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COMMITTEE PRINT NO. 4

STUDY AND INVESTIGATIONS OF USE OF
MATERIALS AND NEW DESIGNS AND
METHODS IN PUBLIC WORKS

THE USE OF MATERIALS FOR THE
NATION'S HIGHWAYS

PREPARED FOR THE
COMMITTEE ON PUBLIC WORKS
UNITED STATES SENATE
BY THE
BUREAU OF PUBLIC ROADS
U.S. DEPARTMENT OF COMMERCE



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WASHINGTON : 1962

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MEMORANDUM OF TRANSMITTAL BY THE CHAIRMAN

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
July 10, 1962.

To the Members of the Committee:

Pursuant to our committee resolution of January 22, 1962, the Bureau of Public Roads has submitted a report on the use of materials for the Nation's highways.

The report discusses the scope of highway use of materials, methods of exploring for materials, and the new and improved design of materials for the highway systems. The report contains a very comprehensive listing of the new equipment which has been developed and put to use in highway construction. It illustrates the large amount of research and development which has been made in the use of nuclear and electronic equipment in testing materials and controlling their installation. The report shows the high degree of technological refinements which are being applied to the construction of our highway system.

I am sure that you will find the report extremely interesting especially because of the responsibility which our committee has in the field of highway legislation. I believe the report shows that every possible method is being used to assure a fine system of highways at the most reasonable cost to our taxpayers.

DENNIS CHAVEZ,
Chairman, Committee on Public Works.

III



COMMUNICATIONS

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
January 30, 1962.

Mr. REX M. WHITTON,
Administrator, Bureau of Public Roads,
Washington, D.C.

DEAR MR. WHITTON: The Committee on Public Works, in executive session on January 16, 1962, approved a committee resolution authorizing hearings, study, and a report on the use of materials in the construction of buildings, roads, water resource projects, and other public works.

To attain the objective of the committee, it will be most helpful if we could obtain the cooperation of industry and the Government agencies in the collection of information called for by the resolution; therefore, it will be appreciated if you will supply us with such information as is related to your interest or activity.

A copy of the resolution is enclosed for your information. If you require further details, please contact Mr. John L. Mutz of the committee staff who is in charge of handling this particular study.

I believe that with the new materials and new uses of known materials being developed and utilized, we should be able to gather considerable information on this subject, thereby making an extremely interesting and constructive contribution to the various producers, fabricators, and users of materials. Furthermore, it would be most useful and helpful if we were to obtain information with respect to new designs and new methods of installation of materials.

It is my hope that your organization will be in a position to appear before the Committee on Public Works to make a formal presentation during the early part of April 1962. After the hearings or presentations are completed, it is planned to have a committee report prepared thereon and submitted to the Senate.

I would appreciate it if you would advise me if you will be able to complete such a report for presentation to the committee at the suggested time, so that we may set tentative dates for the hearings.

Sincerely,

DENNIS CHAVEZ, *Chairman.*

[87th Cong., 2d sess., U.S. Senate, Committee on Public Works]

COMMITTEE RESOLUTION PROVIDING FOR A STUDY AND INVESTIGATION OF USE OF MATERIALS IN PUBLIC WORKS

Whereas the Senate Committee on Public Works has under its jurisdiction measures relating to flood control and rivers and harbors, roads and highways, public buildings, water pollution control, waterpower, and other matters relating to developments with the Nation; and

Whereas the Senate Committee on Public Works has authority to make investigations into any matter within its jurisdiction; and

Whereas the Senate Committee on Public Works members have been vitally interested in the development, protection, and utilization of our Nation's water resources as evidenced by their active participation in the hearing and deliberations of the Senate Select Committee on National Water Resources; and

Whereas there are now being produced and our scientists and technicians, both in industry and Government, are working on and perfecting many new materials and new uses of known materials and it is evident that such materials can be utilized efficiently and economically in the construction of public works, in the protection and operation of such works, in the preservation and proper utilization of our essential water resources and that such materials and their development and use enhance the opportunities for industrial and business growth and strengthening of our Nation's economy; and

Whereas representatives of industry and the Federal Government have shown a keen interest in discussing and disclosing their roles in the fields of research, development, and utilization of materials: Therefore, be it

Resolved, by a unanimous vote of the Senate Committee on Public Works, That the committee shall institute a study and investigation into the use of new materials, new use of materials, and new designs and methods being used or which may be used in flood control and rivers and harbors, roads and highways, public buildings, water pollution control, waterpower, and other development, utilization, preservation, and protection projects, and that a committee report be prepared thereon and submitted to the Senate.

SEC. 2. Such study and investigation shall include but not be limited to metals, plastics, rubber, coal, petroleum, timber, concrete, asphalt, chemicals and their direct use, uses of their derivatives or use in combination with each other or other materials, and shall attempt to determine the following:

- (a) Description of proposed use of application of the subject material;
- (b) General description of the material in terms of physical and chemical characteristics and where possible obtain a description of the physical or chemical phenomenon responsible for obtaining the desired effect;
- (c) Results of laboratory and field tests to prove that the desired effect occurs and prove the durability or duration of the effect of the material;
- (d) The limitations of the materials, i.e., problems of toxicity, limitation of effectiveness under certain climate, soil, or physical conditions;
- (e) Cost of materials per standard units, i.e., square foot, lineal foot, cubic foot, etc., and cost projection in terms of future production capacity, improved manufacturing techniques, etc.; and
- (f) Availability of material both on a current and future basis.

DENNIS CHAVEZ, *Chairman.*

U.S. DEPARTMENT OF COMMERCE,
BUREAU OF PUBLIC ROADS,
Washington, D.C., May 18, 1962.

Hon. DENNIS CHAVEZ,
U.S. SENATE,
Washington, D.C.

DEAR SENATOR CHAVEZ: Your letter of January 30, 1962, and the Senate Committee on Public Works resolution adopted January 22, 1962, regarding the use of materials for roads and other public works programs have been studied with a great deal of interest. I have concluded that the objectives of your Committee on Public Works, as stated in the resolution that was enclosed with your letter, are closely allied to those which we in the Bureau of Public Roads have been striving toward for some time.

A major responsibility in administering the Federal-aid highway program is a constant search for improvement. The improvement of materials for highway construction in itself has many complexities. Traditional materials can be improved; they also can be put to new uses. New materials can be developed. Any material for highway construction can be affected in cost or quality by the way it is used or processed. This brings into the picture, producers, fabricators, equipment, designs, standards and many other considerations. As you and your committee obviously appreciate, materials for highway construction reach a wide segment of our economy.

Because of this wide impact, the study which your committee has resolved to make will provide a major focal point of information on new material developments which have application in public works programs including highway construction. Your report no doubt will encourage investments in needed research and development. It will offer a reliable guide to future markets for new and improved products.

We are enclosing our report on this subject. It is hoped that we are fully responding to the request contained in your letter and in the committee resolution.

Sincerely yours,

REX M. WHITTON,
Federal Highway Administrator.



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THE USE OF MATERIALS FOR THE NATION'S HIGHWAYS

A REPORT TO THE U.S. SENATE COMMITTEE ON PUBLIC WORKS BY
THE U.S. BUREAU OF PUBLIC ROADS, MAY 17, 1962

INTRODUCTION

Request for report on materials

On January 16, 1962, the U.S. Senate Committee on Public Works approved a committee resolution, authorizing hearings, study, and a report on the use of materials in the construction of roads and other public works. Subsequently, by letter dated January 30, 1962, the chairman of the committee, the Honorable Dennis Chavez, requested the Federal Highway Administrator to appear before the Committee on Public Works and make a formal presentation on the use of materials for highways.

The presentation is to cover new materials, new uses of conventional materials, new designs, and new methods of processing or placing in the construction, preservation, and operation of highways. It is to include a description of physical and chemical characteristics, laboratory and field tests, limitations, cost and availability of highway materials. The presentation is to be a constructive contribution to the various producers, fabricators, and users of materials.

Scope of highway use of materials

The highway construction volume to be placed in 1962, exclusive of outlays for right-of-way and engineering, by all levels of government, including Federal-aid, is estimated at \$5.6 billion. In addition, \$2.8 billion will be spent for highway maintenance. Fifty-two percent of the construction dollar will go for materials and supplies and 23 percent for equipment, repair parts, and operating costs to process the materials. Thirteen percent of the maintenance dollar will go for materials and 26 percent for equipment to process the materials and to preserve and operate the completed highways. According to these percentages, approximately \$3.3 billion of materials and about \$2 billion for equipment, repair parts, and operating costs will be used in both the construction and maintenance programs in 1962. Table No. 1, Exhibit K, lists the quantity of materials to be used in the construction and maintenance road programs for 1962 and for the period from 1962 to 1972. Table No. 2, Exhibit L, lists the number of equipment units required for replacement and expansion in the 1962 road program.

The following table A gives a percentage of material used based on highway construction contract costs:

TABLE A.—Percentage of material costs

<i>Item</i>		<i>Item</i>	
Steel.....	25. 0	Lumber.....	2. 0
Aggregates.....	30. 0	Timber piling.....	. 5
Cement.....	10. 0	Petroleum products.....	8. 0
Bitumens.....	10. 0	Explosives.....	1. 0
Concrete pipe.....	4. 0	Others.....	9. 0
Clay pipe.....	. 5		

From the above table, it will be noted that aggregates constitute the largest dollar volume of materials used—30 percent; steel accounts for 25 percent; cement and bitumen, each 10 percent; petroleum products, 8 percent; concrete pipe, 4 percent; and all remaining material items, 13 percent.

Authority to conduct research and development

The Bureau of Public Roads has for many years encouraged the use of proven new materials and new processes and designs that will put conventional materials to new uses in the Federal-aid highway programs. The Congress authorized such activities under title 23, United States Code, section 307, as follows:

Section 307. Research and Planning.

(a) The Secretary is authorized in his discretion to engage in research on all phases of highway construction, modernization, development, design, maintenance, safety, financing, and traffic conditions, including the effect thereon of State laws and is authorized to test, develop, or assist in the testing and developing of any material, invention, patented article, or process. The Secretary may publish the results of such research. The Secretary may carry out the authority granted hereby, either independently or in cooperation with any other branch of the Government, State agency, authority, association, institution, corporation (profit or nonprofit), or any other organization, or person.

These functions have been delegated to the Federal Highway Administrator.

Bureau's activities in the materials field

The Bureau of Public Roads is engaged in many activities in an effort to carry out this responsibility for continuously seeking improvements which will benefit the highway program. Many of these activities have an impact on the use of materials for highways.

For example, the Bureau is cooperating closely with the equipment industry which is currently spending \$100 million annually to develop improved machines. While not all of this work is done on equipment used in highway construction, the highway industry does benefit either directly or indirectly from the expenditure of most of these funds. The improved machines, which have resulted from this effort, are helping to keep down the cost of highways. In addition they are enabling us to construct, maintain, and operate highways more efficiently and are assuring the highest quality in the roads we build. A listing of total bids by States discloses that contractors' bids on Federal-aid work for the calendar year 1961 were \$254 million below the engineers' estimate of \$3,020 million.

But these benefits will not fully accrue to the highway program until the new equipment of proven merit is used for roadwork. Often these benefits are delayed by needless restrictions in specifications. The productive capacity of modern material-processing equipment, such as mixers and pavers, is limited sometimes by mixing time requirements that are in excess of what research has shown to be necessary for best quality. This adds to the cost of processing, reduces the incentive for contractors to buy more productive, more efficient machines, and discourages the manufacturers from further improving their products.

The Bureau is making a considerable effort to eliminate such unnecessary and detrimental restrictions from highway specifications. This is accomplished in a number of ways. Some of these ways are—

- (1) Direct contact with State highway officials.
- (2) American Association of State Highway Officials' committees.
- (3) Highway Research Board committees.
- (4) Joint committees of the American Association of State Highway Officials and the American Road Builders' Association.
- (5) Joint committees of the American Association of State Highway Officials and Associated General Contractors, Inc.
- (6) Other industry associations such as the Asphalt Institute, Portland Cement Association, Construction Industry Manufacturers' Association, National Bituminous Concrete Association, National Crushed Stone Association, and many others.

Through these channels, the Bureau is encouraging the development of further improvements in equipment and their use in the highway program. This effort has a direct impact upon the use of materials for highways because all operations are highly mechanized. The use of improved machines means greater efficiency, economy, and quality in handling, processing, and placing materials in the construction, maintenance, and operation of highways.

Through many of the same channels the Bureau is seeking greater uniformity in highway specifications by encouraging wider use of approved and recommended standards including those for materials as well as their use. This should foster economies by reducing suppliers' overhead costs, it should reduce errors due to misunderstandings, and should promote better quality in the finished product.

The Bureau is constantly evaluating the merits of new materials and new uses or new processes for conventional materials. There are several ways that these evaluations are made.

Sometimes they are made in the laboratory facilities of the Bureau under the Physical Research Division in the Office of Research. In other instances research projects are set up in which the Bureau participates jointly with State highway departments, universities, industry, and others. A third way is to use the experimental project program. Under this program new materials or processes are incorporated or used experimentally on regular Federal-aid highway projects.

Through these and other means the Bureau is making a continuous effort to take advantage of new materials, methods, processes, and equipment for highways. Once the evaluations show that the new development has merit, its use is encouraged, and it is accepted when included in specifications for use on Federal-aid work. The market for these new products thereby encourages industry toward still further improvements.

New methods in exploration for materials

The deposits of natural aggregates are diminishing with increased public works activities. The Bureau of Public Roads, in cooperation with State highway departments and other agencies, has developed techniques for the exploration and general location of aggregate deposits through aerial surveys and photogrammetry. Bureau of Public Roads engineers have promoted the use of these techniques and trained highway department engineers in photogrammetry. By this aerial survey method, characteristic soil deposits and drainage conditions can be studied readily to facilitate the selection of a favorable location for the highway.

The Physical Research Division of the Bureau of Public Roads has also developed an instrument for identifying soils in place by measuring the electrical resistivity of the subsurface layers. Once the general topographical and geological characteristics of an area are determined from an aerial survey, the electrical resistivity instrument may be used for subsurface exploration to locate rock and aggregate deposits suitable for highway construction. Entire States are being surveyed by photogrammetry and related methods to locate aggregate reserves for the road program. A material survey was completed in 1959 for an interstate route in North Dakota. Materials surveys also were completed in conjunction with engineering soil surveys in New Jersey and Rhode Island. Similar surveys are underway in 14 other States and Puerto Rico. As a special research project, color aerial photography was used by the Bureau of Public Roads in a materials survey in Yellowstone National Park in 1961. The objective is to more positively identify the characteristics of ground deposits.

Currently, a system of image processing is under development in which shades of gray are optically scanned from aerial photographic pairs. Each shade has a code number. The digital information, taken from the photographs, is analyzed on a computer for speedier identification of ground characteristics. This development holds promise for expediting the inventory of natural resources.

An equipment manufacturer has developed a new application for a highly portable seismograph for subsurface exploration. It may change the method and lower the cost of exploration. Under former practices when a subsurface ledge was encountered dynamite was used, even near populated areas. Now a seismograph is used to identify the subsurface rock and its condition by measuring the time it takes sound waves to travel through it. If the material is identified as of a softer nature that can be ripped, newer and more powerful tractors equipped with more durable steel pointed rippers are utilized. Formerly, this equipment had to be taken out on the project to determine whether or not subsurface strata could be ripped. With the seismograph technique, the benefits from fast, economical ripping can be used more frequently thus holding down excavation costs.

New methods in highway design for economic utilization of materials

Beginning in 1955, engineers in the Division of Development in cooperation with State highway departments started an intensive evaluation of the electronic computer. They found it had great potential as a means of increasing highway engineering productivity by relieving engineers of repetitive, time-consuming, routine calculations that were being performed manually. This was at a time when additional engineering productivity was urgently needed to get the expanding program underway and keep it on schedule.

Application of electronic computers.—The first problem was to develop programs for the solution of highway engineering problems on this computer. In cooperation with the State highway departments, consulting engineers, universities, and others, the Bureau established a library of computer programs. These were contributed by the participants, including the Bureau. This joint effort saved duplication and greatly expedited the integration of the benefits of the computer into the highway program.

Forty-eight State highway departments and the Bureau of Public Roads now have electronic computers and the remaining highway departments rent computer time commercially. The library established by the Bureau has grown, too. There are now about 500 programs in the electronic computer library relating to many highway functions.

Numerous electronic computer programs are being utilized in the determination of the most economical movement and utilization of materials in embankment construction. On bridge designs, computations can now be made over 100 times as fast as by former methods. It permits the consideration of more alternate designs for structures; it makes feasible a more thorough study of the type of materials to be used in the bridge; and it makes possible a more thorough check of the stresses the materials will carry.

The masses of data involved in forecasting and assigning future traffic to systems of existing and proposed roads and streets can be done far more precisely than ever before. The resulting highway geometrics, including materials comprising base and surfaces of pavements and engineers' estimates for bidding, can be obtained readily. The modern electronic computer technique is being applied to the selection of designs and materials in many areas of highway operations. For example, a computer program is being developed for hydraulic analyses in the design of circular culverts, pipe arch culverts, and box culverts. The program will provide for the quick computation of the size, headwater, and velocity of each type of culvert for given design conditions. This permits the more precise selection of the most economical design and materials from the computed data for the condition involved.

The electronic computer and other new engineering tools have had a tremendous impact upon the highway program. They have been a major factor in increasing engineering productivity. As a result, highway departments have been able to accelerate the construction rate to keep the program on schedule. They are saving millions of dollars annually because with them the highway program is being carried out more efficiently, more economically, and with improved quality.

The high degree of automation in highway engineering today made possible by these new tools has had other far-reaching effects. Because automation enables us to bring more work to the construction stage each year, the markets for labor, equipment, services, and materials have been stimulated, thereby adding to the strength of our economy.

For example, a 1959 study by the Bureau of Public Roads, illustrated by map as Exhibit M, shows an approximation of the widespread economic impact resulting from labor requirements generated in terms of material and equipment production for highway construction. Projects in other locations would generate different labor hour distribution patterns depending on transportation distances and other factors.

High speed data transmission.—Furthermore, with the increasing use of computers and allied equipment for automatic data storage and processing, there has been generated a growing requirement for high speed data transmission between field offices and computer centers. This requirement has increased the demand for existing wire line

communication services such as telephone, telegraph, teletype, and facsimile. It has also encouraged the development of new and improved facilities for high speed data transmission. Some of these new facilities are now available. Some use radio, including microwave, frequencies instead of wire lines. The speed of transmission by teletype, by facsimile, and by other new facilities has been greatly increased. Here again the highway program is adding to the market for new products and for increased use of new and conventional materials.

New test methods for quality control of materials

In order to assure the proper selection and processing of materials in-place, the Bureau of Public Roads and the State highway departments have been encouraging the application of modern technical advancement in faster testing methods. Radioactive materials are being used in devices to test the moisture and density of embankments in determining the degree of each compaction contractors have secured for pavement foundations. In the past it took from 1 to 3 hours to secure field samples, transport them to a laboratory, perform the tests, and inform the contractor that he has or has not accomplished the requirements of the specifications.

Nuclear moisture-density gages.—Now, a small portable device, using back-scattering nuclear radiation principles, can take both moisture and density readings on the jobsite within a fraction of the time required by conventional methods. This saves the contractor excessive rolling time by immediately advising him when the required compaction has been reached. The State and Federal Governments also benefit through the ability to take more readings and secure better quality control. The Bureau of Public Roads, together with Colorado, North Carolina, Ohio, and Wyoming, has made notable advancements in this area.

Many other applications which use nuclear energy are being investigated for possible highway usage. It can be used to determine the soundness of wood in timber structures. Industry has already developed and successfully applied nuclear testing devices for quality control in measuring the thickness of various materials and coatings. Its feasibility is being studied for the measurement of pavement thickness. Radioisotopes are being used to test the soundness of metals. Nuclear energy applications already in use by industry are being studied to determine if they can be adapted to give us a better check on when certain highway materials are properly mixed. The feasibility of sonic and ultrasonic instrumentation for measuring pavement thickness is also being explored.

New scientific developments are taking place very rapidly these days. The Bureau and the State highway departments are evaluating many of these which appear to have application in the highway program. Already some are in use as methods of nondestructive testing for quality control. Fast infrared spectrophotometry tests can now be made in minutes, of the composition of paints, weed eradicators, concrete admixtures, and other materials. Such tests formerly required at least a day. Infrared energy and X-rays are also being used with considerable success for checking the quality of welds on highway bridges.

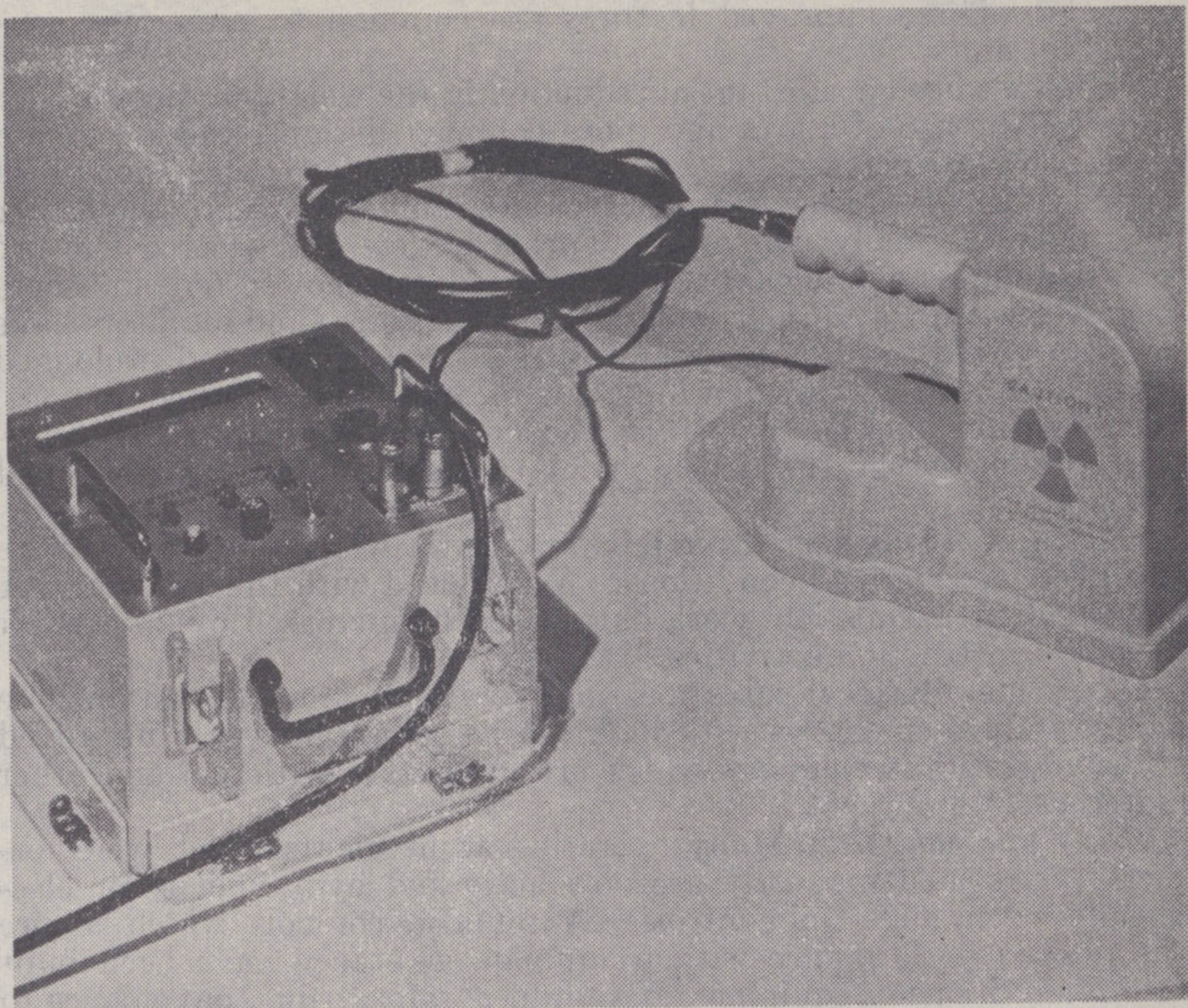


FIGURE 1.—A modern nuclear moisture-density gage developed jointly by the Ohio State University and the Ohio Department of Highways.

Infrared spectroscopy.—Our Physical Research Division on its own or in cooperation with State highway departments has successfully conducted research in spectroscopy in the analysis and fingerprinting of complex road materials such as paints, asphalts and their components, and mineral and organic admixtures for concrete. In addition, it has a record of further accomplishments. It has produced the thin film overweathering test now being used as a quality control for paving asphalt. It has established a spectral identification or “fingerprint” file on chemical composition of service-proved concrete additives to reduce testing time for highway laboratories.

These are a few of the efforts that are being made to secure improved materials and the best use of all materials in the highway program. We feel that progress has been made toward these objectives.

Improvements in basic equipment components

Road equipment, methods, and materials used by the contractors and engineers on the jobsite have many hours and dollars of research and development support off the jobsite. These are being put to good use.

An important factor in efficient highway production is the minimizing of equipment “downtime” and in effectively utilizing manpower in material processing by reducing operator fatigue. Many of the new equipment models feature such improvement to basic com-

ponents. These improved features are common to numerous construction units.

There has been a substantial reduction in the weight of diesel power units by the use of alloys and more compact designs; there is also a corresponding increase in the available horsepower per pound of engine. This trend has resulted in a desirable lowering of the center of gravity for many machines. Turbochargers and aftercoolers are provided in many applications for increased horsepower and efficiency. Engine accessories and particularly the air cleaners and oil filters have been improved to provide greater operating efficiency and prolonged engine life. All of these developments mean more durable equipment, less downtime, and lower operating costs for the contractor. In addition, they encourage the development and use of new and improved materials.

The torque converter drive has provided a wider range of tractive effort for varying load conditions. When used with the automatic or power-shift transmission, work output can be increased by 25 percent in some construction activities.

Other metallurgical advances in overall machine design include lighter frames or chassis with high tensile steel and vastly improved abrasive-resistant members which are in contact with soil and other materials.

