	Los Angeles	CAMEO
Perkins, M.C.	Hood River, Oreg	Hood River County
Peterson, D.L.	Salem, Oregon	Oregon State Hwy Dept
Peterson, V.R.	Missoula, Mont	County
Phillips, J.A.	Salem, Oregon	Oregon State Hwy Dept
Plunkett, J.M.	Portland, Oreg	McCormick & Baxter Co
Pooley, G.C.	Portland, Oreg	Westinghouse Electric
Popovich, M.	Corvallis, Oreg	Oregon State College
Poutte, I.W.	South Bend, Wash.	Pacific County
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Pruyn, J.W.	Corvallis, Oregon	Oregon State College
Rask, P.R.	Pasadena, Calif	Retired
Rhodes, J.W.	Salem, Oregon	Oregon State Hwy Dept
Richardson, E.S.	Eugene, Oregon	Lane County
Richey, Maurice	Helena, Montana	Mont Hwy Commission
Riedl, P.V.	Salem, Oregon	Bur of Public Roads

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Rogge, Hal	Edmonds, Wash.	Flex-O-Lite Corp
Ross, G.W.	Salem, Oregon	Oregon State Hwy Dept
Russell, G.R.	Moscow, Idaho	Univ of Idaho
Ryker, R.R.	Gig Harbor, Wash.	Pierce County
Rynning, P.B.	Medford, Oregon	Jackson County
Sample, W.H.	Salem, Oregon	Oregon State Hwy Dept
Schilling, Leonard	Glenwood, Wash.	Klickitat County
Schwarm, J.A.	Coquille, Oregon	City of Coquille
Schwegler, R.M.	Portland, Oregon	Bur of Public Roads
Severson, Win	Portland, Oregon	Amer Bit. & Asphalt
Shearer, K.C.	Lake Grove, Oreg	Bur of Public Roads
Shumway, Guy	McMinnville, Oreg	Yamhill County
Sipprell, R.B.	Salem, Oregon	Oregon State Hwy Dept
Smith, Elmo	Albany, Oregon	Alb Democrat Herald
Soderquist, C.R.	Portland, Oregon	Multnomah County
Sphar, L.L.	Bothell, Wash.	Concrete Prod Assn
Stark, William	Salem, Oregon	Oregon State Hwy Dept
Stephenson, P.M.	Salem, Oregon	Oregon State Hwy Dept
Stephenson, R.A.	Portland, Oregon	Bur of Public Roads
Sterling, D.J.	Portland, Oregon	Oregon Journal
Stewart, Frank	Portland, Oregon	U.S. Steel
Still, Rex	Olympia, Wash.	Wash. Dept of Hwys
Stillwell, J.F.	Portland, Oregon	Reynolds Metals Co
Stonex, K.A.	Milford, Mich	General Motors Corp
Strombom, H.O.	Eugene, Oregon	Lane County
Succo, E.A.	Seattle, Wash.	City of Seattle
Swanson, Erle	Portland, Oregon	Car Lane Inc
Sweet, H.R.	Yakima, Wash.	Yakima County
Swenson, C.G.	Salem, Oregon	Oregon State Hwy Dept
Tate, Vern	San Francisco	Minn Mng & Mfg
Taylor, W.R.	Goldendale, Wash.	Klickitat County
Teegarden, Charles	McMinnville, Oreg	Yamhill County
Templin, R.L.	Grants Pass, Oreg	Josephine County
Tibbetts, J.R.	Tillamook, Oreg	Tillamook County
Tibbot, B.R.	Seattle, Wash.	ALCOA
Thompson, K.C.	Langlois, Oreg	Curry County
Tollenaar, Ken	Salem, Oregon	Assn of Oreg Counties
Trygstad, Roger	Corvallis, Oreg	Oregon State College
Vala, A.J.	Portland, Oregon	Assn Gen Contractors
VanWormer, B.T.	Salem, Oregon	City of Salem
Voll, R.A.	Mill Valley, Calif	Streeter-Amet Co
Waggoner, R.T.	McMinnville, Oreg	City of McMinnville
Waker, Fred	Portland, Oregon	Crouse-Hinds Co