Automatic controls.—Many operating adjustments which were formerly performed manually are now activated hydraulically or electrically with fingertip controls. Automatic controls which assure the desired performance without human assistance have been built into many items of equipment. Comfort, safety, and convenience to the operator have not been overlooked in new equipment designs. Operator fatigue from shifting gears and clutching has been largely eliminated. All of these foster better results in material processing operations.

The tire manufacturing industry has also helped to decrease equipment downtime by providing major tire improvements for wheel-type construction machinery.

Improvements in petroleum products.—The petroleum industry has also made major contributions to machine operating efficiency by improvements in fuel, oil, and lubricants. The need for dozens of different grades and kinds of lubricants for various moving parts has been eliminated; maintenance problems for the contractor have been reduced; and the economic life of the machines has been greatly increased. These and other achievements of component manufacturers all help out the equipment industry to provide efficient and well-balanced machinery for the highway contractor.

Advanced lubrication systems.—Improvements in lubricating systems are not confined to the modern motor vehicle. For example, the system for lubricating crawler parts has been developed to such an extent that "once in a lifetime" lubrication now takes place of that which was formerly required on a daily basis.

With this background on improved equipment components it is clear that, more often than not, they involve the development and use of new and improved materials.

SUPPLEMENTAL DATA RELATIVE TO THE USE OF SPECIFIC MATERIALS FOR HIGHWAYS

We have looked at general trends and progress pertinent to the current use of materials in the road program. More detailed information regarding the use of specific materials and the processes involved in their handling, treatment, and placement in highway construction, maintenance, or operation may be helpful. The following sections of this report contain this type of information.

NATURAL SOILS AND ROCK AS HIGHWAY MATERIALS

Earthworks—Scope, costs

The greatest volume and by far the least expensive material which goes into the formation of a highway are the natural soil and rock placed in embankments. It is estimated that approximately 2.4 billion cubic yards of common excavation will be placed on all highway systems during 1962.

For 1922, the average bid price, in terms of 1957-59 dollars, for common excavation on Federal-aid highway construction was \$0.40 per cubic yard. Thirty-nine years later in 1961, the bid price was about the same or \$0.41 per cubic yard. During this entire period, the 1922 unit price was exceeded only eight times. It was equal or less than the 1922 bid price for 31 years. Since other highway cost elements have risen as much as threefold during this 39-year period, this stabilization of earthwork prices can largely be attributed to the continuous improvement in earthmoving equipment and the parallel improvement in earthmoving techniques on the part of the highway contractor. Another contributing factor is the free hand the contractor has in selecting the equipment he uses—it lends encouragement to the development of mass production methods.

If the cost of moving, placing, and processing earth had risen as other highway costs have, we would not be able to undertake the highway program as it is today. The fact that we can and are building roads with wider rights-of-way, flatter grades, easier curves, longer sight distances, and other features which add to the comfort, safety, and convenience of motorists is a tribute to the improvements that have been made in earthmoving equipment and techniques.

Earthmoving equipment

Recent improvements in earthmoving equipment such as crawler and wheeled-type tractors feature both increased capacity and operating speeds. Large rear-mounted tractor rippers are available which further expedite highway grading operations. Disintegrated rock, shales, and other materials which formerly required blasting can now be ripped for easier and more economical handling and processing. The off-highway hauling units, including large rear dump trucks and modern hauling scrapers with pneumatic-tired tractors exemplify a combination of both speed and capacity.

If solid rock excavation is involved, a number of new portable air compressor models, with greater capacity, are available. Improved pneumatic drills have also been developed including wheel and crawler mounted rigs which are capable of drilling 4- and 6-inch blast holes to accommodate some of the new type explosives.



FIGURE 2.—A new hauling scraper model with self-loading device.

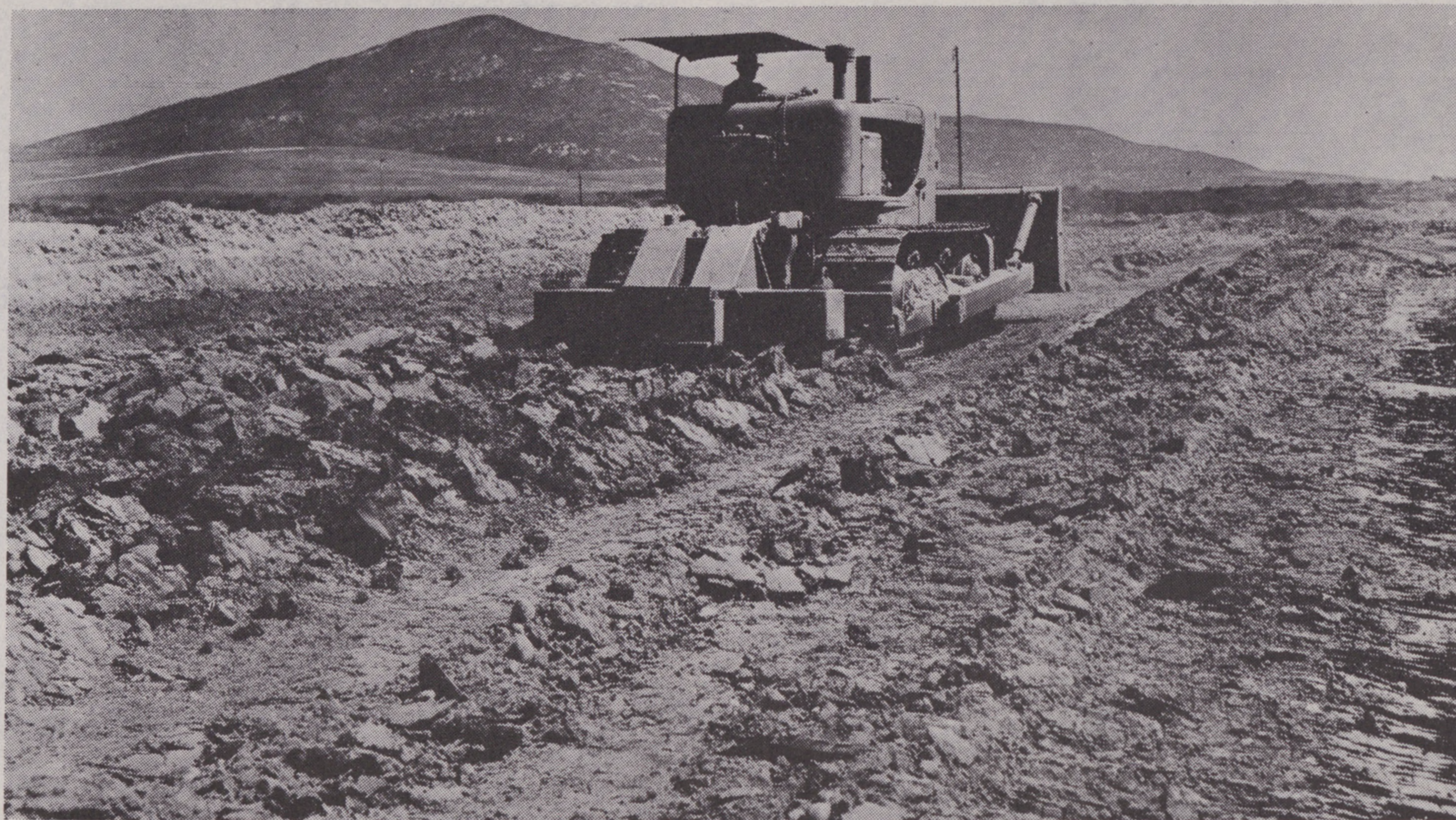


FIGURE 3.—Ripping tight materials with a crawler tractor with rear-mounted ripper.

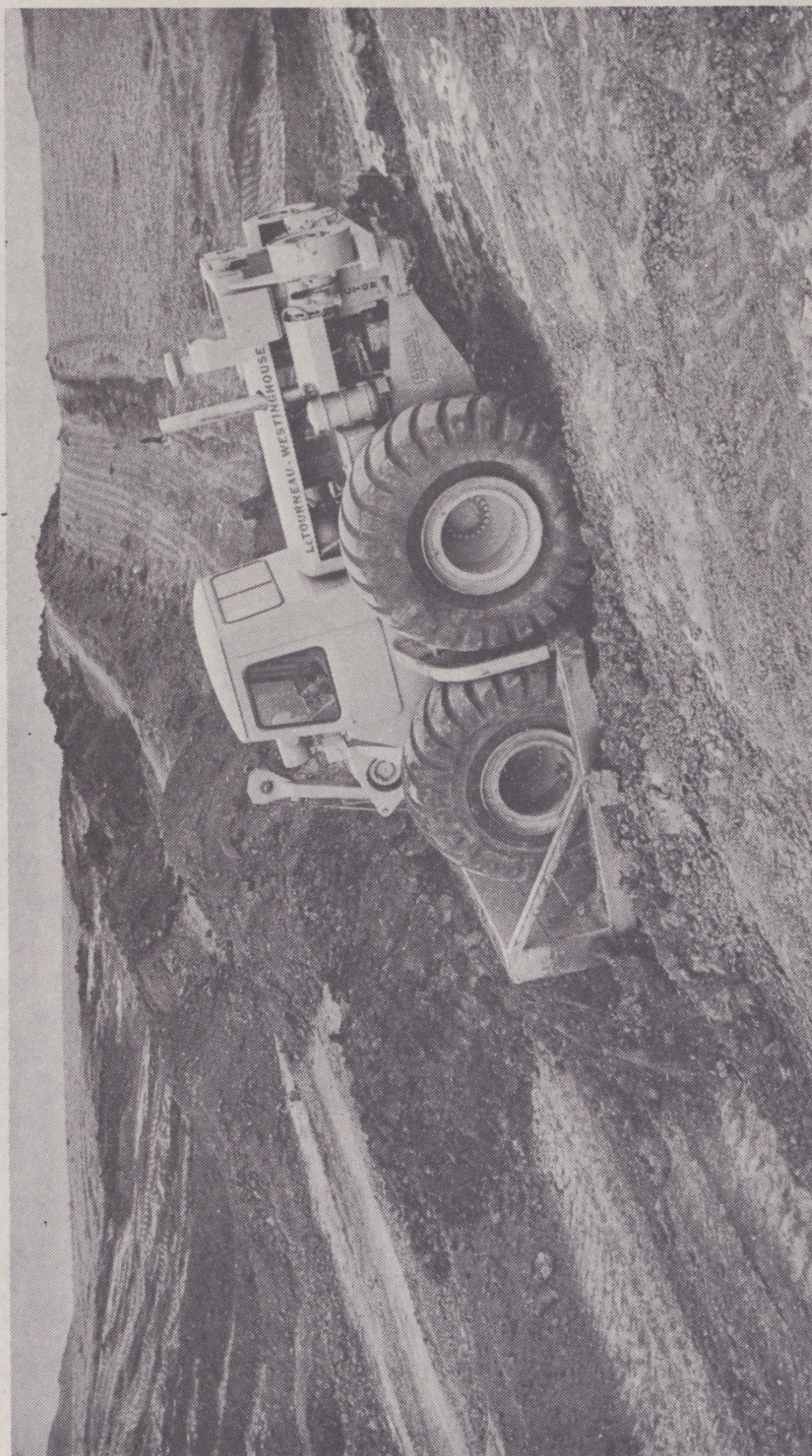
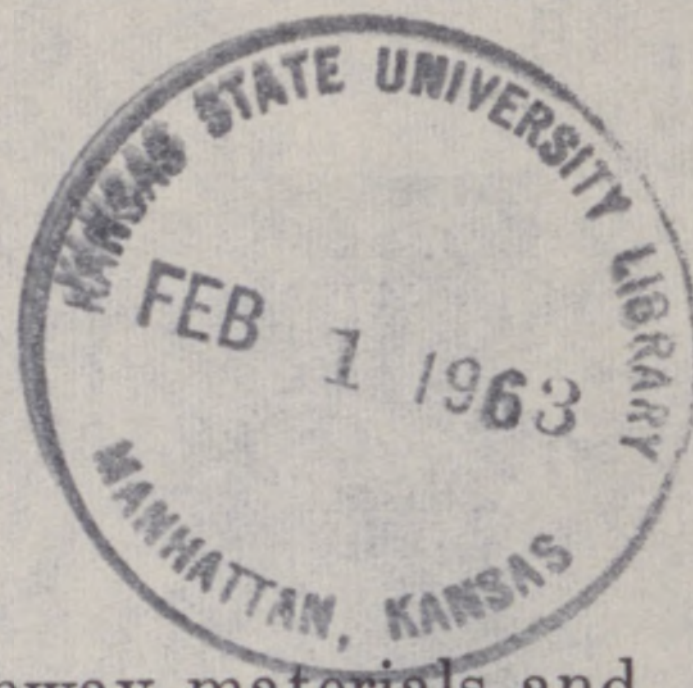


FIGURE 4.—Side dozing with a wheel-type tractor.

Embankment compaction equipment

After these natural soils and rock are hauled to the project, they must be placed to form a firm foundation for the new highway. This is usually accomplished by compacting the material by rolling it with one or more types of equipment. Some of these are conventional equipment that have been in use for some time.

In addition to the conventional steel wheel rollers and the towed sheepsfoot, tamping, and pneumatic types, there are many new compaction units operating on the embankment layers and subgrade.



AGGREGATES

Location and use

Aggregates are one of the more important highway materials and generate over 15 percent of the onsite cost of highway construction. The current annual requirements for highway construction are about 580 million tons. This represents an increase of about 50 percent since 1955. In addition, highway maintenance takes about 170 million tons annually. The Bureau of Public Roads records show that for construction purposes highway contractors produce 54 percent of their aggregates and purchase the remainder.

Aggregates are produced principally from two basic sources:

- (1) From parent rock by quarrying operations, and
- (2) From open-pit mining of natural deposits laid by glacial or sedimentary action.

Some aggregates are also produced from blast furnace slag. One of the most pressing problems associated with highway aggregates is the depletion in glaciated areas where there is no continuing natural replenishment as in the case of river-borne deposits.

Surveys of supplies.—Surveys conducted by the Construction and Maintenance Division of the Bureau of Public Roads in collaboration with the Physical Research Division during the first stages of the expanded highway construction program revealed that aggregate supplies were not considered adequate in Colorado, Mississippi, Oklahoma, and in parts of Kansas, Nebraska, and Virginia. Some of the States which expect shortages resulting from the depletion of glacial deposits include New Hampshire, New York, Oregon, and Pennsylvania. In such areas, processing of other sources and longer hauls will be necessary.

Comprehensive surveys of aggregate sources are available in many States usually on a county basis. States which have critical areas of aggregate shortages, and where surveys have not been made, have been urged to do so as part of their highway planning program. Aerial photographs were used extensively in both Maine and North Dakota to locate possible sources. In North Dakota, preliminary explorations were conducted with electrical resistivity equipment at the sites located by photogrammetric methods.

Upgrading aggregates.—While the construction of highway surfaces and structures demands the continued use of high-quality aggregates, there are many opportunities by which the low-quality materials, including types that formerly would have been rejected, can be used in the base and subgrade area with highly satisfactory results. This may be done either by using admixtures to alter the behavior of natural materials or by removing deleterious particles by a process of beneficiation. For example, lime, limestone dust or chips, or sand may be used to reduce the plastic characteristics of clay-gravels. Gravels containing objectionable lightweight particles are commonly brought within specification requirements by the heavy media process. This process uses flotation to separate light and heavy stone. It will not remove high specific gravity material such as undesirable

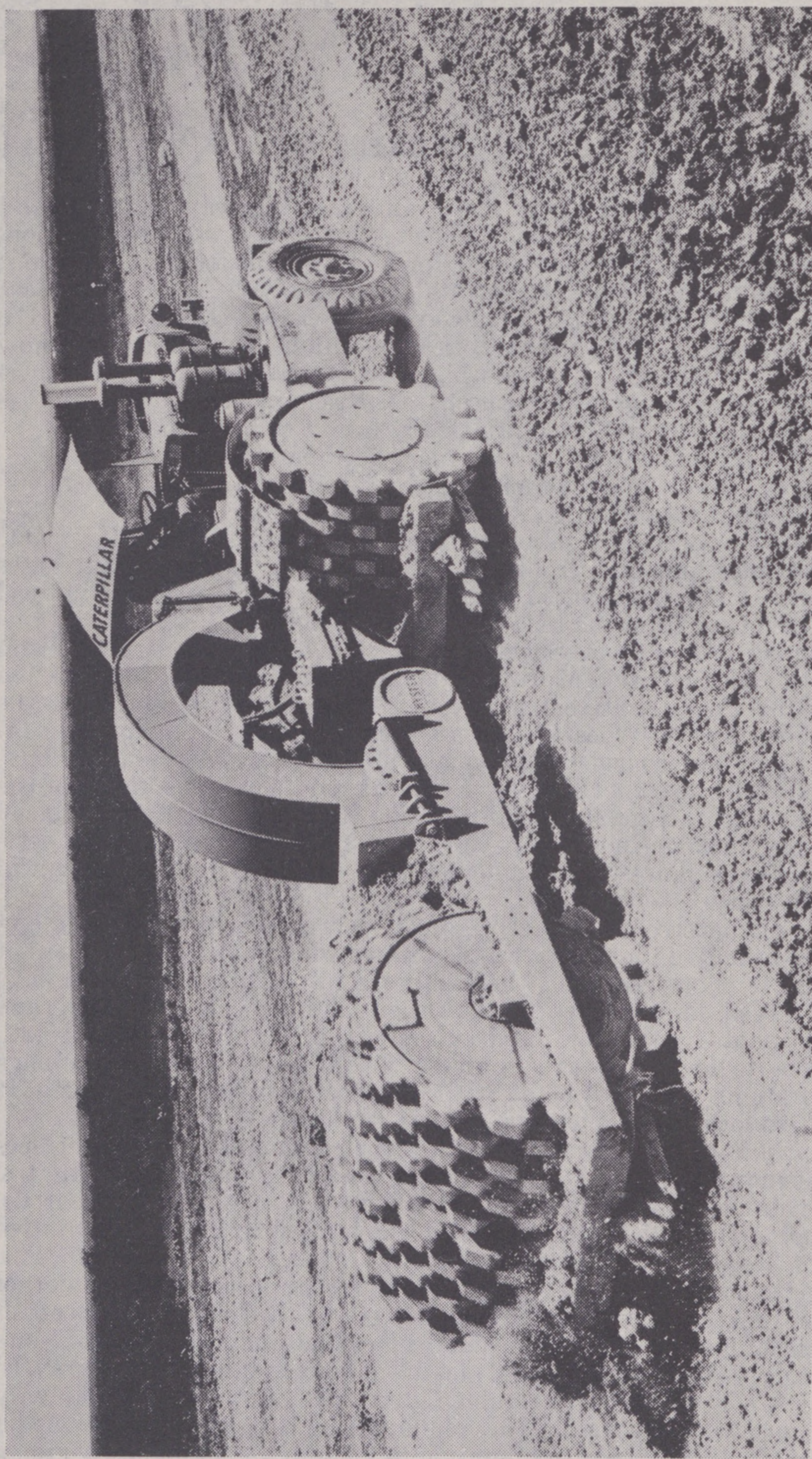


FIGURE 5.—A self-propelled tamping roller provides high speed compaction in many types of soil.

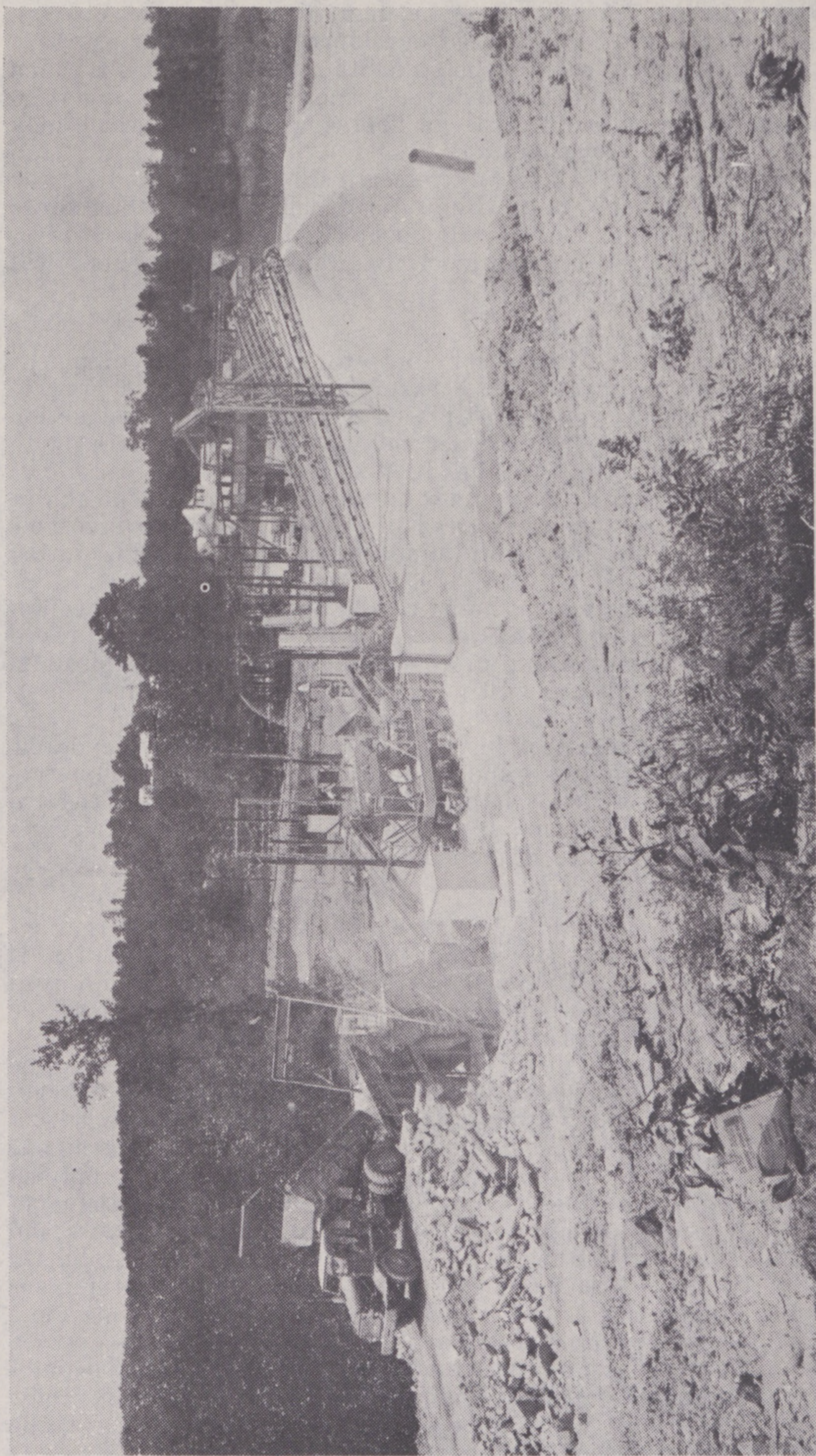


FIGURE 6.—Producing six sizes of crushed stone with a modern portable crushing plant of 400-tons-per-hour capacity.

iron-bearing stone. A new process of upgrading gravel deposits containing nondurable stone has been developed recently and has been employed with some success in the Lake States. The process is called elastic fractionation and employs the principle that soft and hard stone have widely different elastic or bouncing properties which may be used in effecting the separation.

Under a new national highway research program adopted by the American Association of State Highway Officials jointly with 50 State highway departments, the "Development of Methods for Improving the Aggregates Used in Constructing Highway Pavements" will receive high priority attention.

Aggregate producing equipment

Considerable progress has been made in the methods and equipment used to produce aggregates. For example, in 1960 the bid price of macadam or crushed stone base placed on Federal-aid construction averaged \$0.11 per square yard per inch of depth as compared with \$0.135 in 1950, although there has been a substantial increase in the highway construction bid price index during that period. The ability to produce crushed stone at reduced prices has also had a favorable effect on the cost per ton of bituminous concrete pavements during this period.

This favorable situation has been brought about by improved equipment for nearly every phase of aggregate supplying. Improved pneumatic drilling equipment, improved and less expensive explosives, such as ammonium nitrate, vastly improved crushing, handling, hauling, and spreading equipment have all helped to introduce greater economy into this phase of highway construction. The favorable trend is expected to continue; and in the not too distant future, quarrying operation may be further improved by the introduction of electromagnetic radiation, ultrasonic methods, or perhaps nuclear explosives in isolated areas to reduce solid rock into processing sizes.

Base construction equipment

Natural granular materials are also widely used in base construction, both with and without stabilizing agents. Where stabilization is involved with cement, bitumens, or other materials, vastly improved equipment has been developed to process the material both at the roadside and at central plants.

Base spreaders have been developed so that the aggregates can be spread with considerable accuracy and without segregation. Spreading equipment for applying both dry and liquid stabilizing agents is also highly developed. Single pass stabilizing mixers are available which can process the in-place material in a single pass while applying the stabilizing agent. One new model even provides the initial compaction. In order to improve control over material quantities and mixing, there is a trend toward the use of central plants for stabilized bases, particularly those employing calcium chloride and bituminous materials. Some of the new models are capable of processing more than 500 tons of materials per hour.

Since all surface lay-down machines operate either directly or indirectly on a prepared base of subgrade, it is essential that their profile be controlled to nearly the same degree of accuracy that is to be achieved in the surface course or courses.

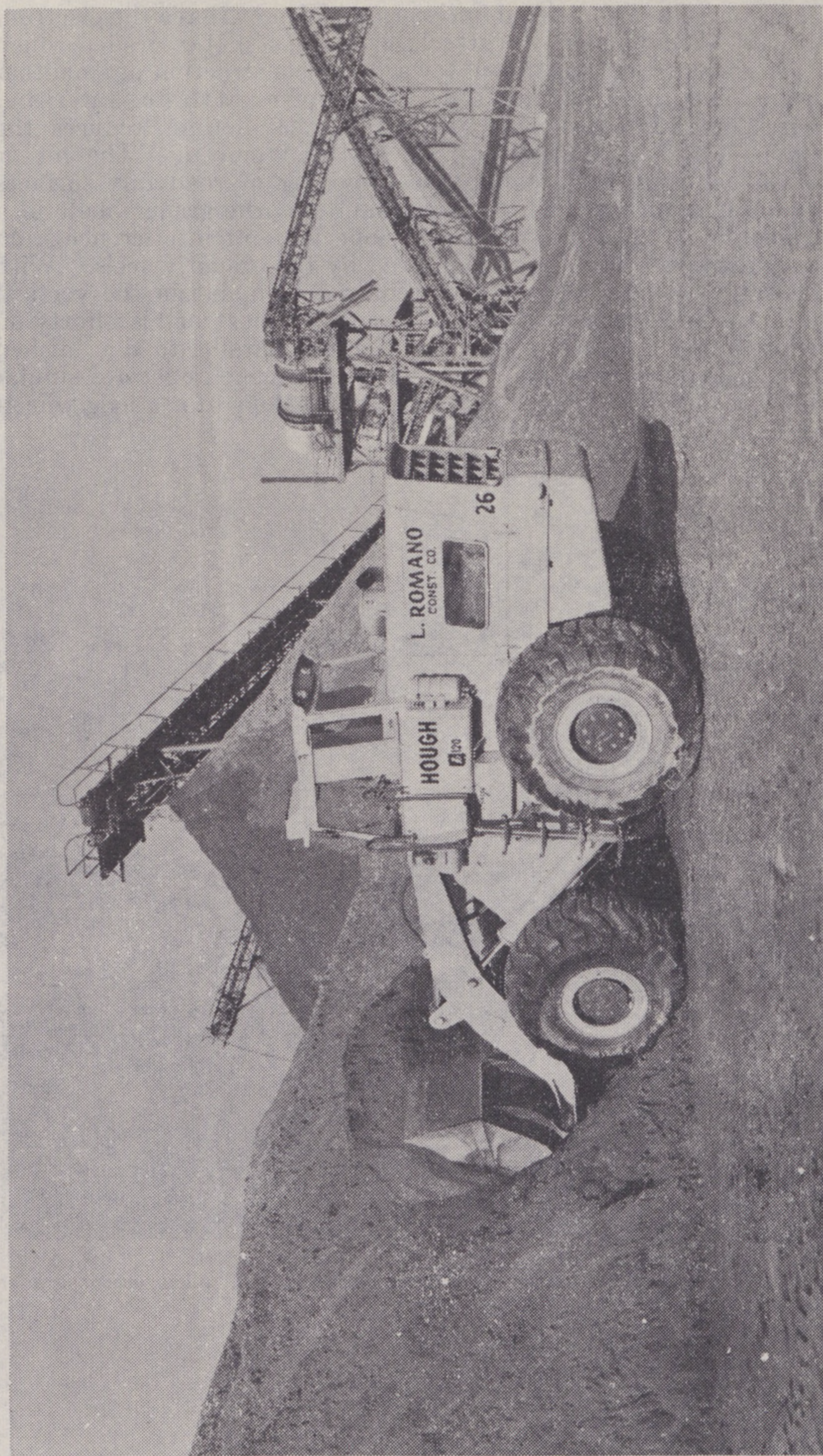


FIGURE 7.—The modern front-end loader is one of the principal machines used in handling aggregates and other stockpiled materials.

Electronic controlled grading equipment.—We now have the electronically controlled fine grader attachments to a motor grader which provides considerable assistance toward the construction of smoother subgrades and soil-aggregate type base courses at faster rates and with less operating personnel. It, at the same time, reduces the amount of grading stakeout by at least 50 percent. The motor grader attachment also enables the crowning of road mix surfaces with greater accuracy. This device maintains the grader blade in a level position or to a desired crown slope without interference from the irregularities which are encountered by the grader wheels. With the operator's attention no longer required to maintain the vertical angle of the blade, he is able to concentrate most of his efforts on following stakes or a string or wire reference parallel to the finished grade. An automatic grade following system which operates similar to the motor grader device, has also been developed for a long wheel-base planer.

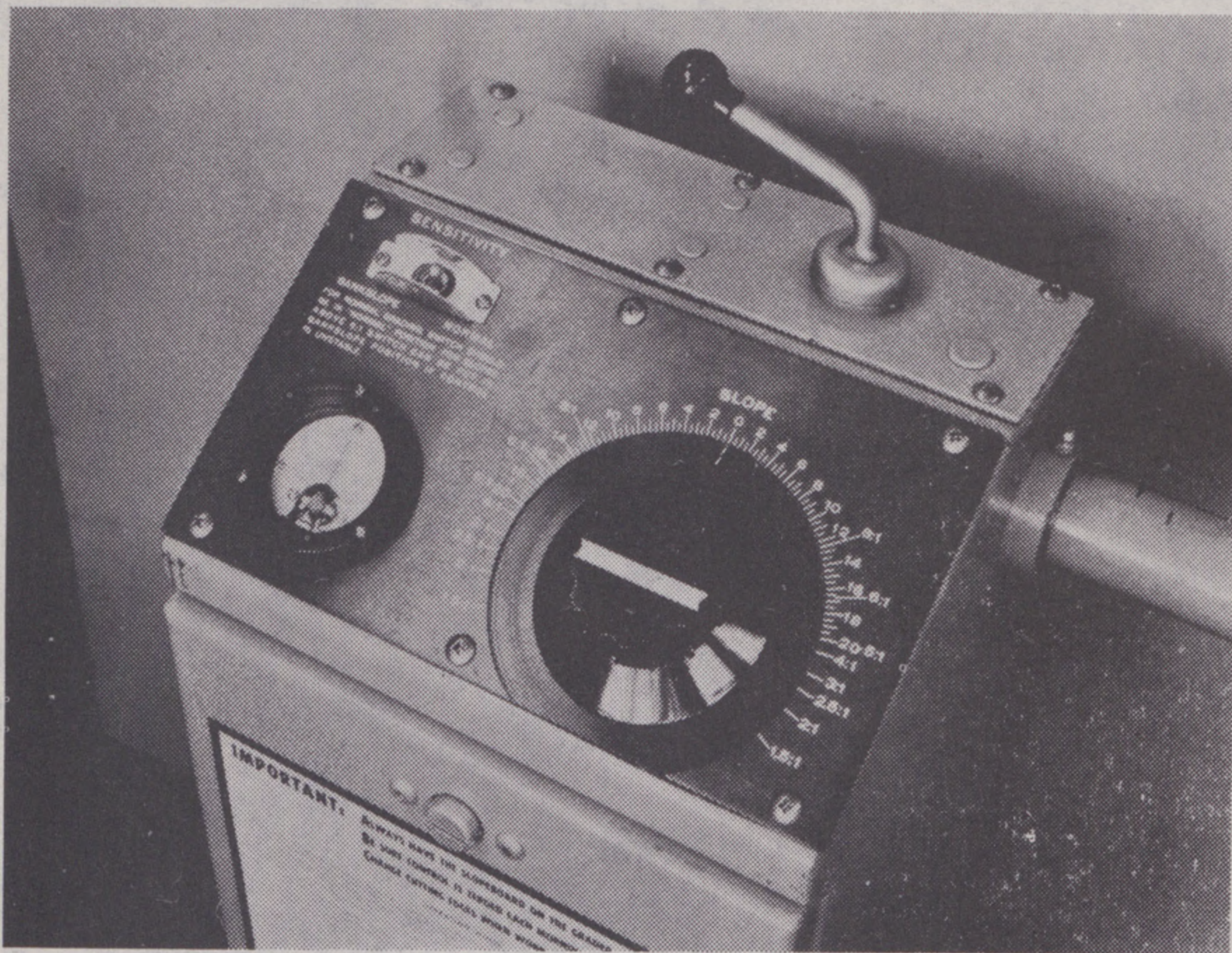


FIGURE 8.—Slope control panel for an electronically controlled motor grader blade.

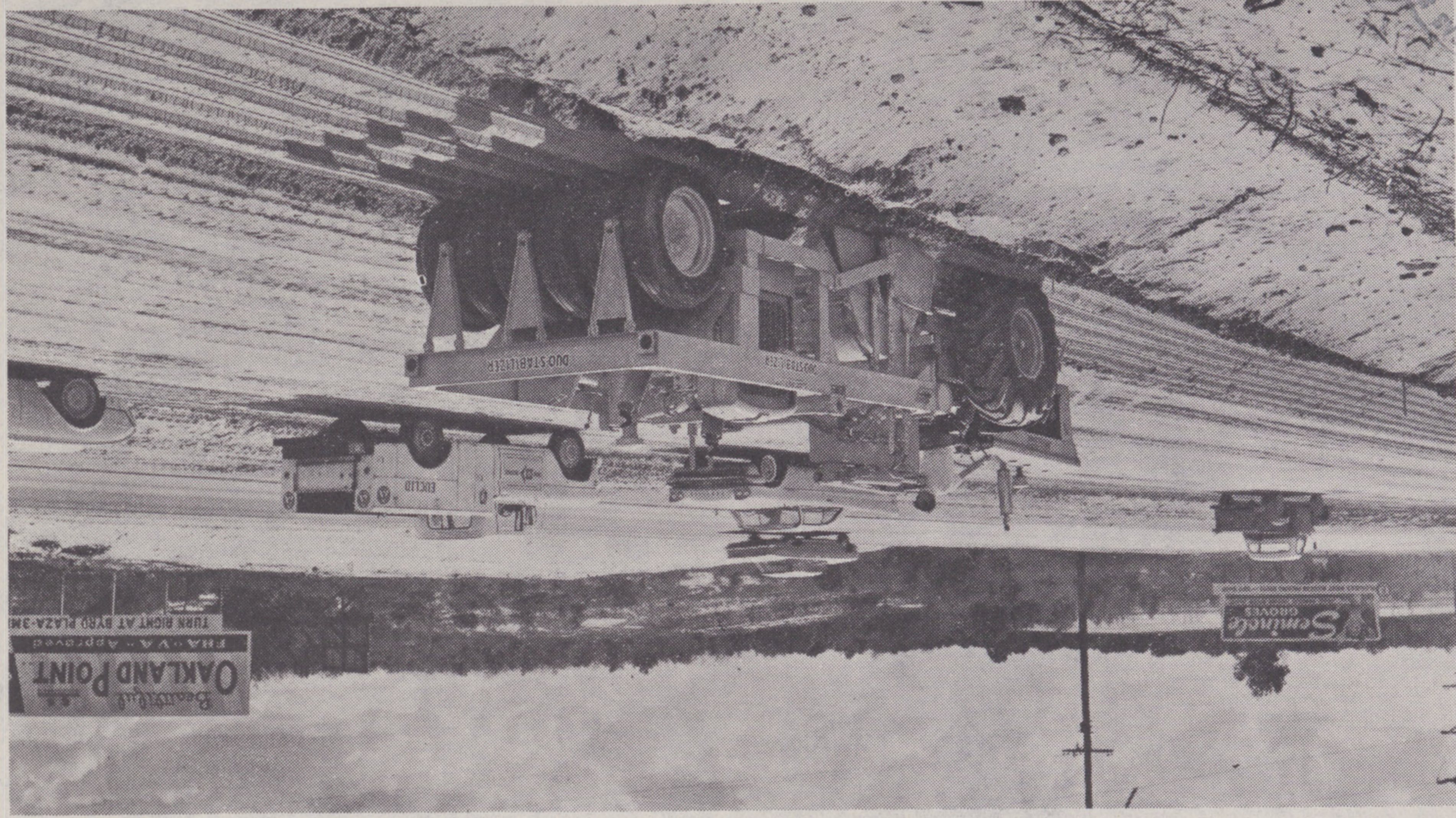


FIGURE 9.—Stabilizing base materials with a single-pass stabilizing machine.

Compaction with pneumatic tired and vibratory equipment.—Base compaction is an all-important construction function, and many surface course failures take the blame for weaknesses which actually originate in the base. Where efficient and effective compaction is being performed, the type of equipment used will vary with the character of the materials. If the base contains fine-grained materials or is stabilized with binding agents, the self-propelled pneumatic roller with tire contact pressures of 80 pounds per square inch and higher will generally obtain the desired density in the fewer number of passes. If the base materials are granular in nature or of the macadam type, dynamic compactors will be most effective in reducing air voids which cause settlement under the vibrating effects of heavy traffic.

Aggregate gradation standards

One of the problems involving the use of coarse aggregates, particularly those used in highway structures and high-type pavements, is the wide variation of sizes and gradations of stone called for in the construction specification of the several States.

In June 1948, after years of effort, the Department of Commerce obtained agreement on and issued "Simplified Practice Recommendation R 163-48" covering sizes and grading of coarse aggregates, including crushed stone, gravel, and slag. These were adopted by the American Association of State Highway Officials.

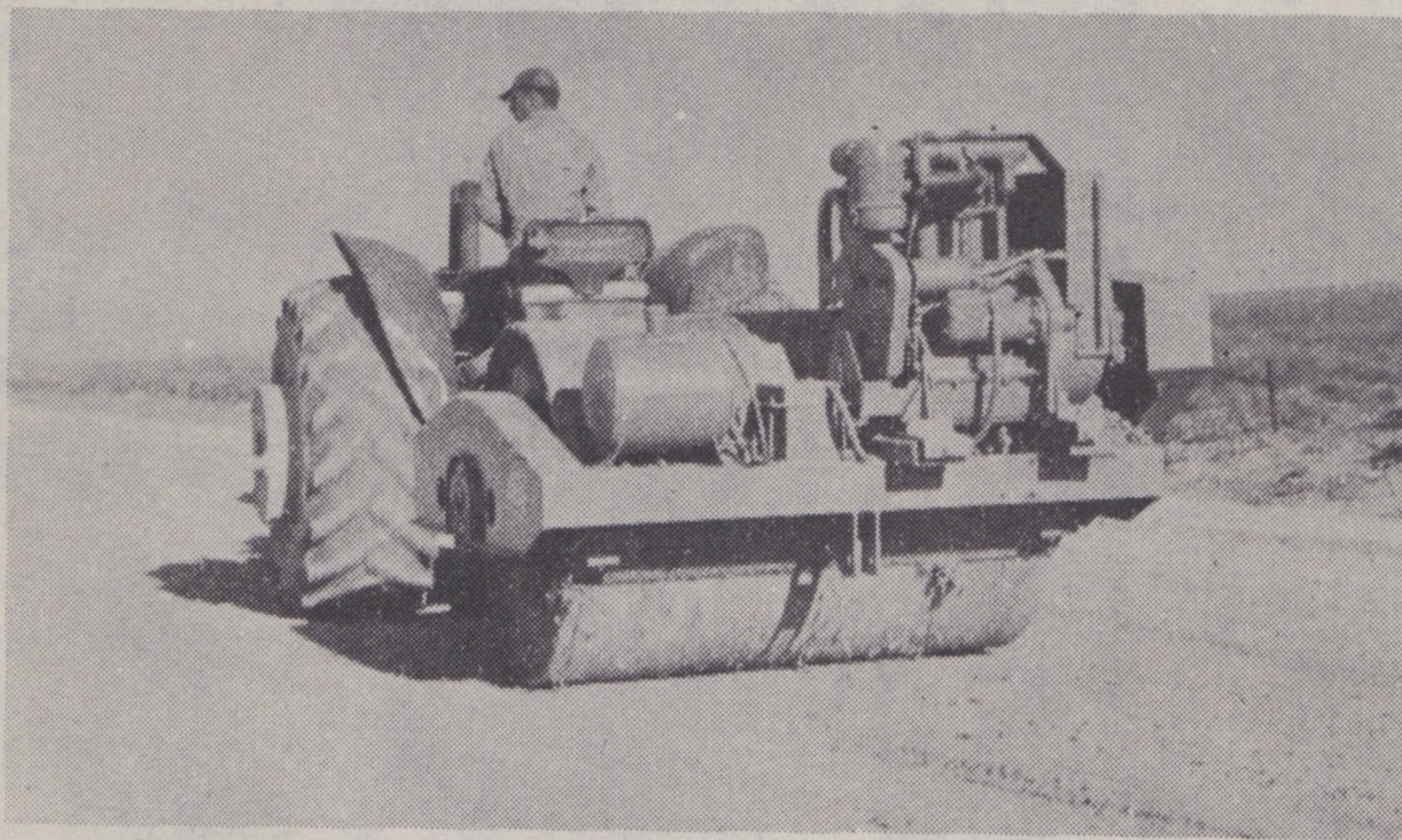


FIGURE 10.—Compacting base materials with a vibratory roller.

A review of the coarse aggregate sizes specified by the 50 State highway departments, the District of Columbia, and Puerto Rico for portland cement concrete for pavements and structures reveals wide variations from established standards. They are now using some 215 dissimilar coarse aggregate sizes for that item alone. Only seven aggregate sizes are recommended for use in concrete pavements and structures in the approved standard. Wide variation also prevails for the sizes of coarse aggregates specified for bituminous surfaces.

One manufacturer of asphalt plants maintains an inventory of 21 different screen opening sizes for the hot bins in increments as low as one thirty-second and one-sixteenth of an inch in order to meet the various aggregate size requirements of the State, city, and county highway departments and other customers. Normally, not over four aggregate sizes are used in an individual mix design. Lack of practical standardization of aggregate sizes in some areas tends to discourage the movement of crushed stone or other coarse aggregates from one State to another, even though it may be within more economical hauling range than the nearest in-State source.

A comprehensive study on the aggregate gradation problem will be the subject of a forthcoming report by the Bureau of Public Roads. This report stresses the need for simplification, standardization, and uniform application. A new graphical evaluation chart is provided to facilitate the selection of aggregate size for bituminous mixes.

Lightweight aggregates

Lightweight aggregates produced from expanded shale and minerals are being used to an increasing extent in highway bridge decks to lessen the amount of dead load. Twelve States have provisions for the use of lightweight aggregates. Expanded shale concrete has generally a good service record on over 100 major bridges in various sections of the country. Precast deck sections have also been installed and are giving good service on over 800 smaller bridges. There have, however, been serious failures in isolated instances.

Analysis of one failure indicated excessive shrinkage due to inadequate wetting of the aggregate prior to mixing and the presence of underburned aggregates. In order to minimize such failures in the future, the Physical Research Division of the Bureau of Public Roads has recently prepared a "proposed specification for lightweight aggregates for structural concrete" which provides for more rigid controls over quality than existing specifications. This proposed specification has been forwarded to all Bureau field offices.

Plastic foams.—Research is also being conducted by other industries on plastic foam expanded by air or other gases to develop a light low-thermal conductive material.

Plastic foams have already been used experimentally on one highway bridge in New York State and another in Illinois. A 1-inch thick coating was sprayed on the underside of these bridge decks to insulate them for the purpose of reducing the premature formation of ice on the bridge surface. Performance data are not available on the installations because of the short period these materials have been in place.

STEEL

Steel uses

Steel is used extensively in modern structures. The Bridge Division of the Bureau of Public Roads reported that 1,933 new steel-type bridges were constructed during the calendar year 1960 for Federal-aid primary, secondary, urban, and interstate road systems. Of this number, more than 1,000 were constructed on the Interstate System. The total cost of construction for these steel bridges amounted to more than \$493 million.

The major forms in which steel is used include structural steel shapes, structural plates, reinforcing bars, and welded wire fabric to improve the physical strength of concrete. Steel is also used in corrugated metal pipe for culverts and drainage structures. It is an important material in fencing, guardrail, lighting standards, bridge railing, and other subsidiary items of highway construction.

New steel alloys

New construction steel, together with new, lighter, more efficient beam sections now available, has influenced advanced concepts in bridge design. The new steels, together with the advanced design concepts, have resulted in improvements or benefits not only for designers of bridges, but for fabricators, contractors, and State highway departments as well.

The new steels include American Society for Testing Materials' designations A-36, A-440, A-441, and heat-treated alloy steels such as T-1, type A, which is a trade name steel. The A-36 steel is being used quite extensively in bridge construction. It was developed in answer to the demand for a more weldable structural carbon steel. This steel is intended for riveted, bolted, and welded fabrication. It has been accepted for use in highway bridges at basic allowable stresses 2,000 pounds per square inch higher than those permitted for A-7 steel, the former type of steel most commonly used in bridge construction.

The A-440 and A-441 steels are high strength and high-strength low alloy steels developed to improve the design application of these types of steels.

New heat-treated alloy steels have been developed and used for bridges when high strength is required in thinner sections. In addition to high mechanical strength properties, the new heat-treated alloy steels have atmospheric corrosion resistance two times that of type A-7 carbon steel. The corrosion resistance of these new steel alloys will add life to the structural members where these steels are used and also lower the maintenance costs for the highway departments.

Bridge construction is also making use of most of the 11 new wide flange beam sections that are now available from the various steel rolling mills. Some economies are being achieved through the use of these new beam sections.

Combining steel types in bridge design

Bridge engineers are continually looking for better means of creating the most efficient structures at the least cost. Some new design concepts in structural steel have been developed recently and used by engineers to make full use of steel as a design material. One new concept and type of bridge construction is combination steel construction. This type of construction employs different grades of steels for the individual members of a structure to obtain greater strength without increased weight, reduction in weight and dimensions without loss of strength, greater durability, and reduced erection costs.

Examples of this design concept are incorporated in the Carquinez Straits Bridge in California and in the bridge spanning the Ohio River between Louisville, Ky., and New Albany, Ind. Each of these truss-type bridges was shop welded and erected in the field with high-strength bolts.

This concept of combination steel construction for a structure has been extended in bridge design. Within an individual member of a structure, different grades of steel have been used to obtain weight and cost savings. The Whiskey Creek Bridge in California is an example of the application of this new concept. In this deck plate girder bridge, portions of the plate girders subjected to the highest bending moments are made of 100,000 pounds per square inch minimum yield steel alloy. Portions of girders subjected to moderate bending moments are fabricated of A-441 steel, and those portions with low bending moments are of A-373 structural carbon steel.

Hybrid designs.—The combination steel construction idea in bridges is being extended still further where different grades of steel having different strengths are being used within the same normal section of a beam. The use of steel in this new manner is referred to as "hybrid" beams. One example might be the use of beams having heat-treated alloy steel in the flanges and structural carbon steel, such as A-373 steel, in the web. The different steels are shop welded to form the hybrid beam. A pilot or test bridge using hybrid structural steel beams is being built in Iowa to explore the practicality of this new concept.

Composite designs.—Modern bridge design also makes use of composite construction with dissimilar materials. By employing dissimilar materials, such as steel and concrete, to make up structural members, it is possible to reduce deadweight and at the same time increase strength and stiffness. In this arrangement, a structural steel section and concrete are combined to form a single member.

High strength reinforcing steel.—High strength reinforcing steel bars or wires are being used in prestressed concrete in nearly all States. Wherever and whenever prestressed concrete is used for bridge construction, the latest material developments and design methods have been used in the building of these bridges. Also, the best and newest types of reinforcing steels have been used to make the most efficient structural member. Another example illustrating that the highway industry is making use of recent material developments wherever possible is in a bridge in the State of New York, using high strength reinforcing steel in a reinforced concrete bridge deck. In this example, the engineers are reducing the total weight of reinforcing steel required with no reduction in the strength and stiffness of the concrete. Some material and cost savings should result from this

application of a new steel. Also, field erection problems or work involving the placement of the reinforcement and the concrete for the bridge deck should be eased or lessened.

Orthotropic plate bridges

Another idea or design using new developments in steel material is the orthotropic plate as a bridge floor. This system uses steelplate welded to reinforcing ribs to form an integral floor. A number of such bridges have been built in Europe, especially in Germany, since World War II. Some studies are being made concerning this new type of bridge in this country, particularly on design principles, fabrication of structural components, and erection methods. It has been concluded by some engineers that orthotropic plate construction can compete favorably in cost in the various States with other types of construction. A bridge built according to the orthotropic plate design would have a much lighter superstructure than conventional construction. Much weight and material is saved in orthotropic plate design. In addition, there can be savings in substructure costs because of the lighter orthotropic bridge floor system.

Two orthotropic plate bridges were designed as part of the study mentioned. One of the highway departments is considering the construction of such a bridge for a pilot study. The availability of steel in a wide range of strength, and improvements in welding techniques are making orthotropic plate construction for bridges available to the highway departments.

Simplified bridge designs with standardized components

The need for simplification and standardization of bridges and component parts has been apparent for some time. At the county level, particularly in our less populous areas, the shortage of engineers has focused attention on this matter. It is felt that a great potential for standardized bridges and components exists with those less urbanized counties, as well as in comparable cases at State and municipal level. Some progress has been made by both industry and the engineering profession in fulfilling needs and providing materials and services in that area.

Standard bridge plans by Bureau of Public Roads.—The Bureau of Public Roads has prepared and published standard plans for highway bridges. The first edition of these plans appeared in 1953. A revised edition was published in 1956, and a second revision is scheduled to be published in 1962. These plans are intended to serve as a useful guide to State, county, and city highway departments in the development of suitable and economical bridge designs for primary, secondary, and urban highways.

In the development of the Bureau of Public Roads standard plans, a particular effort was made to give sufficiently complete information on all plans so that they would approach contract drawings as nearly as practicable. For any given bridge location, however, it must be expected that the requirements imposed by local conditions will necessitate a certain amount of modification. It was thought that the Bureau of Public Roads standard plans for bridges would be particularly valuable to smaller highway departments with limited engineering staffs.

The Bridge Division of the Bureau of Public Roads is constantly searching for ideas and means to build better and more economical

bridges. These ideas, in turn, are disseminated to the engineers of the Nation through the publications of revised editions of "Standard Plans for Highway Bridge Superstructures."

Most State highway departments have prepared and use standard bridge plans similar to those published by the Bureau of Public Roads. To have a good set of standards makes for great savings in engineering time and in the cost of preparing project plans.

The steel industry has been active in the area of standardized bridges since as early as 1900. They have made designs and plans, and have updated them, to include rolled steel beam section bridges, deck girder bridges, and various truss-type bridges. The highway industry has made use of these standardized steel bridges in many areas, particularly in distress areas caused by storms and floods, for the quick erection of quality structures. They have also been used by bridge builders for preparing estimates and submitting proposals.

Standard bridge components.—Some progress has also been made in the marketing of standard bridges. Composite timber-concrete girder bridges are now available for delivery in complete "package" form. Each unit can be ordered by span lengths from 30 to 100 feet for any desired loading or roadway width. Each unit consists of girders, girder bracing, wheel guards, handrails and posts, all necessary hardware, and framing materials cut to size and ready for use. There is much more that can be accomplished toward using economical mass production methods for standard bridges.