NAME	ADDRESS	ORGANIZATION
Walberg, H.O.	Eugene, Oregon	Lane County
Wallan, Bob	Pasco, Wash.	Amer Bit. & Asphalt Co
Walton, R.D.	Portland, Oregon	Bur of Public Roads
Warren, David	Dallas, Oregon	City of Dallas
Weir, A.N.	Portland, Oregon	Oregon State Motor Assn
Wells, C.K.	Klamath Falls	Klamath County
West, D.B.	Wenatchee, Wash.	Chelan County
Westling, A.M.	Eugene, Oregon	Univ of Oregon
Whitnall, W.R.	Eugene, Oregon	Lane County
Widdows, W.O.	Salem, Oregon	Oregon State Hwy Dept
Wildish, N.E.	Eugene, Oregon	Wildish Sand & Gravel
Williams, W.C.	Salem, Oregon	Oregon State Hwy Dept
Wilson, G.E.	Madras, Oregon	City of Madras
Wolfe, V.D.	Salem, Oregon	Oregon State Hwy Dept
Wyckoff, C.P.	Seattle, Wash.	Amer Bit. & Asphalt Co
Young, L.H.	Salem, Oregon	Oregon State Hwy Dept
Ziegler, J.E.	Portland, Oregon	McCormick & Baxter Co
Zumwalt, Warren	Portland, Oregon	Union Oil Company

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Martin P. Coopey, Professor
G. W. Holcomb, Head, Civil Engineering Department

Oregon State Highway Department

Forrest Cooper, Deputy State Highway Engineer
J. Al Head, Asst Traffic Engineer
C. G. Swenson, Co-City Relations Engineer

Oregon Cities

V. L. Goodnight, City Engineer, Corvallis

Oregon Counties

John Anderson, Marion County Engineer, Salem
Kenneth Tollenaar, Executive Secretary, Assn of Oregon Counties

Bureau of Public Roads

James Cameron, Asst Regional Engineer
B. M. French, Regional Engineer
B. J. McClarty, Regional Construction & Maintenance Engineer
James O'Hearne, Regional Secondary Engineer

ITE - Western Section

Robert D. Conklin, Traffic Investigations Engineer, State Highway Department
Dennis Peterson, Engineering Economist, State Highway Department

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J. Al Head, State Highway Department
B. J. McClarty, Bureau of Public Roads

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Student Chapter, American Society of Civil Engineers
Roger Tofte, State Highway Department

PUBLICITY

Donald Dill, State Highway Department
Fred Zwahlen, Oregon State College

PROCEEDINGS & PROGRAM PREPARATION

Mrs. Nadine Cater, State Highway Department
Harry Esch, State Highway Department
Mrs. Beverly Flood, State Highway Department
Roger Tofte, State Highway Department

OREGON STATE COLLEGE
ENGINEERING EXPERIMENT STATION
CORVALLIS, OREGON

PARTIAL LIST OF PUBLICATIONS

(For a complete listing write the Engineering Experiment Station.)

Bulletins—

No. 18. The Use of the Fourier Series in the Solution of Beam Problems, by B. F. Ruffner. 1944. 50¢.

No. 19. 1945 Progress Report on Pollution of Oregon Streams, by Fred Merryfield and W. G. Wilmot. 1945. 40¢.

No. 20. The Fishes of the Willamette River System in Relation to Pollution, by R. E. Dimick and Fred Merryfield. 1945. 40¢.

No. 21. The Use of the Fourier Series in the Solution of Beam-Column Problems, by B. F. Ruffner. 1945. 25¢.

No. 22. Industrial and City Wastes, by Fred Merryfield, W. B. Bollen, and F. C. Kachelhoffer. 1947. 40¢.