Steel in precast, prestressed bridges

Good progress has been noted in the development and use of standardized bridge components. Much of this progress results from the extensive use of precast concrete in bridge construction.

Precast concrete is not a special kind of concrete but a method of fabrication. The term means any concrete member, either plain or reinforced, that is cast in forms somewhere other than its final position. Usually the casting is done in a shop or plant that makes a specialty of such work. The use of precast concrete members has been increasing steadily during the past few years. This subject is discussed further under portland cement concrete.

Corrugated steel culvert pipe

Galvanized steel culvert pipe is widely used for disposing of surface runoff and for carrying small water courses. It is estimated that approximately a quarter of a million tons will be used in 1962 for highway construction and maintenance purposes. Corrugated metal culverts are fabricated in both round and elliptical shapes and are available with bituminous coated inverts or an asbestos bonded bituminous coating with or without paved inverts to minimize deterioration from chemical agents and abrasions.

In 1955, with the aid of a special grade asphalt, a smooth pipe section was developed to increase flow capacity. These sections have been used for storm sewers and longitudinal drainage on a number of expressways.

Until recently, the maximum diameter of the helical corrugated steel pipe was 21 inches. Due to improved manufacturing techniques, the maximum diameter of these pipes has been increased to 36 inches. These new designs are being tried experimentally on Federal forest

and park projects under the supervision of the Federal Highway Projects Division of the Bureau of Public Roads.

Improved jacking and boring methods made it possible to install culverts and conduits through existing highways without disrupting traffic. Recently developed horizontal boring equipment make it possible to drill holes up to 36 inches in diameter and 150 foot lengths in some types of soil.

Steelplate arches and pipes.—In addition to the smaller riveted sections fabricated from sheet steel, the industry manufactures large plate arches and pipe arches which are fabricated in sections from galvanized steel structural plate and are erected with steel bolts.

The plate arches may be used in place of small bridges up to spans of 25 feet for H-20 loading conditions and up to 30-foot spans with no live load conditions.

The pipe arches may be used for single lane underpasses and cattle passes, as well as for watercourses, and are available in spans up to 16 feet and maximum rise or vertical clearance of 10 feet. This conforms to current AASHO specifications.

A new pipe arch section was developed a few years ago in which the maximum span has been increased to 20 feet and the rise increased to over 13 feet. These sections have been used on selected projects after careful analysis of the design stresses by the compression ring method has assured adequate longitudinal seam strength. This method of design analysis is being used to a greater extent, and in some cases it results in a more economical installation. Perhaps the most noteworthy installation to date was made on the Lakeman Expressway in Cleveland, Ohio, last year. On this project, three adjacent pipe arches, each about 1,000 feet long and each with a 20-foot width, were installed under a 20-foot fill. A considerable saving over an alternate design method is reported.

Federal specification development.—At the request of the General Services Administration, the Bridge Division of the Bureau of Public Roads is preparing the Federal specifications for corrugated metal culvert pipe. The Bridge Division is also cooperating with AASHO in developing a bridge and culvert construction manual. This manual will include installation requirements for corrugated metal pipe culverts.

ALUMINUM

Scope of use

An example of technological advances in adapting existing materials to new uses in the highway field is provided by aluminum. Some of the more common uses are lighting standards, warning, regulatory, and directional signs, signposts, guard and guide rails, gratings, auxiliary structural hardware, and, to a limited extent, for bridge superstructures and deck replacements. Some States have made experimental installations of aluminum pipe as drainage culverts.

Bridges

With a few notable exceptions, the use of aluminum for major components of bridges has been quite limited. Structural aluminum would appear to warrant consideration as an alternate to steel, whenever it is vital to save deadweight—as in long-span bridges, in movable bridges, and in the reconstruction of the floor system or portions of existing bridges.

The suspended floor, including floor beams, stringers, roadway, and sidewalks, on two 360-foot lenticular truss spans of the 50-year-old Smithfield Street Bridge over the Monongahela River in Pittsburgh was replaced with aluminum, reducing the deadweight of the structure by 700 tons. This marked the earliest large-scale use of aluminum for highway bridges.

In the field of movable bridges, an aluminum double-leaf trunnion bascule bridge, aggregating 121 feet between bearings, was completed in England in 1948. This was followed by construction in 1949 of an aluminum bridge over the Saguenay River in Canada to connect the towns of Arvida and Shipshaw. Weighing 400,000 pounds, this latter structure consists of a main 290-foot arch span (with a 47.5-foot rise) and five approach spans on the north and south ends.

The world's first welded aluminum girder highway bridge was dedicated in Des Moines, Iowa, on September 24, 1958. Built as a development project under joint sponsorship of the State of Iowa and three leading aluminum manufacturers, this four-span continuous girder structure totals 222 feet in length and 36 feet in width, and contains 75,000 pounds of structural aluminum.

Semimonocoque designs.—A new type of aluminum bridge, employing proven aircraft design principles, has been developed. Known as semimonocoque (or stressed skin) construction, it consists primarily of a thin shell which is reinforced by a network of stiffening members. Test installations of this type of structure have demonstrated potentials, particularly for intermediate span lengths. Actual bridges of this type have been completed in Maryland and Virginia. Under conditions of mass production, the cost-benefit ratios related to dead load weight factors could provide significant savings in the future.

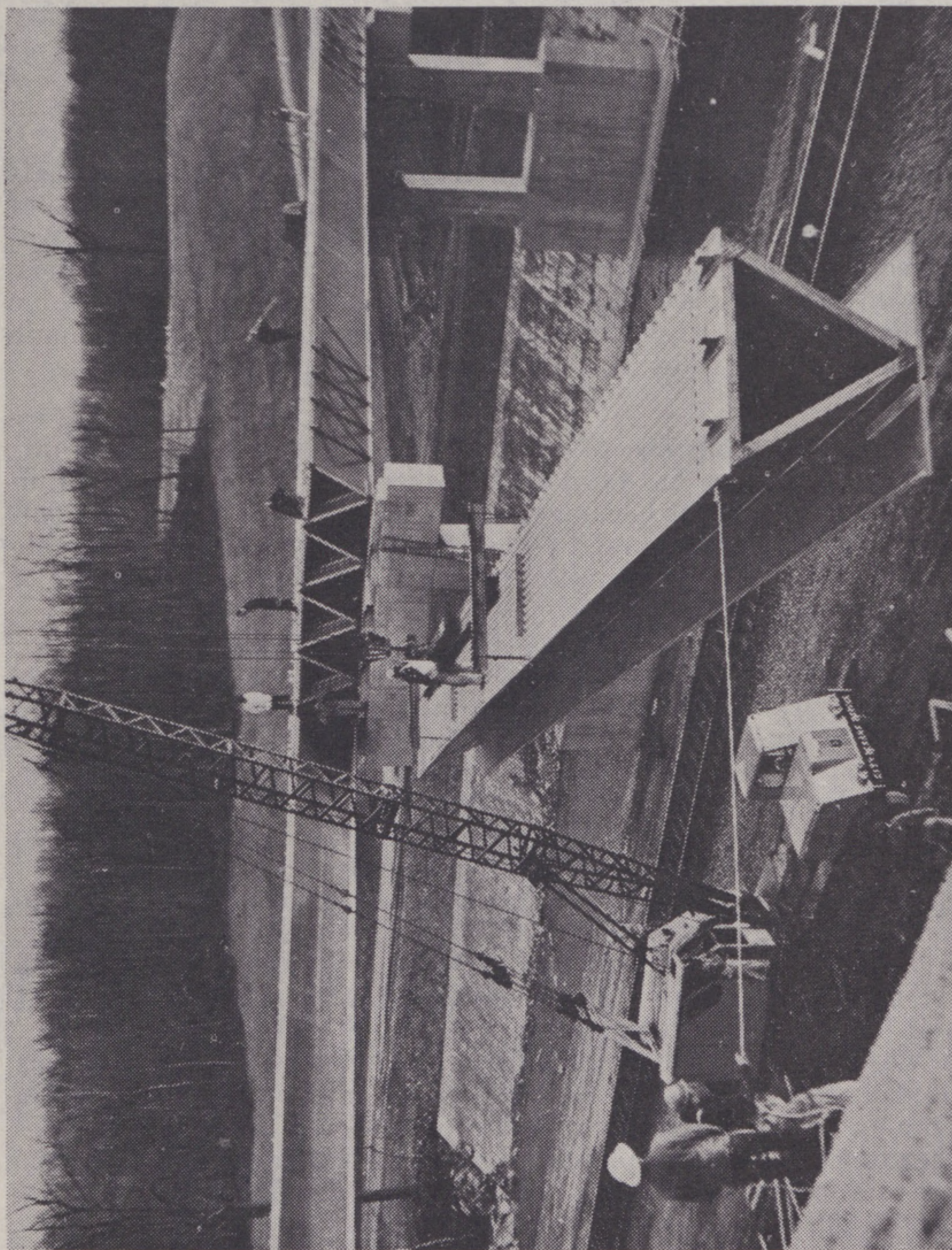


FIGURE 11.—Placing an aluminum V-beam of semimonocoque construction. Top of the beam provides the bottom deck forming for the concrete deck.

Culverts

Experimental installations of corrugated aluminum pipe culverts have been made to test them for deformation under stress and for possible evidence of either erosion or corrosion. Pipes used in these installations were corrugated and fabricated by independent suppliers from flat aluminum sheets rolled by the manufacturer.

From these tests the feasibility of aluminum culvert is being evaluated—at least for the smaller diameters, and for a range of fill heights comparable to corresponding criteria for the more conventional materials. As a further extension of this experimentation, additional test installations were arranged by the producer at both State and local highway department levels. Twenty States have now installed, and another eighteen States have made provisions to install, aluminum culverts on a trial basis.

Preliminary reports and appraisals of initial aluminum culvert test installations in California, Georgia, and elsewhere confirm the structural strength of aluminum culvert and indicate no measurable corrosion at test installations in natural soils having pH values from 4 to 9. Another preliminary report from California indicates both untreated aluminum and galvanized steel culverts corroded in a highly acid soil having a pH factor as low as 2.5.

Closely allied with the relatively new use of aluminum for culvert is the adaptation of this material for guardrail. At least seven State highway departments provide for aluminum guardrail installation through the medium of standard specifications. In addition, a number of States authorize this type of design and construction by special provisions.

Aluminum-magnesium alloys

Magnesium appears to offer possibilities for future lightweight materials for construction. Currently used aluminum-magnesium alloys such as 5083 plate or sheet and 5183 filler wire alloys, seem to be virtually indispensable for use in welded aluminum structures. The quality provided by the magnesium in these alloys is that of retention of strength after welding. As a companion of aluminum in the light metal field, and as the lightest structural metal, magnesium is regarded as on the threshold of a new and expanding career. Usage for beams in the textile industry, coupled with varied applications ranging from handtrucks and ladders to lawnmowers and handtools, may well lead to more extensive use and translation to the highway field.

PORTLAND CEMENT AND PORTLAND CEMENT PRODUCTS

Scope of use

Portland cement is one of the more important materials used in highway structures and paving. In 1961, national production amounted to approximately 320 million barrels. It is estimated that the highway construction and maintenance programs for 1961 required about 70 million barrels, or about one-fourth of the total production. This includes the cement used in reinforced concrete pipe culverts.

Concrete structures

Bureau of Public Roads records show that pavements take about three-fourths of the highway volume, and structures one-fourth. In the bridge construction field, greater use is being made of prestressed concrete beam designs as they become competitive in cost with other short span designs. Federal-aid bridge construction for 1961 included 684 prestressed concrete bridges out of a total of 4,541 structures, or about 15 percent.

Precast and prestressed sections.—Precasting concrete structural units offers some saving when compared to cast-in-place concrete. The savings are realized primarily from the economies in the cost of forms. The precast plants have more opportunity to reuse the forms.

Prestressed concrete is another new use of conventional construction material. It is usually a form of precast concrete. Prestressing places the concrete material under compression. The concrete is squeezed together by means of stretching or elongating steel embedded in the beam. In conventional construction of reinforced concrete beams, cracking occurred due to bending or elongation of the member. In prestressed members this does not occur. A large number of plants engaged in this type of work are located in Florida, North Carolina, and Texas, although a recent survey lists nearly 300 precast concrete plants located in 43 of the 50 States.

The use of prestressed concrete in highway bridges in the United States has been limited to the last 10 or 15 years. In contrast, steel or reinforced concrete have been in extensive use for more than a half century. European engineers have been building prestressed concrete structures for many more years than we in the United States because of differences in national economy. Some of their structures are long and impressive. We have been advancing rapidly in mass production of shop or plant prefabricated or precast units for short span bridges.

Examples of this type of construction in the United States may be found on the Garden State Parkway in New Jersey. Most of these structures were the usual short grade separation type of structures. More than 3 miles of the Sunshine Skyway over the lower Tampa Bay in Florida is a concrete trestle using precast and prestressed concrete girders. Also, nearly 2 miles of 50-foot prestressed concrete beam spans were constructed for the Hampton Roads Bridge-Tunnel crossing in Virginia. There are similar spans being used for causeways

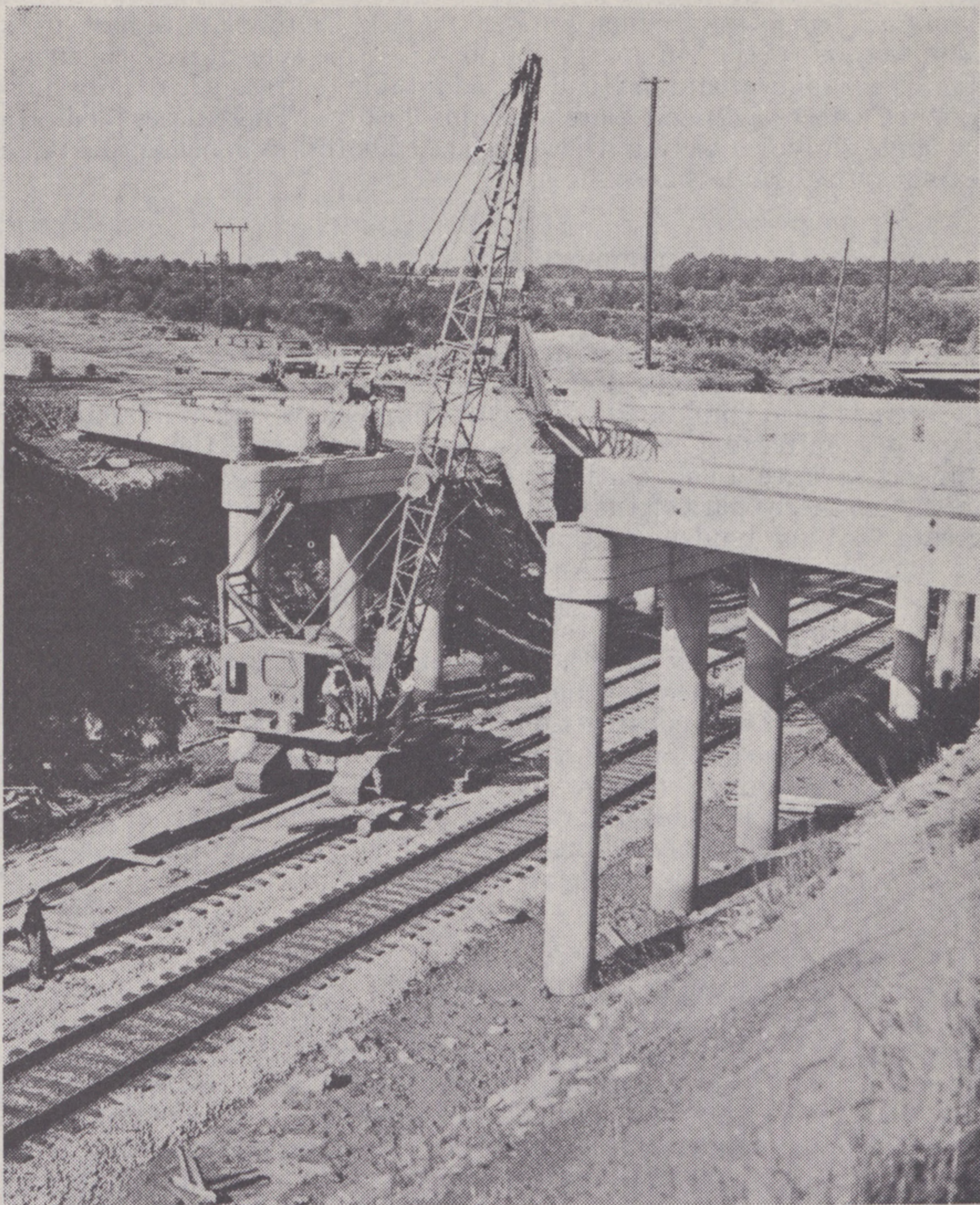


FIGURE 12.—Placing a precast prestressed concrete beam in a railroad overpass structure.

in Texas. All of the States report good and wide use of precast concrete structural units for bridges.

One other noteworthy example of this type of bridge construction is the 24-mile causeway across Lake Pontchartrain in Louisiana. Each span, 56 feet long and weighing 180 tons, was precast, pretensioned, and erected as a unit.

Cement stabilized bases

In recent years there has been a substantial increase in the amount of cement stabilized bases used in both the pavement and shoulder areas. The base material may be composed of sized aggregates, pit run gravels, or even the fine native subgrade soils which are prevalent in a number of States. Concrete pavement specifications in California

require a cement treated base under the slab. Other States have used similar construction on an optional basis. This type of base construction is economical and particularly adaptable to areas where only fine-grained soils or aggregates are available locally. These bases facilitate concrete slip-form paving where surface smoothness depends to a large extent on subgrade smoothness.

Concrete pavement

The use of air entrainment admixtures to introduce very small separate air bubbles into the mix has increased the durability of concrete exposed to thawing and freezing cycles and to snow and ice control chemicals. Scaling of pavements during their first winter under maintenance operations where chemicals are used to a large degree has been eliminated. Recent studies show that the number of days of nonfreezing weather between the pour and the first freeze appears to have a substantial effect on durability. Concrete poured in the northerly part of the country during the fall generally exhibits greater scaling tendencies than concrete poured in the late spring or summer.

Cost trends.—While there have not been any major developments in new portland cement concrete materials, pavements are being placed with greater economy especially within the last 2 years. In 1959, the average bid price for portland cement concrete pavement on Federal-aid highway construction was \$3.99 per square yard. In 1961 it was \$3.84, a reduction of 3.8 percent. This has been brought about by the introduction of new pavement designs, new construction methods and techniques, improved equipment, and above all a better understanding of the capabilities of both conventional paving equipment and the new developments made available to the paving contractor.

New design practices

One of the most significant findings in the design field resulted from studies made in Indiana and others made by the Portland Cement Association. Performance data was developed from normal paving operations and from experimental projects. These studies indicated that 3 to 6 inches of granular subbase performs as well or better under concrete slabs than depths running from 8 to 12 inches or more. This has resulted in a substantial saving in materials where these types of base courses are used.

Expansion and contraction joints.—In modern practice the use of expansion joints is being held to a minimum. Their use is largely confined to the termination of pouring operations, to proximity of structures, and to unsymmetrical intersections. This eliminates many of the maintenance problems associated with load transfer devices.

A promising new practice for the placement of sawed contraction joints has been developed in the States of California and Washington. The joints are placed on an angle or skew with a line normal to the pavement edge. This results in a smoother ride due to reducing the force caused by simultaneous reaction between the vehicle tires on a single axle and the pavement joint. It also results in reduced strains and deflection in the pavement which tends to improve and extend its useful service life. Studies of road loading mechanics also reveal that smoother riding qualities are achieved when the contraction joints are placed at least 30 feet apart.

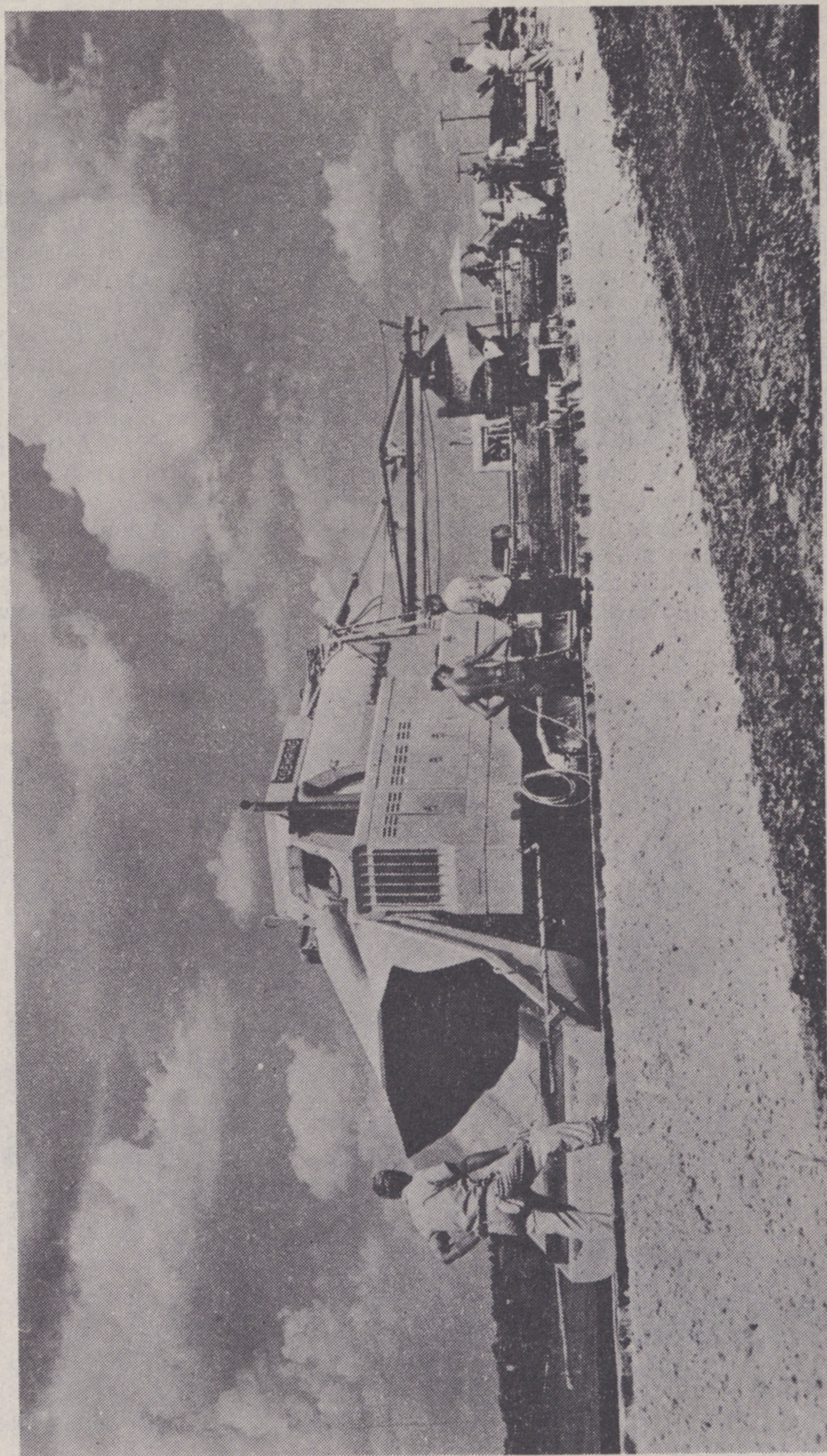


FIGURE 13.—The triple compartment (or drum) paver has made it possible to increase production of quality concrete at the worksite.

New equipment developments and applications

One of the new machines which has gained ready acceptance in most States is the triple compartment paver which is capable of producing approximately 40 percent more concrete per hour than the conventional dual compartment models. Paving contractors have found it quite adaptable on two layer construction where the wire-reinforced mesh is placed on the top of the first pour. Since the initial pour is usually about twice the thickness of the upper pour, the three compartment paver can be used effectively for the bottom lift and a dual compartment paver for the top lift. Synchronization of the output of these two pavers provides a highly efficient operation.

Concrete paver mixing time—Costs.—Recent studies by the Bureau of Public Roads, in cooperation with 12 State highway departments showed that the higher mixing times (75 to 120 seconds) do not add strength to pavement concrete and introduce a hazard of reduced quality. These studies with the followthrough by the Joint AASHO-ARBA Subcommittee on Mixing Time have led to a better understanding of the capabilities of multicompartment paver-mixers. It was shown that a mixing time of 50 to 60 seconds, including the transfer time between mixing drums, will generally produce concrete of the greatest strength.

Some idea of the savings resulting from the clarification as to how long concrete should be mixed can be gained from cost studies that were made. These studies show that concrete bids on a 60-second mixing time specification were priced at about \$16 per cubic yard and

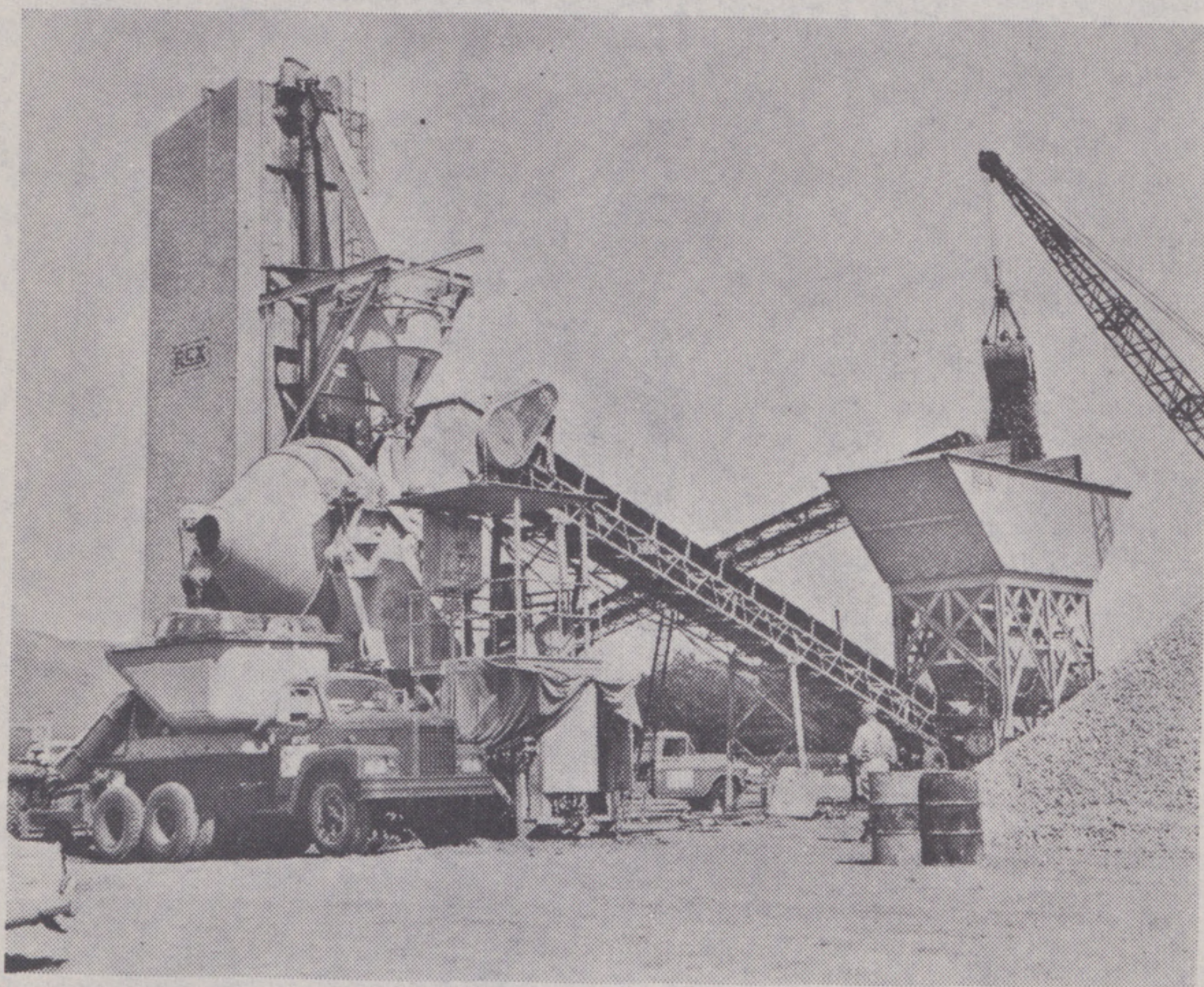


FIGURE 14.—A modern portable central mix plant and nonagitator truck for producing and hauling portland cement concrete.

concrete requiring 70 seconds of mixing was priced at approximately \$18 per cubic yard. It follows that reduction in total mixing time, and recognition of transfer time as mixing time, results in substantial savings in material processing with better assurance of high quality. It also tends to make portland cement concrete more competitive with other paving materials.

Central mixing plants—Mixing time.—Another relatively new equipment development which will provide for greater economy and quality in portland cement concrete production is the highly portable central mix plants with stationary mixers of 4 to 8 cubic yards capacity. Many of these plants have automatic batching features, including moisture meters and compensators for controlling the amounts of aggregates in equivalent dry weights with accuracy and the correct amount of total mixing water. This assures the production of concrete of highly uniform consistency for each batch. Highway departments cannot realize the full potentials of improved central plant mixing if they continue the old practice of requiring an additional 15 seconds of mixing for every additional cubic yard capacity above 1 cubic yard. Studies conducted by the Ohio State Department of Highways and other organizations tend to confirm that a mixing time of about 60 seconds for any available size of mixer appears to be entirely feasible. Ohio reduced its mixing time from 120 to 90 seconds for stationary mixers up to 10 cubic-yard capacity pending further studies. Substantial savings are possible if the central plant operation can be phased to the lower mixing times.

Other new equipment developments.—Actually the acceptance of centrally mixed concrete for paving is a step toward mass production, at least partially due to two other recent equipment developments. Segregation of the concrete mix had been a problem both in hauling and placing. Several new hauling truck models, including a specially designed body for nonagitated haul have now been developed. Hopper type spreaders have also been developed which can receive a full truck-load of concrete and deposit it uniformly between the side forms without segregation.

One of the newest developments in processing the concrete placed between side forms is a spreader-finisher-float which performs all three of these functions in a single pass. One man can now control all operations from a single control panel. Quality work is accomplished with a reduction in personnel and power requirements.

Concrete slip-form pavers

The slip-form paver is not a new development, but several models have been continuously improved so that this method of placing concrete is an approved alternate to the side-form method in a number of States. It has been employed in 14 States with the largest volumes of concrete having been poured by this method in California and Colorado. The machines are designed to pour two or three lanes (24 feet and 36 feet) of nonreinforced concrete in a single pass. Wire mesh reinforcement, however, has been successfully placed in slip-form operations.

The advantages of the slip-form method are the substantial reduction in the paving equipment train and in operating personnel. One machine performs spreading, tamping, vibration, and finishing in a single pass without the aid of preset side forms. The concrete which

is extruded under high pressure forms a slab with the aid of vibration to a relatively dry mix.

The effective use of slip-form pavers does require experience and operating know-how. Concrete of uniform consistency must be supplied and the speed of the paver must be kept constant and continuous if a smooth pavement is to be obtained.

Experience gained in California in the last several years has enabled them to initiate measures which will assure conformance to their rigid pavement smoothness tolerance of 7 inches of total deflection per mile. They were able to produce concrete pavements by the slip-form method last year with a total deflection of less than 3 inches per mile. In earlier operations in some States this high degree of smooth-

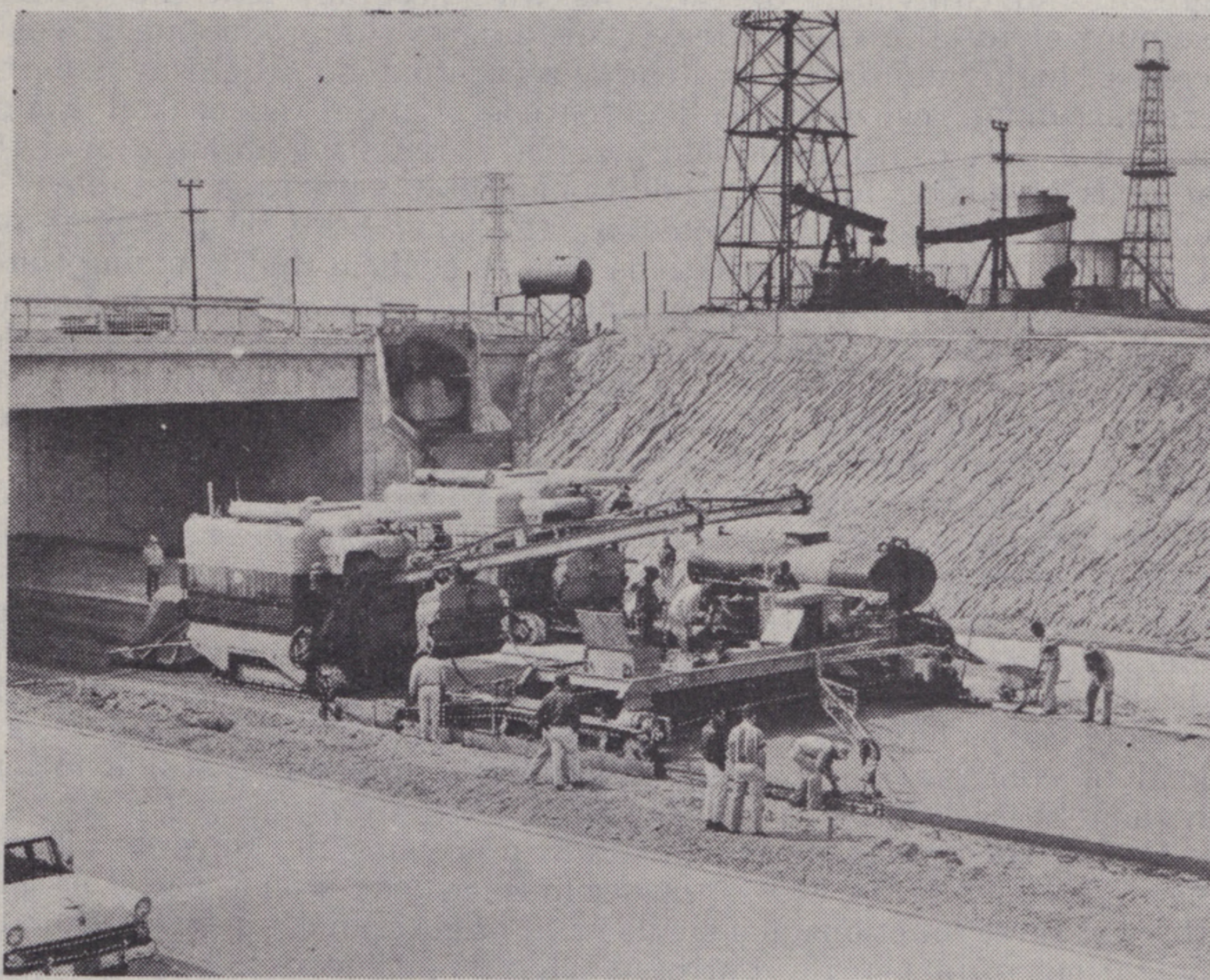


FIGURE 15.—Extruding a nonreinforced concrete slab with a slip-form paver which is fed by two dual compartment paver mixers.

ness had not been achieved and it was necessary to correct this by expensive surface grinding.

Slip-form pavers have not reached their ultimate stage of development, but with further improvements, it is thought they will contribute to greater efficiency in concrete paving operations, particularly when teamed with the highly productive central mixing plants.

Continuously reinforced concrete pavement

The first continuously reinforced concrete pavement was constructed in Arlington, Va., in 1921 by the Bureau of Public Roads. Interest in this design type has increased recently. In the last 3 years some 230 lane-miles have been constructed in seven States. Some of these sections were built as Bureau of Public Roads experimental projects,

and their inservice performance will be closely observed in the future by our field engineers.

General characteristics.—Continuously reinforced concrete pavement makes possible the construction of a slab of any length without the installation of intermediate planned expansion and contraction joints. The many fine transverse cracks which characteristically form in such pavement are usually not noticeable by sight, sound, or feel to the motorist. These cracks ravel only superficially, do not fault, and apparently do not open enough to permit the passage of damaging amounts of water to the subbase and subgrade. The periodic crack and joint sealing common to conventional pavements is not required, accompanying traffic inconveniences are thus avoided, and the cost of maintenance is reduced.

The reduced number of planned expansion and contraction joints should permit the initial riding smoothness of the pavement to be maintained over a longer period of years. Structural weaknesses and difficulties such as faulting, spalling, and concentrated pressure failures due to infiltration of inert material and pumping often associated with the use of transverse joints in conventional concrete pavements are minimized and longer useful life of the pavement may be expected.

Design requirements.—Based on these potential advantages, the Bureau issued minimum design requirements in November 1959 under which Federal-aid projects for this type of construction would be approved.

Equipment for bridges and drainage structures

In the bridge construction area, several new deck finishing machines have been developed to assist in securing improved riding qualities.

Cast-in-place concrete culverts have been used in the Western States for longitudinal drainage installations outside of the pavement area. Nonreinforced culverts up to 72-inch diameters can now be extruded with a new machine which operates similar to the smaller extrusion machines used to produce curbs of portland cement or asphaltic concrete. Available cost comparisons with the prefabricated types of concrete culverts indicate savings up to 20 percent may be achieved by the cast-in-place method.

Reinforced concrete culvert pipe

Portland cement concrete culverts of the reinforced type remain one of the principal materials used for small drainage installation. It is estimated that well over 3 million tons will be installed this year for highway construction and maintenance purposes.

Design standards and installation criteria.—New design and installation criteria developed by the Bridge Division of the Bureau in cooperation with AASHTO, ASTM, and the American Concrete Pipe Association were issued in April 1957. This joint effort resulted in a complete redesign of reinforced concrete culvert pipe for improved strength and for increased applications in the expanded highway construction program. Five classes of pipe each having a minimum ultimate load rating were established.

Under these new criteria, reinforced concrete pipe of the proper class can be used in fills up to 100 feet in height and more as compared to a maximum cover of 25 to 30 feet which prevailed previously.

The installation criteria provide for the proper bedding and backfilling to assure keeping within the culvert design stresses and of minimizing settlement of the backfill.

Standardization.—Reinforced concrete pipe is now fabricated in several shapes including an elipsoid for low clearance installations, arch sections which may be used as cattle passes, and complete precast manhole barrels in base, riser, and top sections. Tentative specifications for precast reinforced manhole sections were developed last year as ASTM designation C478-61T.

Standardization of the smaller sizes for concrete pipe has also been accomplished in recent years. Perforated concrete pipe was standardized by ASTM designation C444-59T and concrete drain tile as ASTM designation C412-60.

One of the newer methods of sealing reinforced concrete culvert pipe joints is with preformed rubber gaskets.

Handling equipment.—Excavations for concrete culverts placed in trenches are normally made with a trencher or backhoe. Some of the horizontal boring machines, however, are capable of forming holes through existing embankments up to 36 inches in diameter. Special equipment for loading and unloading concrete culverts from trucks without damage has been developed.

Use of latex modified portland cement mortars

Next to the repainting of structural steel, the disintegration of portland cement concrete is the most pressing problem associated with the maintenance of highway structures. The disintegration of concrete bridge decks is probably the most critical area, especially where air-entrainments have not been used, and it presents a difficult repair problem because the impaired area is relatively shallow and is not readily susceptible to replacement in kind. In the last several years a number of latex modifiers for sand-cement mortar have been used with considerable success in repairing scaled and disintegrated bridge floors. They show excellent promise of being an invaluable new material for this purpose. One latex used dispersion in water of polymeric particles designed to achieve compatibility with highly alkaline portland cement mortars with resulting improved adhesion, flexibility, compressive strength, chemical resistance, and greatly improved freeze-thaw stability. The ability to resist chemicals such as the chloride salts and to withstand thaw-freeze cycles is highly important since these two factors are contributory causes of the premature disintegration of portland cement concrete. Latex mortars also have the advantage of curing to almost the natural color of concrete. Successful use of latex modified mortars in repairing concrete bridge decks has been made in 14 States including recent ones in Kentucky, Michigan, Maine, and Texas.

CLAY PIPE AND TILE PRODUCTS

Scope of use

There have been several improvements in the clay drainage pipe field including stronger and smoother sections produced by modern extrusion machines. The 2- and 3-foot lengths have been replaced with new standard lengths of 4 feet 4 inches and 5 feet. This results in a substantial saving in installation costs. It is estimated that approximately 90,000 tons of clay pipe and tile for subsurface drainage will be used for all highway purposes in 1962.

As in the case of reinforced concrete culvert pipe, there is widespread use of resilient materials for compression type joints. Tentative specifications for factory-installed gasket material were issued in 1958 as ASTM designation C425-58T. In the same year tentative specifications for installing clay sewer pipes were also introduced as ASTM designation C12-58T.

ADDITIVES AND ADMIXTURES FOR PORTLAND CEMENT CONCRETE

Additives are substances or agents added in small amounts to a basic ingredient of a mixture prior to mixing.

Admixtures are substances or agents added in small amounts to the basic ingredients of a mixture during the mixing.

The same substances or agents may be either, or both, depending on when they are added to the mixture. Investigation regarding the use of admixtures in portland cement concrete has been carried on in this country since about 1885. Prior to 1950, however, there was a reluctance on the part of highway departments to specify and use them, attributed by some research groups to a lack of understanding the chemical nature of these materials and ability to predict how the physical characteristics of the concrete could be improved by their use. Constant research by industry and by many Government agencies and State highway departments has produced a vast amount of technical information in this area. For example, the American Concrete Institute Committee No. 212 on Admixtures in Concrete published a report in 1954 suggesting the classification of additives and admixtures into the following groups:

- | | |
|---------------------------|--|
| 1. Accelerators | 7. Pozzolans |
| 2. Retarders | 8. Alkali-aggregate inhibitors |
| 3. Air entraining agents | 9. Dampproofing and permeability reducing agents |
| 4. Gas forming agents | 10. Workability agents |
| 5. Cementitious materials | 11. Miscellaneous |
| 6. Grouting agents | |

Accelerators

These materials speed up the strength development of concrete. This permits earlier stripping of the forms and use of the structure and shortens the time for protecting concrete placed in winter. Calcium chloride is one of the most widely used accelerators used in concrete.

Retarders

These materials sometimes called dispersing agents delay the setting or stiffening of concrete which may be desirable because of hot weather or to aid in the placement of complicated geometric shapes or concrete containing closely spaced reinforcement. Among the agents which produce this effect are sugars, starches, calcium lignosulphate, and certain organic compounds.

Air entraining agents

These materials, now the most widely used admixtures for concrete, introduce very small separate air bubbles into the concrete. This entrained air materially aids the concrete to resist damage from freezing and thawing, improves the workability and plasticity which permits lower water-cement ratios, helps to reduce segregation and the

tendency to bleed. This in turn permits earlier finishing of flat surfaces.

In February 1954, the Physical Research Branch of the Bureau of Public Roads, published a report entitled "Evaluation of Air Entraining Admixtures for Concrete," which gave the results of tests performed on 27 different materials produced by 19 manufacturers. These were classified with respect to their major constituents into the following seven groups:

- | | |
|-------------------------------------|---|
| A. Salts of wood resins | F. Fatty resinous acids and their salts |
| B. Synthetic detergents | G. Organic salts of sulfonated hydrocarbons |
| C. Salts of sulfonated lignin | |
| D. Salts of petroleum acids | |
| E. Salts of proteinaceous materials | |

This report includes a list of "Admixtures Approved by the Bureau of Public Roads for Use on Direct Government Contracts in the National Parks and National Forests."

A companion report "Chemical Analysis and Sources of Air Entraining Admixtures for Concrete" also by the Physical Research Branch, was published by the Bureau in February 1954. This report presented the results of an investigation of the practicability of applying chemical analyses as a means of identifying and controlling the uniformity of the various admixtures used in concrete.

Grouting agents

These materials are used as lubricants to aid in the penetration of grout into seams, cracks, and gravel pockets at reasonable pressure. Bentonite, pumicite, fly ash, and various proprietary materials have been used for this purpose.

Research has also been conducted by the Bureau on other admixtures including retarders and accelerators.

Workability agents

As the name implies, these agents assist in the handling and placing of concrete. Some materials used for this purpose are powdered or finely ground inert materials such as hydrated lime, bentonite, pumicite, fly ash, diatomaceous earth, and some sulfonated organic compounds.

Pozzolans

These materials have the ability of reacting with the lime freed by the hydration of portland cement to form additional cementitious compounds which add to the strength of the hardened concrete. Some of these are natural materials such as volcanic ash. Some are artificial such as fly ash. A number of proprietary products with these pozzolanic properties are available from industry.

Dampproofing agents

These agents as the name implies are intended to reduce the penetration of moisture through hardened concrete. In concrete of moderate to high cement content, air entraining agents have been effective for this purpose. For concretes of low cement content, other admixtures such as certain soaps, stearates, and asphalt emulsions have been used to reduce concrete permeability.

Trends in acceptance

That the reluctance on the part of State highway departments to use additives and admixtures in portland cement concrete pavements and structures has disappeared is evidenced by the AASHTO designation M-154 (ASTM designation C-260), which was developed in 1948 and revised in 1960, "Standard Specifications for Air Entraining Admixtures for Concrete" and AASHTO designation T-157 "Standard Methods of Testing Air Entraining Admixtures for Concrete" and the inclusion in many State highway standard specifications of requirements for air entrained concretes, agents, and air entraining portland cement.

BITUMINOUS MATERIALS

Scope of use

Bituminous materials used in highway work are products resulting from processing asphalts from native deposits, the refining of petroleum, and the destructive distillation of bituminous coal.

Coal tar products were used as binder materials in our early paving program, especially in the Northeast, where coal tar was a byproduct of the coal coking industry. Tar is still used in these areas to a limited extent. Chemical demands for coal tar have limited the use of this product in highway construction and maintenance.

The market for bituminous materials has increased greatly in recent years. The current annual requirements for highway construction and maintenance are running about 14 million tons. Based on projected highway activities and expenditures, some 172 million tons of bitumen, including asphalt and coal tar products, will be required in the 1962-72 period for highway construction and maintenance purposes.

Trends in prices of petroleum asphalt

The prices of asphalt cement from six sources of delivery within the United States were nearly 3 percent lower in the 1960-61 period than the price 10 years earlier. Cutback asphalt (asphalt cement liquified with volatile solvents) in this same 10-year period has shown an increase of only 10 percent.

Quality control

For many years the need for methods of evaluating the quality of asphaltic materials has been recognized. The petroleum industry, individually and through its associations, including the Asphalt Institute and the National Bituminous Concrete Association, is cooperating with State highway departments and the Bureau of Public Roads in seeking these improvements.

Bureau studies of asphalt consistency.—In 1954 and 1955, the Bureau of Public Roads began a study of asphalt cements being manufactured for use in highway construction. The samples were taken by our field offices and were representative of the materials then in use in the States. A total of 323 samples from more than 100 refineries were obtained. In February 1959, the first report of this study, which included the results for the samples in the 85-100 penetration grade, was presented.

Of the 119 materials included in the first report, 12 were out of grade by a few penetration points, but only 3 would fail to meet any of the other standard requirements of the American Association of State Highway Officials. However, the results of our tests show a very wide range in the engineering properties of these materials. If the mixing temperature was to be set at 275° F., the viscosities of the asphalts during mixing would range from a minimum of 85 seconds to a maximum over 300 seconds. Other tests indicate that the hardening that occurs when these materials go through the normal mixing process

may vary from only a few penetration points to as much as 50 or 60 percent of the original penetration.

Industry, the highway departments, and the Bureau are endeavoring to develop improvements among which are the following:

- (1) Laboratory tests that directly measure the quality of the material;

- (2) Greater knowledge of the fundamental characteristics of asphalts and the relation between these characteristics and the performance of the pavement;

- (3) More uniformity of materials meeting the same specifications.

New laboratory tests.—Progress has been made toward improved laboratory tests. The Bureau's efforts along this line have resulted in the development of the thin-film oven test. This test has now been accepted for many State specifications, by the Asphalt Institute, and by the American Association of State Highway Officials. This is a simple test. A one-eighth-inch film of asphalt is heated in an oven for 5 hours at 325° F., the penetration is determined before and after heating, and the amount of hardening is expressed as the percentage of retained penetration. This hardening correlates relatively with the hardening that is likely to occur in the mixing plant. That is, those asphalts that harden the most in this test are likely to harden most during the mixing process under the same conditions.

Efforts are being made to develop tests which will provide better methods to define engineering stability of asphalts. The Asphalt Institute, asphalt producers, and the Physical Research Division of the Bureau are experimenting with tests for obtaining fundamental consistency relationships which eventually may supplement or even eliminate the empirical test methods now used.

The development of new tests and instrumentation is opening the way for determining fundamental viscosities of asphalts. Perfection of these tests will enable highway departments to define construction temperatures more precisely in their specifications. In the case of hot asphaltic concrete, it will probably be necessary to control consistency at more than one temperature.

Coal tar products

In 1959, an industrial firm developed a bituminous binder, produced by the digestion of powdered coal in coal tar and tar oils, for highway construction and maintenance. The producer claimed the product to be comparable to, and could be used in the same manner as, asphaltic cements in hot-mix bituminous concrete.

Several coal-producing States investigated the feasibility of utilizing the new binder material in their highway construction programs. Kentucky, however, was the first and only State to set up a production plant and incorporate the coal modified coal-tar binder into pavement surfaces for experimental purposes. At the same time, control sections using standard asphaltic binder were constructed for comparative evaluation.

The experimental sections of coal tar totaled 10.2 miles of two-lane road sections, and the standard asphalt control sections totaled 13 miles. During the first year, continuous evaluations of these sections were carried on by laboratory tests and visual observation of performance.

Reports were made periodically of the performance and behavior of the test sections. The report of performance after 2 years indicated that the experimental material was less flexible than the standard asphalt binder and edge cracking developed rapidly. Raveling, and loss of fine aggregates, soon occurred which produced a rough-textured surface. The experimental binder did not satisfactorily bond with itself or other paving mixtures, causing an opening of the centerline and transverse construction joints.

As the coal-tar binder was laid, wherever hand placement and compaction was required on the surface and approaches the work was difficult. In regard to the roughness of pavement, the surface composed of coal-tar binder material deteriorated more rapidly than the standard asphalt binder mixes. Another factor was the excessive fumes given off by the coal-tar mix, creating a difficult working condition for the construction personnel.

Some of the above deficiencies were observed in the standard asphalt binder, but they have not developed to such a severe degree in the test sections. It may be possible that better results might be obtained if this new material were treated as a tar rather than as a substitute for asphaltic cement.

Aggregates and mineral fillers

The mineral aggregate comprises the bulk component of a bituminous concrete and is equally important in the performance and durability to the binding agent—be it asphalt or tar. The physical and chemical characteristics of the aggregate and the gradation of the particles within a mix influence greatly the stability and suitability of the product when subjected to traffic and weather.

Aggregate gradation chart by Bureau.—A new aggregate gradation chart, which will be especially useful in developing more realistic specifications and in evaluating individual gradation for bituminous concrete mixtures, has been recently developed by the Bureau of Public Roads. The new chart can be used to convert a nonconforming State specification gradation to the simplified practices gradation.

Effects of mineral fillers.—It has been demonstrated by research that mineral aggregate material, passing a 200 sieve, has a significant influence on properties and performance of bituminous mixtures. By contrast, the effects of fillers cannot be precisely predicted from easily measured characteristics of the filler itself. Studies were made to ascertain effects of mineral fillers on bituminous mixtures and to assess their suitability for pavement performance. Variations in the character, grading of aggregates, and the amount and characteristics of asphalt cements used also affect test findings when evaluating specific materials for use as fillers.