No. 23. Ten-Year Mortar Strength Tests of Some Oregon Sands, by C. E. Thomas and S. H. Graf. 1948. 25¢.

No. 24. Space Heating by Electric Radiant Panels and by Reverse-Cycle, by Louis Slegel. 1948. 50¢.

No. 25. The Banki Water Turbine, by C. A. Mockmore and Fred Merryfield. Feb 1949. 40¢.

No. 26. Ignition Temperatures of Various Papers, Woods, and Fabrics, by S. H. Graf. Mar 1949. 60¢.

No. 27. Cylinder Head Temperatures in Four Airplanes with Continental A-65 Engines, by S. H. Lowy. July 1949.

No. 28. Dielectric Properties of Douglas Fir at High Frequencies, by J. J. Wittkopf and M. D. Macdonald. July 1949. 40¢.

No. 29. Dielectric Properties of Ponderosa Pine at High Frequencies, by J. J. Wittkopf and M. D. Macdonald. September 1949. 40¢.

No. 30. Expanded Shale Aggregate in Structural Concrete, by D. D. Ritchie and S. H. Graf. Aug 1951. 60¢.

No. 31. Improvements in the Field Distillation of Peppermint Oil, by A. D. Hughes. Aug 1952. 60¢.

No. 32. A Gage for the Measurement of Transient Hydraulic Pressures, by E. F. Rice. Oct 1952. 40¢.

No. 33. The Effect of Fuel Sulfur and Jacket Temperature on Piston Ring Wear as Determined by Radioactive Tracer, by M. Popovich and R. W. Peterson. July 1953. 40¢.

No. 34. Pozzolanic Properties of Several Oregon Pumicites, by C. O. Heath, Jr. and N. R. Brandenburg. 1953. 50¢.

No. 35. Model Studies of Inlet Designs for Pipe Culverts on Steep Grades, by Malcolm H. Karr and Leslie A. Clayton. June 1954. 40¢.

No. 36. A Study of Ductile Iron and Its Response to Welding, by W. R. Rice and O. G. Paasche. Mar 1955. 60¢.

No. 37. Evaluation of Typical Oregon Base-Course Materials by Triaxial Testing, by M. A. Ring, Jr. July 1956. 50¢.

No. 38. Bacterial Fermentation of Spent Sulfite Liquor for the Production of Protein Concentrate Animal Feed Supplement, by Herman R. Amberg. Oct. 1956. 50¢.

No. 39. Wood Waste Disposal and Utilization, by R. W. Boubel, M. Northcraft, A. Van Vliet, M. Popovich. Aug. 1958. $1.00

Circulars—

No. 16. Water Works Operators' Manual, by Warren C. Westgarth. Mar 1953. 75¢.

No. 17. Proceedings of the 1953 Northwest Conference on Road Building. July 1953. 60¢.

No. 18. Proceedings of the 1955 Northwest Conference on Road Building. June 1955. 60¢.

No. 19. Review for Engineering Registration, 1. Fundamentals Section, by Leslie A. Clayton. Dec 1955. 60¢.

No. 20. Digest of Oregon Land Surveying Laws, by Kenneth J. O'Connell. June 1956. 75¢.

No. 21. Review for Engineering Registration, 2. Civil Engineering, by Leslie A. Clayton and Marvin A. Ring. July 1956. $1.25.

No. 22. Review for Engineering Registration, 3. Mechanical Engineering, by Charles O. Heath, Jr. Feb 1957. $1.25.

No. 23. Research and Testing in the School of Engineering, by M. Popovich. May 1957. 25¢.

No. 24. Proceedings of the 1957 Northwest Conference on Road Building, July 1957. $1.00.

No. 25. Proceedings of the 1959 Northwest Conference on Road Building, Aug 1959. $1.00.

No. 26. Research Activities in the School of Engineering, by J. G. Knudsen, Nov. 1960. 25¢.

No. 27. Proceedings of the 1960 Northwest Highway Engineering Conference, Dec 1960. $1.00.

Reprints—

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