The strength and stability of bituminous mixtures are affected by the shape and texture of the fine mineral aggregates incorporated in the bituminous concrete mix. Research is being undertaken to determine what influence the shape and texture of the fine material will have on the behavior of the mix in service. It has been found that mixtures containing mineral aggregates having a high percentage of angular and rough-textured characteristics generally developed a greater strength than the same mix consisting of round, smooth-textured aggregates.

Spectroscopy tests.—A new procedure to assess the uniformity and mineralogical nature of mineral fillers for bituminous mixes is the use

of infrared light spectroscopy. It is being adopted as a relatively new practice. Extension and further development of this technique and equipment adaptation are almost assured by virtue of the highway needs in this area.

For economic reasons and because of the growing scarcity of high quality aggregates in some areas, it is essential to make as much use as possible of aggregates that are locally available. This often necessitates tailoring specification requirements to fit the physical characteristics of such local aggregates to whatever extent may be compatible with producing high quality construction at economical prices.

Bituminous stabilization and protection.—Soils and aggregate materials are sometimes treated with liquid asphalts and emulsions to provide sufficient adhesion and cohesion between the particles to allow for compaction and stability. This has permitted the use of natural materials which have been previously unusable, reducing construction costs and conserving the supply of higher quality materials for other highway purposes.

Linked with the addition of bituminous materials in soils and aggregates for improved stability is the desired effect of the reduction of moisture absorption by these materials when placed in base course and subgrade layers. This process has also promoted the use of many aggregates not usable in high-type pavement construction. The placing of an asphalt membrane on the bottom, sides, and top of base courses, subgrades, and embankments, or to encompass all three structures in one application is being performed to prevent the infiltration and absorption of moistures in these structures.

New equipment and procedures for bituminous paving

There are a number of significant changes in both the appearance and performance of a modern bituminous paving train.

The paving contractor has his choice of using a batch or a continuous plant in practically all States; but in either case, it will be equipped with automatic electric or hydraulic controls which assure that the plant will go through the various operations following a predetermined material makeup and processing schedule with a minimum of human supervision.

In a modern plant, the aggregate dryers have been increased in diameter. This is the result of an extensive research study on the part of industry to speed up and provide more efficient drying. The dryer may be equipped with an automatic burner unit by which the intensity of the flame is automatically adjusted to the moisture conditions of the cold aggregate.

Reduction in mixing time for bituminous concrete.—Although no major design changes have been made at the pugmill, the wet mixing may now be timed for 20 or 25 seconds instead of 45 seconds or more that generally prevailed 10 or 12 years ago and which still applies in some States.

A practical method has been developed for determining when a bituminous concrete mix is mixed. A recent study by the Virginia Council of Investigation and Research, at 17 batch plant setups, revealed that it is entirely feasible and desirable to determine wet mixing time by the Ross count method for individual plants and mix design. The Ross count method involves the evaluation of aggregate particle coating by visual observation.

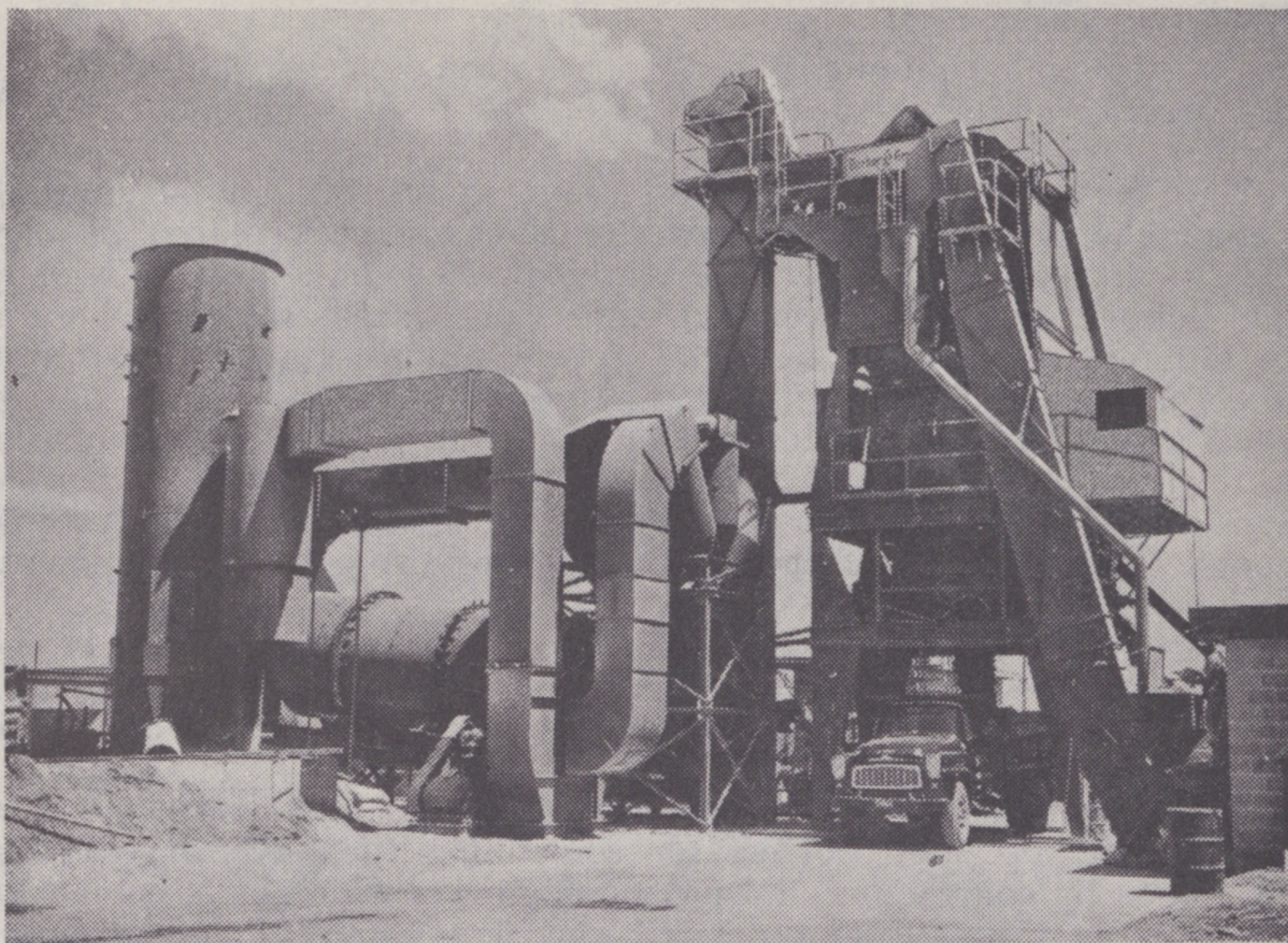


FIGURE 16.—A modern batch-type plant discharging bituminous concrete into the bed of a dump truck.

Virginia mixing time study.—The Virginia study showed that a 98- to 100-percent coating of aggregate particles, on the road, can be achieved in an average of about 20 seconds of mixing at the pugmill. Also, that a substantial amount of coating occurs in the discharge, hauling, and placing operations.

An experiment is being started in Ohio to determine the possible advantages in the new impact method of mixing bituminous concrete related to improved durability, stability, and economy for both construction and maintenance. Under the impact method, hot liquid bitumen is pumped into the mixing chamber at high pressure through special nozzles which atomize the bitumen to effect a more thorough coating of aggregates. Under present conventional methods, the hot liquid bitumen flows through a spray bar under low pressure or is introduced into the mixing chamber by force of gravity. It is claimed that the impact method requires a shorter mixing cycle.

Effect of overmixing on production and costs.—Studies conducted by the Oregon State Highway Department show that every second of unnecessary mixing time increases the cost of mixing by 2 percent. A reduction of only 10 seconds of wet mixing can increase the potential seasonal output of a mixing plant by 23 miles of two-lane bituminous concrete pavement. The trend toward reduced mixing time for hot bituminous mixes not only results in a substantial increase in production, but also reduces the oxidizing tendencies from excessive mixing at high temperatures.

New paving equipment

On the large bituminous paving jobs, 15-ton capacity hauling trucks are becoming more evident instead of the 8- or 9-ton conventional haulers.

The bituminous paver-finishers have gone through substantial design changes and several new models have been placed on the market in recent years. Higher working speeds have been provided, and hopper capacities have been increased. Speeds are available up to 100 feet per minute, but a 50-feet-per-minute maximum is more likely to prevail because of mixing plant and hauling capacity. Last year, a single paver handled the total output of three mixing plants in Iowa (over 500 tons per hour) while operating on base construction at average speeds of about 54 feet per minute. This laydown rate is about three times as fast as former rates using older equipment designs.

The higher vehicle speeds prevalent on expressways built to interstate standards have created a demand for smoother riding pavements. There is also a need for a practical method to smooth out distorted pavements in resurfacing operations.

Electronic grade and slope controls for bituminous finishers.—A number of manually operated devices for controlling the paver have been developed by contractors and paving engineers which have helped to improve laydown smoothness. The equipment manufacturing industry has sponsored the development of several different electronic devices on pavers for automatically controlling transverse slope and longitudinal profile from a single grade-line reference such as a steel piano wire mounted on adjustable steel pins and installed parallel to finished grade. With field testing complete, several paver manufacturers are making this device available for the current construction season. Some improvement in grade reference systems is needed before the full potentials of this device can be realized. The automatic grade and slope following device not only assures smoother pavements, but in addition it permits the construction of the various bituminous layers in closer conformance to the design thickness and conserves the higher priced materials.

Sealing joints with infrared heat.—One of the problems associated with hot-mix laydown is the bonding of longitudinal joints of abutting pavement courses. A new infrared heating device, fueled with propane, which is attached to conventional type bituminous finishers now makes it possible to obtain smooth, well-bonded joints with a single laydown machine. The design of this unit is based on the property of dark objects or materials of absorbing infrared energy which is converted to heat.

Compaction with pneumatic-tired rollers.—There are some new procedures in compacting hot bituminous mixes. The self-propelled pneumatic roller operating with tire contact pressures of about 80 pounds per square inch is now generally used at the intermediate stage following the breakdown rolling. While no substantial increase in average density is achieved on most mixes, the kneading action appears to provide an aggregate particle placement similar to what would be produced by the tire loads and inflations employed by the trucking industry. A more uniform stability is built into the pavement during construction which will minimize rutting in the wheel

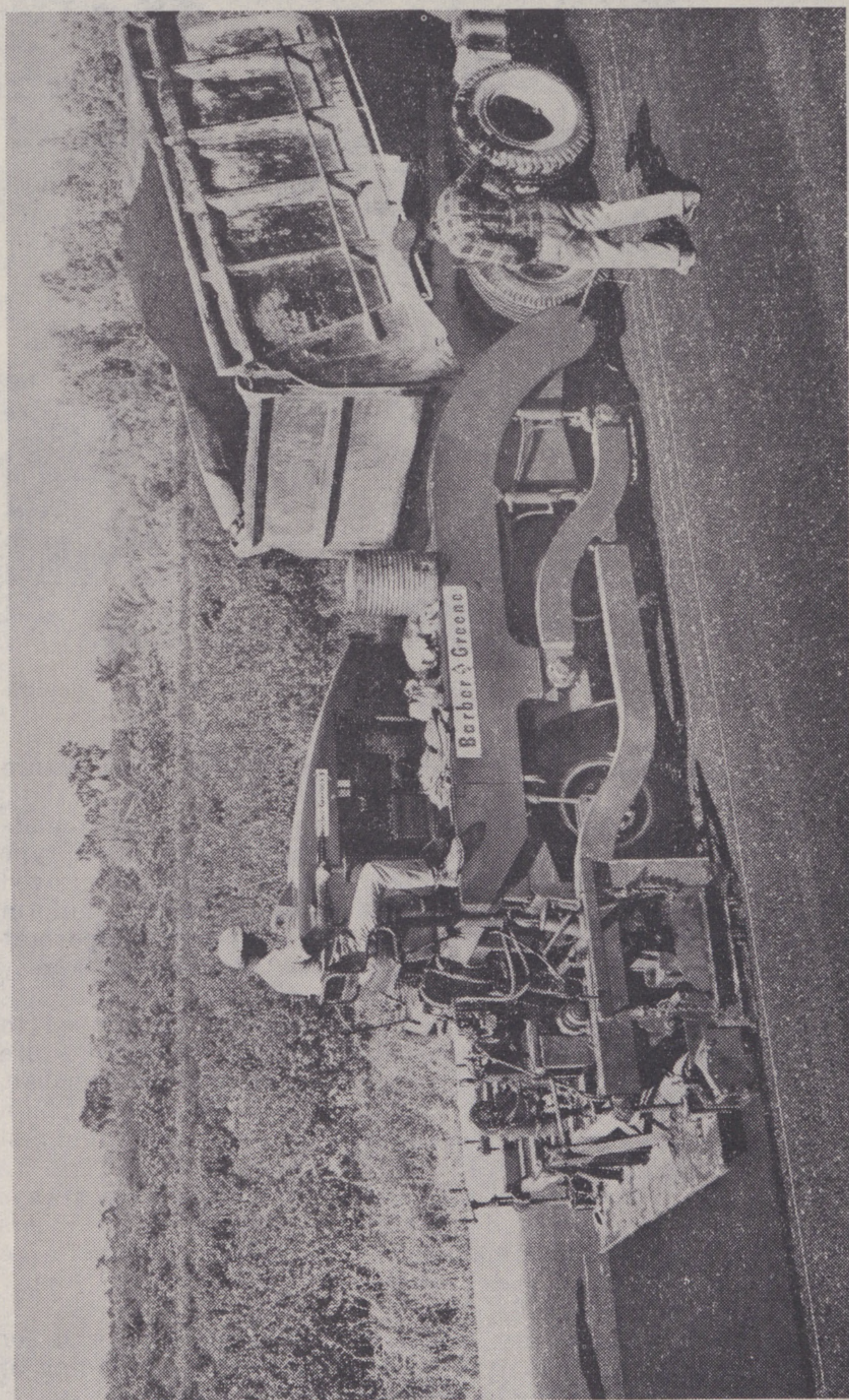


FIGURE 17.—Placing bituminous concrete with one of the new pneumatic tired bituminous finishers.

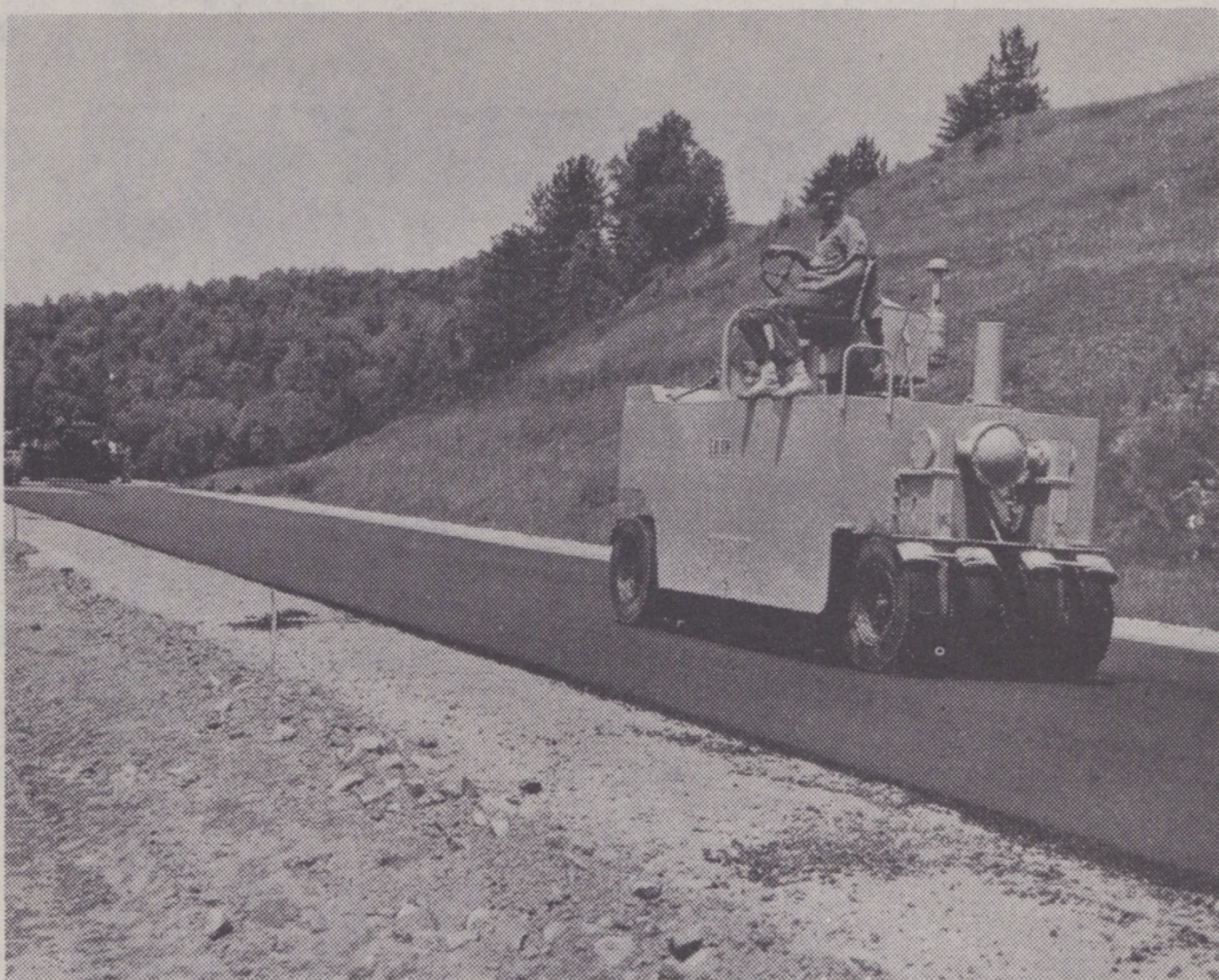


FIGURE 18.—Rolling a bituminous concrete course with a self-propelled pneumatic roller.

tracks from channelized traffic during high ambient temperature conditions.

Other new equipment developments.—Improvements have been made to several bituminous paving units used extensively on lower type bituminous surfaces. New distributor designs provide improved nozzles and circulating systems, making it possible to spray a uniform and evenly heated application at all nozzles. This is highly important for surface treatments and resealing activities where serviceability depends on good aggregate embedment in the bitumen.

Self-propelled aggregate spreaders have also been developed to work closely behind the bituminous distributor. These units are capable of placing a layer of cover stone over the newly applied asphalt which is uniform in both thickness and width while operating at high speeds. This assures proper embedment of the stone with minimum waste and gives neat appearance to the wearing course.

Settlement of repaired areas in bituminous pavements has always been a serious problem. The development of small vibratory rollers and plate type vibrators now make it possible to recompact both the base layers and the surface patch so that they will not settle to any substantial degree under traffic.

A number of heater-planer machines have been developed for smoothing up distorted high type pavements without discarding or covering up all of the existing paving material.



FIGURE 19.—Applying liquid asphalt in resealing operation with one of the new bituminous distributor models.

Addition of asbestos, rubber, or plastics to bitumen

The introduction of certain compounds to asphaltic materials and mixtures for the purpose of improving service performance to bituminous pavements is the subject of continuing research and experimentation. Additional compounds for this purpose are subjects of continuing research and development.

The addition of asbestos fiber in a finely divided form has proved to be a satisfactory ingredient for upgrading bituminous mixes. The asbestos material is actually a fraction of the mineral filler incorporated in the bituminous mix that tends to produce a more resilient pavement. These fibers have an electropositive surface which makes for retention of excessive binder, chemically and mechanically, within the mixture. The use of asbestos in connection with materials used in pavement construction had its beginning in 1917. The addition of asbestos in hot bituminous mixtures has been expanded recently. Its use has reduced rolling time during placement operations and has made possible the opening of paved sections to traffic within minutes after rolling has been completed. This characteristic of the mixture may have considerable use in areas where urgent traffic requirements are a factor.

Rubber.—The effect of the addition of rubber to bituminous concrete mixtures on experimental sections of highways has been under observation by the Bureau's Office of Engineering for a number of years. Based on the performance of 18 experimental projects,

neither beneficial nor detrimental effects on the quality or durability of the pavements have been observed to date. Rubber compounds when added to standard cutback asphalts in surface treatment and seal coat applications, however, are reported by some States to achieve an improvement in the performance of the material. Based on the continued interest in rubber additives and admixtures, the Bureau developed a "tentative guide specification for rubberized asphalts" in 1960. It covers one grade of asphalt cement (85-100) and one rapid curing cutback (RC-3). Research and development of rubberized bituminous binders are being continued, principally through the rubber industry itself.

Epoxy blends.—As a result of industry's years of laboratory research and field developmental work, a new binder consisting of epoxy blends in asphaltic cements and liquid asphalts is now commercially available. These epoxy blends in asphalt have been developed for surface treatments, seal coatings, and plant-mix operations. The epoxy asphalt binder, when used in hot-mix bituminous concrete production, employs conventional methods and equipment in the mixing process. The behavior of the combined materials during mixing, hauling, spreading, and compaction is similar to the standard asphalt mixtures. During this process, and for some time after placement, the epoxy binder in a chemical-physical process converts into a thermosetting plastic, which is flexible and has high tensile strength. The material usage in highway work is limited because its cost is high. The prevailing prices of epoxy material are about 20 times the cost of an equivalent amount of asphalt. While these materials are promising, they are not fully developed.

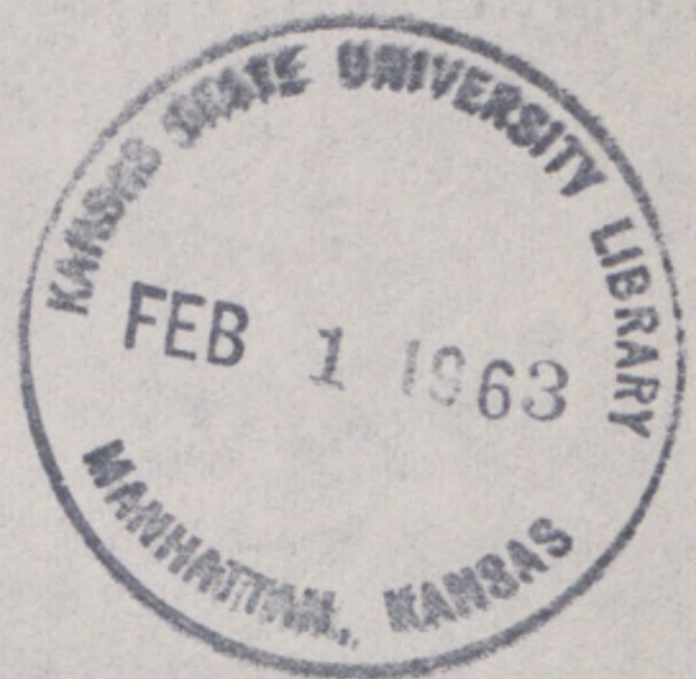
Asphalt emulsions.—Industry is continuously researching and developing new asphaltic products, chiefly in the liquid asphalt category, to improve the workability and durability of the material and to widen the scope of its use. Frequently, these new products receive proprietary labels. Recent developments of asphalt in the emulsified form have made commercially available an emulsion in which the electrochemical charge of the asphalt can be controlled as desired. The development of an emulsifier, which affects a positively or negatively charged emulsion, improves its performance as a binder when used with certain aggregates. The prevailing electrochemical attraction of the aggregate determines the type of emulsifier to be used.

Color blends.—Other uses of asphalt cements and liquid asphalts include the incorporation of color blends of the binder for such purposes as traffic lane delineation, edge markings, and similar demarcations. They are applied as a seal coating to the pavement. These uses have been developed for guiding the flow of traffic. Color-blend materials may also be placed on pavement areas requiring special delineation, such as interchange ramps, acceleration and deceleration lanes, and on shoulder areas. Colored polymeric binders without an asphalt component are under development in some areas. This material may be used as a substitute for asphalt color blends.

Other asphalt uses.—As a structural material, asphalt concrete is being increasingly used for constructing curbs and gutters, waterways, ditches, berms, and similar structures. Special equipment has been designed and is available commercially for use in applying these materials for construction and maintenance operations. Research

and development of other mechanized techniques are continuing to advance the further use of bituminous mixtures, principally under industrial sponsorship and financing.

Although not a completely new application of bituminous materials, the extension of the use of an asphalt spray to retain mulch in place on roadside areas is becoming more widely used. The asphalt spray is also applied directly to a newly seeded slope to prevent erosion before stabilization of the area is effected by grass cover. The thin asphaltic film aids in germination of grass seeds and hastens the growth cycle of the ground cover.



PETROLEUM PRODUCTS

Scope of use

The substantial growth in highway construction volume since the middle 1950's and a gradual annual increase in outlays for highway maintenance have resulted in larger demands for petroleum products including fuel, oil, and lubricants.

It is estimated some 1.3 billion gallons will be consumed in highway construction and maintenance operations during the current year. Of this amount, about 800 million gallons will be used on highway construction.

Simplification of lubrication requirements

One of the most significant developments in the petroleum products field is the substantial reduction that has been made by manufacturers in the types and classes of oil and lubricants necessary to support equipment operations. This has introduced economies into both the warehousing and handling areas. One multipurpose grease now replaces three former automotive greases—a chassis lubricant, a water pump grease, and a wheel-bearing lubricant. It also reduces the chances of misapplication. Triple purpose oil has also helped to reduce overall consumption. The widespread use of multigrade SAE 10W-30 motor oil is a good example.

Detergent oils

The use of additives in lubricating oils, such as metallic soap type chemicals to produce detergency by which the initial deposition of the products of fuel combustion and oil decomposition in new and clean engines is prevented, is an outstanding contribution to greater economy of equipment operations. Different additives produce a dispersion of soot and other impurities into a finely divided state, prevent oxidation and corrosion of bearings, and provide good lubrication for extreme pressure operations. Heavy duty detergent oil which was initially developed for diesel engines is now widely used in many gasoline engines as well.

The petroleum industry continues to explore the possibilities of making additional multipurpose lubricants available which will further benefit the highway contractor and the public highway department.

RUBBER PRODUCTS

Major improvements

The tire and rubber manufacturing industry has provided four major tire improvements for wheel-type construction machinery which has given impetus to its phenomenal development in a short span of years:

(1) The development of nylon cords has greatly increased durability and heat resistance.

(2) Wide base treads afford better traction and flotation and permit higher operating speeds.

(3) The new tubeless tires for earthmovers and graders have eliminated flap and tube troubles, facilitated field mounting and repairs, and thereby greatly reduced downtime.

(4) High pressure compactor tires for pneumatic rollers which are capable of exerting contact pressures of 80-95 pounds per square inch.

In addition, the industry is now producing conveyor belts which provide eight times greater performance than those previously used and wire-braided hose that can withstand up to 1,000 pounds per square inch. Greater efficiency from these improvements in tires and other rubber products are reflected in thousands of units of construction machinery.

Duplex truck tires

Duplex tires which were developed recently for military purposes as a replacement for dual tires have also been successfully operated on commercial transport trucks and on several types of highway construction machinery on an experimental basis. In addition to providing easier riding, less vehicle maintenance, better traction and mobility, they also exert less contact pressure on highway pavements and therefore their widespread adoption would tend to reduce pavement damage and maintenance costs.

CHLORIDE SALTS

Calcium chloride

Calcium chloride is produced from natural brine wells and as a byproduct of the ammonia soda process of producing soda ash.

Annual production at the present time is estimated at about 600,000 tons, of which slightly more than half is devoted to highway purposes. It is used as a dust palliative for soil-aggregate roads, for snow and ice control purposes, and as an accelerator for portland cement concrete poured in cold weather.

Field tests have revealed that calcium chloride materially assists in compacting soil mixtures by reducing the compactive effort required for certain soils. The effects of calcium chloride seem to be most pronounced on base course mixtures which contain an appreciable amount of minus 200 mesh material. Conversely, the calcium chloride permits the use of less binder material than would otherwise be required.

In addition to facilitating compaction, it has been demonstrated that resistance to the penetration of moisture into the compacted soil and to subsequent damage by frost action is increased.

For high-type pavements where calcium chloride is used to aid compaction, the materials are normally mixed at a modern central plant in order to achieve close control on the amounts of flakes and water added. As previously mentioned, a modern plant is capable of producing in excess of 500 tons of mix per hour.

In winter maintenance, calcium chloride is used in flake or pellet form by itself and in combination with sodium chloride. It is also used as an agent to keep sand and other abrasives in condition to apply with mechanical spreading equipment. When mixed with sodium chloride, the ratio is usually one part to three parts of the sodium salt. The decision as to whether calcium chloride will be applied with or without sodium chloride depends on existing and anticipated temperatures and pavement conditions. The mixture of chloride salts is usually more effective at a temperature range of 30° F. to 25° F. The chemical mixture combined with sand is quite effective for temperatures under 25° F. and to a point where plowing operations will provide a clear pavement.

Sodium chloride

Coarse sodium chloride salt which is largely produced from mining operations is used principally as a snow and ice control chemical. It has also been used to a limited extent for mixing with base and surface courses of secondary roads. It is estimated that 5 million tons were used for highway purposes in 1961.

Sodium chloride is particularly effective for melting snow and ice when the temperature is about 30° F. and above. As previously indicated, its effectiveness at temperature under 30° F. is enhanced by the addition of one part calcium chloride to three parts sodium chloride.

When used in proper amounts and with reasonably controlled moisture conditions, compaction is facilitated through the use of sodium chloride.



FIGURE 20.—Specialized equipment for hauling and spreading chlorides reduces application costs.

EPOXY AND POLYESTER RESINS

The epoxy and polyester resins are newcomers to highway usage. Most of the plastics have greater strength per unit of weight than metals; they also offer a wide range of chemical resistance properties.

Epoxy resins

During the past 5 years, an increasing number of State highway departments have used epoxy or thermosetting resins for seal coating—primarily on portland cement concrete bridge decks. These epoxy cements are applied as a thin layer, in quick-setting liquid form, to a clean roadway surface for sealing and waterproofing. Fine crushed aggregate of hard, sharp, and angular character is then added, before the resin hardens, to provide a skid resistant sandpaperlike finished product. This type of seal coat construction has been used in California, Connecticut, Kansas, Minnesota, New Jersey, New York, Ohio, and Wisconsin. The material has also been used in maintenance work for spot patching of pavements and for repairing disintegrated concrete in bridges.

Although this type of construction is relatively new, an estimated 1 million pounds of epoxy resin have been used in the past 5 years for highway construction and maintenance. The material has the following qualities: resistance to chemicals and other solvents; light weight; good adhesion; quick cure; toughness; resistance to cracking and freezing; and antiskid qualities in combination with abrasives.

Polyester resins

Another possible adaptation of plastics to the highway field is for guardrail beams. During 1959, car impact tests on beams made of polyester resin reinforced with glass fibers were conducted in Rhode Island. These beams were cast in the same form as conventional metal guardrail. The results of the test did not seem sufficiently conclusive either to warrant use of this new type of guardrail as standard or as a fully competitive alternate to conventional types. Additional experimentation by industry with this material for guardrail, culvert, underdrains, and other highway uses is desirable.

Polyethylene films.—At least 23 State highway departments have published specifications on the use of polyethylene film as a curing blanket or vapor barrier for portland cement concrete pavement. One of the principal advantages of this new adaptation of existing materials to the highway field is the flexibility of the film in providing good contact with the pavement. It aids in keeping the surface uniformly moist throughout the curing period. These plastic films also do not gain weight after rainfall and do not crack or mildew when wet. They can be reused by the contractor from 6 to 20 times without replacement.

Polyethylene film is also used in tape form to cover sawed joints in concrete paving during the curing period.

EXPLOSIVES

The constant increase in crawler tractor size and the more recent development of rear-end-mounted rippers have made it possible to excavate shale, weathered rocks, and other tight materials without the aid of explosives. These trends have been more than offset by the increased volumes of excavation required for a modern highway and by a 50-percent increase in aggregate requirements since the initiation of the expanded highway construction program. As a result, highway construction and maintenance during 1962 are expected to require about 140 million pounds of explosives.

Ammonium nitrate

Ammonium nitrate, which is also a fertilizer, is one of the newer types of explosives which are becoming more popular in quarrying operations and in the excavation of rock cuts. The relatively recent adaptation of diesel fuel as the hydrocarbon additive once the powder has been "prilled" or formed into small globes appears to have produced an extremely low-priced and effective explosive. A special surface treatment applied to the prills instead of a clay coating imparts anticaking characteristics and increases the blast sensitivity of the ammonium nitrate-fuel oil mixture.

This new method of using ammonium nitrate was due in part to the development of suitable rotary drills which are capable of producing dry blast holes, thus eliminating the need for water-resistant explosives. Several explosives manufacturers now furnish prilled ammonium nitrate in weatherproof plastic bags to facilitate handling and storage.

Other new developments

Ammonium nitrate is also used to replace a part of the nitroglycerin in extra grade dynamite to help impart lower velocity characteristics. Other new developments in explosive materials include—

- (1) Cast primers to prime explosive columns, particularly those using ammonium nitrate with diesel fuel. These primers do not contain nitroglycerin, are highly waterproof, and provide a very high detonation pressure.

- (2) Electric detonators with precise delay interval that will assure no overlapping of discharges.

- (3) Improved nonelectric detonators for use in areas where electrical interference presents a hazard. These are especially adaptable to bottom primes and produce less noise than ordinary prime cord.

- (4) A nonnitroglycerin gelatin explosive which has more explosive punch per pound and is particularly adaptable to bottom loads in hard massive rock.

LUMBER, PLYWOOD, AND TIMBER PILING

Lumber

The highway program requires substantial quantities of lumber and sized timber for both construction and maintenance. In addition to lumber for concrete forms, dimension stock is used for signs, sign posts, guardrail posts, bridges, bridge decks, picnic tables, maintenance buildings, and many other purposes. It is estimated that over 850 million board feet of lumber will be used for highway construction and maintenance this year.

In addition to treated structural lumber for bridge replacements, the maintenance requirements include a substantial amount of untreated lumber for local bridge redecking purposes, particularly on some of the older truss spans which are not capable of carrying a heavier flooring material. Many rural areas are still not within economical haul range of pressure-treating facilities. In most of these areas, the practice is to use the most durable local wood available or to import untreated planking. Some of the local species have a life expectancy of only about 5 years in areas of medium to high precipitation. On the other hand, bridge decking which is pressure treated with coal tar creosote, pentachlorophenol or wolman salts has a life expectancy of 20 to 30 years.

Prefabrication and treating.—Some of the large wood preserving companies stock prefabricated bridges of various span lengths including pier members, stringers, guardrail, sills, decking, and even component parts for small abutments.

An increasing number of highway departments are using guardrails and sign posts which have been treated with pentachlorophenol or some other light-colored preservative which is receptive to painting.

Plywood

High density overlaid plywood is used to a considerable extent in some States for signs. One claimed advantage is that in hunting areas it sustains less damage from rifle bullets than other types and is more readily repaired.

Timber piling

Timber piling has a number of uses in highway construction and maintenance. In construction it is used principally for bridge foundation support, for fender protection of bridge piers carrying movable spans, and for trestle bents on secondary roads. In maintenance, in addition to repairs and replacements, it is used to check slides and to control scouring or undercutting in streams that threaten bridges or highway embankments.

Most piling used in highway work is pressure treated with coal tar creosote or some similar preservative.

It is estimated that some 130 million board feet of timber piling will be used in 1962 for construction and maintenance purposes.

New pile-driving equipment.—One of the newest types of pile-driving equipment is the self-contained diesel pile-driving hammer. The unit was introduced into this country following World War II and is now manufactured or distributed by three American firms. One of its advantages is that it operates under its own power and does not require a steam generator or air compressor. Another new pile-driving concept which employs a sonic driving unit has been used successfully in experimenting with driving steel sheet piling for several soil conditions and will be tried experimentally on treated timber piles in the near future. In this driving method, the pile is vibrated to its resonant frequency with a mechanical oscillator which takes the place of a conventional driving head. As the pile alternately expands and contracts, the elongations made at expansion displace the soil at the tip of the pile, and under the superimposed oscillator the pile is forced into the ground.

Preboring for foundation piles.—The use of prebored pilot holes, for foundation piles, is on the increase and is particularly adaptable to some highway conditions such as penetration through hard surface strata or where expected settlement would add to the pile load by frictional down drag.

STRUCTURAL PAINTS

Surveys conducted by the Committee on the Maintenance of Highway Structures of the Highway Research Board indicate that the repainting of structural steel is the primary bridge maintenance problem.

Repainting costs

The cost of repainting steel to a considerable extent depends on how much cleaning and other preparatory work is required. It also varies with the type of steel members used in the structure. Costs ranging from \$6 to \$16 per ton have been experienced in applying two-coat systems.

Some of the more common materials used for prime coats include red lead and zinc chromate formulations. A red lead-iron oxide pigment is also used extensively for priming. Aluminum, white lead, and chrome green are commonly used in the wearing coat of a two- or three-coat system.

New paint formulations

The newer developments in aluminum paints include a nonflaking type for intermediate coats. This new paint has proven durability and provides a good color contrast with the leafing types which are commonly used as the finish coat. It eliminates the need for using blue coloring in the intermediate coat which becomes unsightly as the cover coat flakes away. Another recent development in aluminum paint is a semigloss green tinted aluminum enamel. Although aluminum paints generally have a good service record in most conditions of exposure, the light color is sometimes objectionable. This new green tinted aluminum enamel appears to satisfy both durability and esthetic considerations.

One of the newest paint systems which employs the same rust inhibitive material in all three coats is a basic lead silicochromate formulation which has given outstanding performance in weathering tests and in actual field performance. This pigment is used in varying quantities in the three coats. The basic orange color may be tinted for the finish coat to almost any color that is desired. The system is used almost exclusively in New York and is being tried out in five or six other States.

It has been estimated that over 4 million gallons of paint, including the metallic types, are used annually in the construction and maintenance of various types of highway structures.

TRAFFIC PAINTS

The steady increase in vehicular traffic and in the mileage of paved streets and highways is generating the need for a substantial amount of painted pavement markings. Another factor is the expanded use of pavement edge lines on expressways and for areas subject to fog conditions. It is estimated that over 8 million gallons of traffic paints will be applied on all highway systems during the current year. Under the provisions of the Manual of Uniform Traffic Control Devices which was revised in June 1961, all barrier markings, which are not to be crossed, including the double center lines on multilaned pavements will be marked with yellow paint. White was formerly permitted as an alternate color. This new standard will require a substantial increase in the use of yellow paint in which high grade chrome pigments are commonly used.

Cost of reflectorized markings

Most traffic paints are reflectorized for nighttime use by adding approximately 6 pounds of glass beads to each gallon of paint either before or after the paint has been applied. The cost of reflectorized painted markings, 4 inches wide, varies from about \$0.01 to \$0.02 per linear foot for each application depending on initial paint cost and film thickness applied. One application per year will often suffice on rural highways, but markings must be replaced three or four times a year on some high traffic routes, particularly where sand and other abrasives are used in snow and ice control operations.

Continuous experiments and testing of new traffic paints are going forward in many States. The objective is to develop a fast drying and durable painted marking with good reflective characteristics.

Trends in paint formulations

Most States are continuing to use the straight alkyd resin-type traffic paint. In the formulation of these paints, there is a trend toward greater use of soybean oil. Chlorinated rubber was introduced into traffic paints about 10 years ago to give them very fast drying properties and is being used to a considerable extent in some States. One of the newer traffic paints which shows considerable promise is formulated with a polyvinyl toluene—butadiene copolymer vehicle. Some experimental work is being done with traffic paints that use epoxy resin vehicles.

New testing methods

Traffic paints are purchased either by a composition or performance specification. When a composition type of specification is used, the exact amounts of all ingredients in the pigment and vehicle are spelled out in detail. The Ohio State Department of Highways has recently introduced infrared spectrophotometry for comparing the makeup of field shipments with the test paint sample on which acceptance of the bid was based. This quality control measure assures the delivery of paint which conforms to the approved formulation.

Those States which purchase paints on a performance basis give the manufacturer a wide selection of ingredients. They base competition on paints that have given acceptable performance under actual traffic test conditions.

Heating for viscosity control

One of the problems in applying paints in cold weather is their reduced viscosity. This required the introduction of thinners which tended to lessen their durability. Today, most pavement marking machines are equipped with heating units which assure uniform flow of the paint regardless of the ambient temperatures. Heating of the paint when the air temperature is below 65° F. also expedites drying. Modern paving marking machines are capable of placing three longitudinal markings at the same time, with two different paint colors, while operating at speeds of 10 to 15 miles per hour. These machines are capable of duplicating broken or dashed lines with a high degree of accuracy. Special machines have been developed for retrieving the rubber or plastic line protectors placed over longitudinal markings so that every phase of the pavement marking operation is now highly mechanized.

Thermoplastic pavement markings

There has been some increase in the use of thermoplastic pavement markings, particularly on high traffic routes in urban areas. To date, no practical mass production methods have been developed to make thermoplastic materials more competitive with traffic paints for rural marking applications.

PLASTICIZED SULFUR PAVEMENT MARKINGS

General characteristics

One of the newest pavement marking materials, which shows promise at the experimental stage, is plasticized sulfur. Basic sulfur, which costs only about a cent per pound, is modified by a plasticizer and applied to the pavement in a molten condition (about 400° F.). It hardens almost immediately and requires no protection after application. Present indications are that it can be applied in wet and freezing weather, when it is not possible to apply paints. The material has exceptional bonding qualities when applied to bituminous or portland cement concrete pavements; its outstanding durability has been demonstrated in tests conducted to date in Texas and California and in the Dominion of Canada.

Initial experience indicates there will be no difficulty in matching the standard "highway yellow" color, but some difficulty is encountered in obtaining a clear white color similar to that obtained with traffic paints containing white oxide pigments.

The successful development of sulfur pavement marking materials will require some modification of existing pavement marking machines, particularly if high production application rates are to be achieved in marking rural highways.

Other potential uses

Another potential use of plasticized sulfur is in the repair of shallow disintegrated areas on concrete bridge decks. This material has about the same compressive strength as portland cement concrete and may be bleached to about the same color. As previously mentioned, it has exceptional bonding qualities to pavement materials. It may also have application as a sealing material in constructing watertight bridge decks.

HIGHWAY SIGNS

General considerations

The principal sign background materials include aluminum, carbon steel, and high-density overlaid plywood. Nearly all signs which have application at night with the exception of no parking signs in the downtown areas of cities are reflectorized. Materials for reflectorizing sign backgrounds include flexible reflective sheeting and glass beads-on-paint. In addition, letters, numbers, and symbols may be reflectorized entirely or by component parts. Special application equipment has been developed for applying reflective sheeting and beads-on-paint to sign backgrounds.

Sign supports for signs of ordinary dimensions ($4 \pm$ square feet) include surfaced lumber both treated and untreated, half round treated timber posts and various light steel sections of which the U channel of about 2 pounds per linear foot is quite popular.

The intensity of signing varies to a considerable extent depending largely on the amount of traffic carried. Signing on the State primary systems will vary from about 15 to 25 signs per mile. The minimum sign assembly such as a single standard warning sign will cost about \$15 in place.

Cost of vandalism

One of the biggest sign maintenance problems is the repairs necessitated by vandalism. Experience shows that in some States vandalism generates one-third of the repair and replacement costs. A recent survey by the California Division of Highways reveals that vandalism to signs on the State system costs about \$300,000 per year. Two States report annual costs of \$50,000 to \$70,000 for repairing and replacing vandalized signs. In many areas, particularly where big game hunting prevails, it is difficult to appraise the durability of various sign materials because few signs are allowed to deteriorate under natural conditions.

Revision of national highway signing standards

Last year the national sign standards were revised and brought up to date through the joint efforts of the Bureau, the American Association of State Highway Officials, and other interested organizations. These standards include the "Manual on Uniform Traffic Control Devices for Streets and Highways," last prepared in 1948, and the AASHO "Manual for Signing and Pavement Marking of the National System of Interstate and Defense Highways" originally developed in 1958. These manuals establish the shape, color, and the dimensions of the materials which go into the smaller signs and the size of the messages to be carried on nearly all types of signs.

Design specifications for large sign supports

The large informational and directional signs specified for the Interstate System, particularly for overhead installations, introduced

a problem in the design and uniformity of supporting structures. A Joint AASHO-ARBA Subcommittee on Structural Support for Highway Signs, on which the Office of Engineering, Bureau of Public Roads, is represented, has recently developed design specifications for the construction of these sign supports. These large overhead sign supports add to the requirements of materials, particularly steel and aluminum, for the highway program.

Self-luminous signs

The incorporation of radioactive material into a highway structure is under development in producing a self-luminous highway sign. Electrically illuminated signs require an appreciable capital outlay for installation, maintenance, and power consumption. The costs increase considerably in remote areas due to powerload requirements. Remote signs are quite susceptible to loss of service from power breakdown, vandalism, and lamp failure. The power and maintenance problems may be sharply reduced with the use of radioactive self-luminous signs.

The materials proposed to provide radioactive energy are such elements as tritium, krypton, strontium or similar radioactive materials. The radioactive agent will be incorporated with a suitable phosphor. These luminescent materials may be of organic or inorganic composition. Materials making up the bulk of the sign will be similar to the standard electrical or reflectorized signs now in use.

Research is in progress supported by the Atomic Energy Commission to develop a self-luminous sign for directional, warning, and regulatory purposes, having the required peripheral range, legibility, and light intensity specified for traffic use. The half-life of the radioactive source encased in a ceramic would be expected to be about 12 years.

ELECTRONIC AND SCIENTIFIC PRODUCTS

Almost overnight a very sizable market has been generated by the demand of highway departments for electronic and scientific products. Many of these demands stemmed from the need to increase engineering productivity and accelerate the rate of highway construction so that we could carry out the tremendous highway program which is now underway. At the beginning of this program in 1956, progressive highway officials had for some time been looking at new developments in electronics and the sciences. They felt that these new developments could be and should be put to work to help them carry out the highway program efficiently, economically and with the highest possible quality. The fact that these officials were correct in their judgment has stimulated a large and growing market for these products.

Data-processing equipment

In 1955, after considerable study, the Bureau of Public Roads and some highway departments were convinced that the electronic computer, which was just becoming commercially available, could greatly facilitate all phases of highway engineering and administration. A series of regional meetings were held in 1956 and 1957 to encourage highway departments to study this possibility. Almost overnight interest in these high-speed computers grew and the demand for these facilities increased rapidly. Today, 48 State highway departments have computers, and the remainder are availing themselves of commercial facilities. At the present time a new demand for second-generation computer equipment is growing rapidly. This trend should continue in the future.

The rapid rise in the use of the computer has stimulated a demand for auxiliary data-processing equipment. In fact, the whole process of collecting, processing, and presenting highway engineering data is rapidly becoming an almost fully automatic production line with the equipment that has been developed and put to use by highway departments.

Today aerial surveys are, to a large extent, replacing many surveys formerly made on the ground. Data can now be taken from aerial photographs in digital form with the new equipment developments in stereoplotters that have taken place in the last few years. In this digitized form, the data is ready for storage and automatic processing in the computer. The results may be printed out automatically by the computer or may be fed to an electronic line plotter for graphic presentation. These new techniques have generated a substantial demand for all units of electronic equipment in this production line.

Transmission of field data to computer centers

More recently, with the addition of the larger capacities of the second generation equipment, additional new markets have appeared as the computer and other electronic equipment became more fully

integrated into highway operations. As the benefits of the computer became more established, field offices of the highway departments wanted computer service. This immediately entailed a data transmission problem. Industry endeavored to find a solution for this problem of transmitting large masses of data between field offices and computer centers. As a result, highway departments can meet their data transmission requirements through a variety of facilities. These include wire line equipment such as telegraph, facsimile, and teletype. Other systems combine wire line with radio transmission. An instrument developed specifically for the purpose permits the automatic transmission of data from punched cards or magnetic tape over wire lines or radio facilities to a computer center. Here the data are automatically received, recorded, stored, processed, and the results automatically transmitted back to the source.

Radio communications

There is a demand for many other electronic devices, and this too is growing rapidly. Radio was one of the earlier electronic devices that was used by highway departments. Since 1949 the number of highway departments which now have radio as an indispensable facility for their operations has grown from practically none to over a thousand. The State, county, and local highway departments used their radio systems primarily for voice communications.

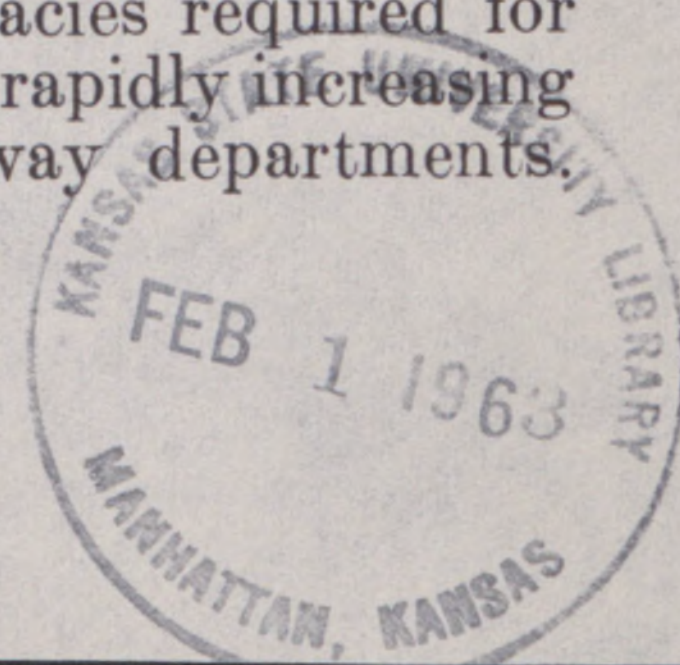
Microwave transmission systems

A great many more applications, however, have been developed in recent years. The advent of microwave has opened up a great many more new uses. Microwave is ideally suited to the transmission of masses of data. The number of State highway departments which have or are installing statewide microwave systems to supplement their low-band systems is growing rapidly. In the District of Columbia microwave radio facilities are now controlling the timing of traffic signals at several hundred intersections. It is planned that eventually over a thousand intersections will be so controlled. In New York City microwave is used to transmit a television picture of traffic in the Lincoln Tunnel to a traffic control center in New Jersey. Ohio plans to install television in each of its division offices which will operate on microwave channels. These statewide facilities will be used to train and assist field engineers from headquarters in the solution of a variety of problem such as those involved in right-of-way, pavement inspections, uniform specification interpretation, materials testing, etc.

New land surveying equipment

The wider use of aerial surveys in highway location design led to a need for more rapid means of installing ground control. Industry again endeavored to meet this new need. As a result, the geodimeter is now available which utilizes a beam of light to measure distances for ground control surveys.

In addition, the tellurometer is now available. With this instrument, which utilizes microwave radio frequencies, lines from 500 feet up to 40 miles can be measured within accuracies required for most highway work in a matter of half an hour. A rapidly increasing number of these units are now in use by highway departments.



Many new applications for microwave radio will no doubt generate a rapidly expanding market for these facilities.

Other electronic and scientific products

Electronic and other scientific devices are in increasing demand for the study and control of traffic, particularly in urban areas. On the Lodge Expressway in Detroit, 14 industrial television cameras continuously monitor traffic movement throughout its length. The pictures are transmitted by cable to a central traffic control office. Fast action can be taken from here to relieve congestion or handle accidents.

This system has recently been supplemented by a series of vehicle detectors. These detectors are connected to a battery of computers in the traffic control center. They give at any instant data on the number of vehicles, the speed of individual vehicles, the average speed of all vehicles, the percentage of lane occupied, and the types of vehicles. Further developments in this and similar systems will add to the demand for these devices.

Photoelectric, infrared, sonic, and radar devices are available and in use for studying traffic characteristics and for improving the movement of motor vehicles. There has been considerable experimental work by highway departments and industry in the development of automatic controls for motor vehicles. It has been demonstrated that full automatic control of motor vehicles is technically feasible but prohibitively expensive. There are, however, substantial fractions of the total automatic control system which can be and are being used to aid drivers. The market for these units should grow, too.

New developments in one field often go hand in hand or lead to new or improved products in others. For instance, the development of the nuclear moisture-density gage was accompanied by the production of an electronic scaler to count the backscatter gamma rays and the slow neutrons. Automatic controls for grading and paving equipment have encouraged an effort to develop a light-sensing device to follow a beam that is parallel to grade and alinement.

Wider application of nuclear energy for many highway applications will stimulate the market for gages to measure radiation intensities. Spectroscopes will be in greater demand as a means of identifying the composition of paints, asphalt, additives, admixtures, and other materials to check their conformance with specifications. Infrared photography seems destined for wider use to check the soundness of welds, for aerial surveys, and other purposes.

These are some of the new developments which will add to the market for electronic and scientific products as the highway program progresses. This trend will continue, probably at an accelerated rate. As these needs are met, they will foster further improvements in carrying out the highway program.

EXHIBITS

EXHIBIT A

[BPR 62-1, U.S. Department of Commerce, Bureau of Public Roads, for release Sunday, Jan. 7, 1962]

ESTIMATE OF RECEIPTS AND DISBURSEMENTS FOR HIGHWAYS, 1959-62

Nationwide receipts for highways will reach \$11.9 billion in 1961, and are expected to exceed \$12.2 billion in 1962, Rex M. Whitton, Federal Highway Administrator, announced today.

According to the latest estimates compiled by the Bureau of Public Roads, U.S. Department of Commerce, as shown in the accompanying table 1, imposts on highway users, including tolls and parking fees, will account for over \$9 billion or nearly three-fourths of all highway receipts in 1962, with Federal funds alone providing \$3.4 billion or slightly more than one-fourth of the total. These are receipts after deduction of the costs of collecting highway-user imposts, and of the allocations of some of these imposts (and in some instances of tolls) for non-highway purposes.

Most Federal funds are not expended directly, but are paid to States as Federal aid in reimbursement for work performed. The States also transfer to local governments about one-fourth of all State highway-user imposts as State aid for local roads and streets. Taking into account these intergovernmental transfers, the States in 1962 will administer \$8.2 billion of highway funds, or about two-thirds of the total.

Federal-aid reimbursements to the States are expected to increase about \$330 million over 1961, reflecting the strong financial position of the Federal Highway Trust Fund.

Total long-term debt outstanding for highway purposes at the end of 1960 was \$13.2 billion. It is estimated that there will be debt increases of \$686 million in 1961 and \$530 million in 1962, with the total outstanding debt reaching \$14.4 billion by the end of 1962. State obligations for highways will account for \$10.2 billion of this total, those of local rural governments \$1.5 billion, and of municipalities \$2.7 billion. The total debt will be almost equally divided between obligations for toll facilities and those for toll-free facilities.

Capital outlay (expenditures for highway right-of-way, engineering, and construction) is expected to reach \$7.3 billion in 1962, as shown in table 2. This is a substantial gain over the \$6.7 billion for 1961. Expenditures on municipal roads and streets will account for \$2.6 billion, or slightly more than one-third of the total.

Expenditures for maintenance, administration, policing, and debt service are all expected to show increases in 1962.

Highway construction expenditures (excluding right-of-way and engineering costs) are expected to reach \$5.6 billion in 1962, compared with \$5.1 billion in 1961 and \$4.9 billion in 1960, as shown on table 3. Right-of-way accounts for about 15 percent of the total capital expenditures for all roads and streets, and over one-fifth of the total expenditure on the Interstate System. Preliminary and construction engineering expenditures are nearly 8 percent of total capital expenditures. Construction expenditures on the Interstate System will account for one-third of the total in 1962, and three-fourths of the total will be expended on the various Federal-aid systems.

BUREAU OF PUBLIC ROADS REPORT

TABLE 1.—Total receipts for highways, all units of government, 1959-62¹

[Amounts in millions of dollars]

Item	Collecting agencies									
	1959					1960				
	Federal Government	State agencies and District of Columbia	Local rural governments	Municipalities	Total	Federal Government	State agencies and District of Columbia	Local rural governments	Municipalities	Total
Imposts on highway users: ²										
Motor fuel and vehicle taxes	3 2, 240	4, 428	9	66	6, 743	3 2, 826	4, 732	11	68	7, 637
Tolls	-----	396	20	54	470	-----	430	21	57	508
Parking fees	-----	1	-----	56	57	-----	1	-----	70	71
Total	2, 240	4, 825	29	176	7, 270	2, 826	5, 163	32	195	8, 216
Other taxes and fees:										
Property taxes and assessments	-----	-----	512	389	901	-----	-----	485	412	897
General fund appropriations	156	48	153	346	703	159	56	121	348	684
Miscellaneous taxes and fees	10	47	3	7	67	11	62	3	7	83
Total	166	95	668	742	1, 671	170	118	609	767	1, 664
Investment income and other receipts	22	89	45	71	227	21	100	47	73	241
Bond issue proceeds (par value) ⁴	-----	669	153	336	1, 158	-----	680	190	336	1, 206
Grand total, receipts	5 2, 428	5, 678	895	1, 325	10, 326	5 3, 017	6, 061	878	1, 371	11, 327
Intergovernmental payments:										
Federal Government	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
State agencies	-3, 080	+3, 059	+21	+364	-----	-2, 543	+2, 521	+22	-----	-----
Local rural governments	-----	-1, 176	+812	+37	-----	-----	-1, 235	+845	+390	-----
Municipalities	-----	+63	-100	-55	-----	-----	+55	-93	+38	-----
Total	-3, 080	+1, 998	+736	+346	-----	-2, 543	+1, 387	+777	+379	-----

	1961 (preliminary)					1962 (forecast)				
	+809	-266	-21	+38	+560	-313	-323	+12	+40	-584
Funds drawn from (+) or placed in (-) reserves-----										
Total funds available-----	157	7,410	1,610	1,709	10,886	161	7,125	1,667	1,790	10,743
Imposts on highway users: ²										
Motor fuel and vehicle taxes-----	³ 2,922	4,924	13	71	7,930	³ 3,128	5,195	15	73	8,411
Tolls-----		455	23	58	536		475	24	59	558
Parking fees-----		1	1	80	82		1	1	90	92
Total-----	2,922	5,380	37	209	8,548	3,128	5,671	40	222	9,061
Other taxes and fees:										
Property taxes and assessments-----										
General fund appropriations-----	192	59	501	436	937			495	460	955
Miscellaneous taxes and fees-----	12	62	2	7	83	209	59	100	366	734
Total-----						11	62	2	8	83
Investment income and other receipts-----	204	121	618	803	1,746	220	121	597	834	1,772
Bond issue proceeds (par value) ⁴ -----	24	100	43	77	244	25	100	43	80	248
Total-----		800	190	335	1,325		641	202	342	1,185
Grand total receipts-----	³ 3,150	6,401	888	1,424	11,863	³ 3,373	6,533	882	1,478	12,266
Intergovernmental payments:										
Federal Government-----	-2,960	+2,938	+22			-3,299	+3,277	+22		
State agencies-----		-1,263	+885	+378			-1,312	+920	+392	
Local rural governments-----		+55	-93	+38			+55	-93	+38	
Municipalities-----		+48	+3	-51			+48	+3	-51	
Total-----	-2,960	+1,778	+817	+365		-3,299	+2,068	+852	+379	
Funds drawn from (+) or placed in (-) reserves-----	-7	-667	+13	+56	-605	+118	-410	+17	+46	-229
Total funds available-----	183	7,512	1,718	1,845	11,258	192	8,191	1,751	1,903	12,037

¹ Federal and State data are for calendar years; local data for fiscal years ending in various months of the calendar year. Data for 1959 are final; those for later years are subject to future adjustment.

² Excludes amounts allocated for collection expenses and nonhighway purposes.

³ Receipts of the Federal highway trust fund.

⁴ Proceeds of short-term notes and refunding issues are excluded. Premium and discounts on sale of bonds are included in miscellaneous income.

⁵ Includes forest highway and other funds administered by the Bureau of Public Roads, as well as funds of other Federal agencies not derived from the highway trust fund.

TABLE 2.—Total disbursements for highways, all units of Government, 1959-62¹

[Amounts in millions of dollars]

Item	Expending agencies							
	Federal Government	State agencies and District of Columbia	Local rural governments	Municipalities	Total	1960		
						Federal Government	Total	
1959								
Capital outlay (right-of-way and construction):								
On rural State-administered highways		3,605	22		3,627		23	3,317
On municipal extensions of State highways		1,471		14	1,485			1,391
On local rural roads		279	474		753		500	737
On local municipal roads and streets		47	25	617	689		21	754
On roads in Puerto Rico	8				8	5		5
Not classified by system	94				94	102		102
Total	102	5,402	521	631	6,656	107	544	6,306
Maintenance:								
On rural State-administered highways		814	2		816		2	886
On municipal extensions of State highways		89		1	90			102
On local rural roads		13	869		882		890	903
On local municipal roads and streets		7	3	658	668		3	690
On roads in Puerto Rico					25	26		26
Not classified by system	25							
Total	25	923	874	659	2,481	26	895	2,607
Administration and research ²	30	287	86	62	465	28	94	484
Highway police and safety		218	5	72	295		5	317
Interest on debt		272	32	75	379		33	413

Debt retirement (par value) ³	-----		-----		-----		-----		-----		-----		-----	
	157	308	92	210	610	-----	-----	-----	-----	-----	-----	-----	-----	-----
Grand total, disbursements	-----	7,410	1,610	1,709	10,886	161	7,125	1,667	1,790	220	-----	616	-----	-----

1961 (preliminary)														

1962 (forecast)														

Capital outlay (right-of-way and construction):														
On rural State-administered highways	-----	3,395	25	-----	3,420	-----	3,797	25	-----	-----	-----	3,822	-----	-----
Municipal extensions of State highways	-----	1,572	-----	18	1,590	-----	1,718	-----	19	-----	-----	1,737	-----	-----
On local rural roads	-----	201	523	-----	724	-----	232	538	-----	-----	-----	770	-----	-----
On local municipal roads and streets	-----	109	22	672	803	-----	126	23	689	-----	-----	838	-----	-----
On roads in Puerto Rico	5	-----	-----	-----	5	-----	-----	-----	-----	-----	-----	6	-----	-----
Not classified by system	118	-----	-----	-----	118	-----	-----	-----	-----	-----	-----	124	-----	-----
Total	123	5,277	570	690	6,660	130	5,873	586	708	-----	-----	7,297	-----	-----

Maintenance:														
On rural State-administered highways	-----	926	2	-----	928	-----	958	2	-----	-----	-----	960	-----	-----
On municipal extensions of State highways	-----	106	-----	1	107	-----	111	-----	1	-----	-----	112	-----	-----
On local rural roads	-----	14	910	-----	924	-----	15	921	-----	-----	-----	936	-----	-----
On local municipal roads and streets	-----	6	3	700	709	-----	6	3	718	-----	-----	727	-----	-----
On roads in Puerto Rico	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Not classified by system	27	-----	-----	-----	27	-----	-----	-----	-----	-----	-----	29	-----	-----
Total	27	1,052	915	701	2,695	29	1,090	926	719	-----	-----	2,764	-----	-----
Administration and research ²	33	305	97	68	503	33	314	100	75	-----	-----	522	-----	-----
Highway police and safety	-----	250	5	80	335	-----	264	5	83	-----	-----	352	-----	-----
Interest on debt	-----	315	33	78	426	-----	331	34	82	-----	-----	447	-----	-----
Debt retirement (par value) ³	-----	313	98	228	639	-----	319	100	236	-----	-----	655	-----	-----
Grand total, disbursements	183	7,512	1,718	1,845	11,258	192	8,191	1,751	1,903	-----	-----	12,037	-----	-----

¹ Federal and State data are for calendar years; local data for fiscal years ending in various months of the calendar year. Data for 1959 are final; those for later years are subject to future adjustment.

² Includes small amounts of engineering and equipment costs not charged to capital outlay and maintenance, and miscellaneous expenditures.

³ Redemption premiums and discounts are included with interest payments. Redemption of short-term notes, or by refunding, is excluded.

TABLE 3.—Estimated capital expenditures for highways, 1959-62, by Federal systems, by expending agencies

[In millions of dollars]

Expending agencies	Federal-aid systems								Other State roads				Other local roads and streets				All systems			
	Interstate system				Other A-B-C systems				Right-of-way	Engi-neer-ing	Con-struction	Total	Right-of-way	Engi-neer-ing	Con-struction	Total	Right-of-way	Engi-neer-ing	Con-struction	Total
	Right-of-way	Engi-neer-ing	Con-struction	Total	Right-of-way	Engi-neer-ing	Con-struction	Total												
1959	473	186	1,553	2,212	275	218	2,136	2,629	53	22	221	296	---	3	52	55	801	429	3,962	5,192
	2	3	159	164	2	1	19	22	---	---	19	19	---	---	5	5	4	4	202	210
	3	4	43	50	1	---	5	6	---	---	---	---	---	---	22	23	4	5	70	79
	---	---	---	---	19	1	2	22	---	---	---	---	23	35	439	497	42	36	441	519
	---	---	---	---	11	1	2	14	---	---	---	---	33	38	469	540	44	39	471	554
	---	---	---	---	---	---	---	---	---	---	---	---	---	3	91	94	---	3	91	94
Total	478	193	1,755	2,426	308	221	2,164	2,693	53	22	240	315	56	80	1,078	1,214	895	516	5,237	6,648
1960	408	170	1,467	2,045	307	205	1,942	2,454	34	20	208	262	1	3	52	56	750	398	3,669	4,817
	8	3	93	104	2	2	35	39	3	1	19	23	---	---	---	---	13	6	147	166
	2	5	53	60	---	---	5	5	---	---	---	---	1	2	19	22	3	7	77	87
	---	---	---	---	19	2	2	23	---	---	---	---	25	36	458	519	44	38	460	542
	---	---	---	---	12	1	3	16	---	---	---	---	38	40	493	571	50	41	496	587
	---	---	---	---	---	---	---	---	---	---	---	---	---	3	99	102	---	3	99	102
Total	418	178	1,613	2,209	340	210	1,987	2,537	37	21	227	285	65	84	1,121	1,270	860	493	4,948	6,301
1961 (PRELIMINARY)	516	187	1,539	2,242	324	212	1,997	2,533	38	21	221	280	1	2	43	46	879	422	3,800	5,101
	---	2	79	81	3	4	66	73	---	---	20	22	---	---	---	---	3	8	165	176
	1	3	30	34	---	---	5	5	---	---	---	---	1	2	19	22	2	5	54	61
	---	---	---	---	20	2	3	25	---	---	---	---	27	38	478	543	47	40	481	568
	---	---	---	---	13	1	4	18	---	---	---	---	40	43	530	613	53	44	534	631
	---	---	---	---	---	---	---	---	---	---	---	---	---	4	114	118	---	4	114	118
Total	517	192	1,648	2,357	360	219	2,075	2,654	38	23	241	302	69	89	1,184	1,342	984	523	5,148	6,655

1962 (FORECAST)	599	218	1,791	2,608	312	214	2,046	2,572	47	30	320	397	1	2	49	52	959	464	4,206	5,629
State highway departments.	1	3	78	82	7	7	99	113	1	5	43	49					9	15	220	244
State toll facilities-----	2	3	39	44			5	5					1	2	19	22	3	5	63	71
Local toll facilities-----							3	25					29	39	491	559	49	41	494	584
Local rural governments-----					20	2	3	19					41	44	535	620	54	45	540	639
Municipalities-----					13	1	5							3	121	124		3	121	124
Federal Government-----																				
Total-----	602	224	1,908	2,734	352	224	2,158	2,734	48	35	363	446	72	90	1,215	1,377	1,074	573	5,644	7,291

1 Excludes expenditures on roads in Puerto Rico.

EXHIBIT B

MIXING TIME ON MULTICOMPARTMENT PAVERS—SUMMARY AND ANALYSIS

(By William Byrd Huffine, Chief, Procedures and Operations Branch, Division of Development, Office of Operations, Bureau of Public Roads, U.S. Department of Commerce, March 1961)

Reported nationwide variations in mixing time specified for multicompartment pavers are currently as delineated on the accompanying summary form No. 1. By this alphabetical listing of States under the five specific numerical specifications now in force, the apparent lack of consensus as to such requirements is clearly shown. It should be noted, however, that data for six States have been excluded from those groupings as not applicable due to little or no current activity on their part in portland cement concrete paving. Accordingly, the remaining States constitute the statistical universe whose range of variability is analyzed.

Indicated variance among States in such mixing time apparently stems only partially from differences of opinion concerning requirements considered necessary to insure quality control. In other words, such variations appear secondarily ascribable—and to a somewhat measurable degree—both to lack of accord with respect to the question of transfer time, and to absence of a common denominator in defining “when mixing time begins.” Respective positions of the States with respect to both of those factors are incorporated on the accompanying summaries, the first mentioned on form No. 1 and the latter on form No. 2. Fortunately, however, no corresponding lack of agreement is apparent with respect to “when mixing time ends.” Consequently, and in view of a seeming consensus to the effect that current usage of modern automatic timing devices has minimized the importance of that question, it has been eliminated from this discussion. No corresponding conclusion is possible, however, with respect to either transfer time or initiation of mixing time. Accordingly, both of those problems merit further consideration.

The accompanying summaries reflect a condensation of responses to the Commissioner's circular memorandum of January 16, 1961. They are significant, not only in portraying widespread variations among the States in specified mixing time, but also—and more importantly—in pointing up or identifying areas of possible improvement. Noteworthy, from the standpoint of economy of operations, is the recent lessening—by a number of States as indicated—of previously existing restrictions precluding full realization of modern multicompartment paver capabilities. To those actions there no doubt may be attributed proportionate savings in the cost of concrete pavement. Overall potentialities of a more widespread acceptance among the States of such savings—when translated and accrued through proven economies in the highway program—are obviously tremendous. It is likewise noteworthy to witness the progress in that direction evidenced by the actions footnoted on form No. 1. A definitely favorable trend seemingly is being established.

One fundamental index of such trend is the fact more than half of the States now reportedly agree with American Association of State Highway Officials' endorsement of a 60-second mixing time overall adequacy for multicompartment pavers. In addition, five States have further extended such acceptance to realize additional benefits by authorizing a 50-second optional mixing time under circumstances outlined on summary form No. 1. By way of contrast, 10 States still cling to the once predominantly accepted requirement of 75 seconds for batch capacities in excess of 1 cubic yard. This becomes a limiting feature in view of the fact capacities of that order of magnitude are indigenous to multicompartment paver operation. To complete the spectrum, we find two States claiming distinction in each of two other uncommon groupings; namely, 65 and 90 seconds, respectively. However, one of the two States in the 90-second category reportedly is actively in the process of joining the 60-second majority consensus.

As implied by the foregoing discussion, the lack of uniformity among States with respect to mixing time is associated with lack of accord concerning inclusion or exclusion of transfer time. In addition, a corollary complication exists in the form of inconsistency in defining when mixing actually begins. Both of these aspects of the problem may be brought quite clearly into focus by examination of the background material and supporting data forwarded with the aforementioned Commissioner's memorandum of January 16. It was therein demonstrated quite conclusively that no valid reason exists for considering transfer time as a proper exclusion from mixing time in modern multicompartment paver operation. Accordingly, it is encouraging to witness the increasing accord with that conclusion. However, with respect to defining when mixing time begins, the outlook is less determinate. The complete lack of pattern disclosed by self-explanatory summarizations on form No. 2 is indicative of a need for concerted action toward solution of that problem. However, through efforts of the Joint ARBA-AASHO Committee on Mixing Time, there have been evoked certain conclusions, the acceptance of which will no doubt be a forward step in that direction. These are now actively under consideration.

In summary, except for the subsidiary minor question of defining when mixing time actually begins, the problem of bringing into more universal acceptance mixing time criteria in consonance with modern equipment capabilities would appear well along the road to resolution.

Summary Form No. 1—Specified mixing time on Multicompartment pavers

Specified number of seconds mixing time					Not applicable; little or no concrete pavement currently placed
50	60	65	75	90	
Arizona* California* Oregon* ¹ Texas Washington* ²	Alabama* Arkansas Colorado* Florida Illinois* Indiana ³ Iowa* Kansas* Kentucky ³ Louisiana ³ Maryland* Michigan Mississippi* Missouri* Nebraska New Mexico ³ North Carolina ⁴ North Dakota* Ohio* Oklahoma ³ Rhode Island South Carolina South Dakota ⁵ Virginia* West Virginia Wisconsin* Wyoming	Alaska* Minnesota ⁶	Connecticut* District of Columbia ⁷ Georgia ⁸ Maine* Massachusetts Montana New York* Pennsylvania ⁹ Puerto Rico* ⁷ Tennessee*	Delaware ¹⁰ New Jersey	Hawaii Idaho Nevada New Hampshire Utah Vermont

¹ 50 seconds authorized only for automatically controlled operations.

² 50 seconds authorized by special provisions.

³ Revision of specifications to include transfer time under study.

⁴ Transfer time included only for new tribatch paver operations.

⁵ Specifications being revised to include transfer time.

⁶ One-half of estimated 10-second transfer time included.

⁷ District of Columbia and Puerto Rico counted as States.

⁸ 75 seconds required for all batches greater than 1 cubic yard.

⁹ Transfer time included for capacities greater than 1 cubic yard.

¹⁰ Less restrictive specifications under study.

*Indicates transfer time included in mixing time.

Summary Form No. 2—Definition of when mixing time begins

When all materials except water are in drum	When all materials (including water) are in drum	Otherwise as indicated	Not applicable; little or no concrete pavement currently placed
California Delaware District of Columbia ¹ Georgia Illinois Indiana Iowa Kentucky Louisiana New Mexico North Carolina Oregon South Carolina South Dakota Tennessee Texas Virginia Wisconsin	Alabama Alaska Arizona Arkansas Colorado Florida Maryland Mississippi Montana New Jersey New York North Dakota Ohio Oklahoma Pennsylvania Rhode Island West Virginia Wyoming	Connecticut ² Kansas ² Maine ³ Massachusetts ³ Michigan ³ Minnesota ⁴ Missouri ² Nebraska ⁵ Puerto Rico ⁵ Washington ⁵	Hawaii Idaho Nevada New Hampshire Utah Vermont

¹ District of Columbia and Puerto Rico counted as States.

² When all materials except part of water are in drum.

³ Not definitely specified.

⁴ When all materials have been discharged from skip.

⁵ When skip reaches highest elevation.

EXHIBIT C

U. S. DEPARTMENT OF COMMERCE Bureau of Public Roads	POLICY AND PROCEDURE MEMORANDUM 60-2 Date of issuance: June 22, 1959
RESEARCH	
SUBJECT: HIGHWAY PROJECTS INVOLVING EXPERIMENTAL FEATURES	
Supersedes: Memoranda dated November 1, 1938, April 30, 1948, May 22, 1950, and November 6, 1950, Temporary Topic 60-B.	

1. PURPOSE

The purpose of this memorandum is to prescribe the objectives, policies and procedures relating to highway construction projects in which experimental features are incorporated.

2. OBJECTIVES

The objectives of the experimental highway construction program are:

- To determine and evaluate the absolute or relative merits of new, nonstandard or alternate highway design and construction features by utilizing them in highway construction work and observing their behavior under actual highway service conditions.
- To disseminate the findings and promote the adoption and use in future highway design and construction of those features found to produce the best results from the standpoint of service behavior and economy of construction and maintenance.
- To ascertain the desirability of further experimentation and research with respect to such features.

3. DEFINITIONS AND CHARACTER OF PROJECTS

a. Experimental highway construction is construction in which one or more experimental features have been incorporated or utilized for the purpose of accomplishing the objectives set forth in paragraph 2, regardless of whether the incorporation or utilization of the experimental feature is a primary or incidental consideration in undertaking the project.

b. Experimental projects may vary greatly in the degree to which they are controlled varying from (1) projects requiring extensive planning and with precisely controlled conditions in which provision is made for determination of results with a high degree of detail and accuracy through close observation and extensive instrumentation, to (2) projects requiring little advance planning and with only moderately controlled conditions without instrumentation where observations are limited to a visual comparison between the experimental and control sections.

c. An experimental feature may be either a material, process, method, equipment item or other feature that:

- (1) has not been sufficiently tested under actual service conditions to merit acceptance without reservation in normal Federal-aid highway construction; or
- (2) has already been accepted but is included along with alternate accepted features for the purpose of determining their relative merits under comparable conditions.

d. A control section, as used in this memorandum, is a section of highway designed and constructed in standard manner on the same project as the experimental section and as nearly as practicable under identical conditions so that comparisons may be made between the standard and the experimental construction.

4. GENERAL PRINCIPLES AND POLICIES

a. Experimental construction projects may be initiated by the State highway departments or may be undertaken by them at the suggestion or request of the Bureau of Public Roads.

b. The approval of the experimental project or of experimental or nonstandard features to be incorporated in a project will be given by the division engineer, in accordance with the usual procedure for approval of plans, specifications, and estimates for Federal-aid projects. In the case of projects for which the experimental aspects are of major importance, or which involve financing with 1-1/2 per cent funds authorized by 23 USC 307(c), approval of the PS&E should not be given prior to receipt and

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June 22, 1959

consideration of the Washington office comments and recommendations in accordance with the provisions of paragraph 5a. Whenever time will permit, it will be desirable to follow the same procedure for all other experimental projects.

c. The experimental program will be jointly administered by the Offices of Engineering and Research as a cooperative effort.

d. All available data bearing on the subject of the experiment should be assembled and analyzed, the nature and objective of the experiment should be determined, and the materials and construction methods to be used should be agreed upon between the State and Public Roads, to the maximum extent practicable, well in advance of preparing the plans and specifications.

e. To facilitate evaluation and determination of the effect of the designated experimental features on the success or failure of the construction, provision should be made for control sections on all experimental construction projects.

f. When more than one alternate experimental feature is to be studied on the same project, each one should be incorporated in a separate section of otherwise identical construction so that the effects of each can be ascertained individually.

g. Sufficient cost data should be compiled for each alternate, whenever feasible, to afford a comparison of costs as well as results. In some instances, it may be necessary to extend the cost studies to the maintenance of the completed project and to the life of the construction if a true comparison of ultimate costs is to be provided.

h. In addition to setting up experimental construction projects in such manner that a comparison can be made between alternate features having considerable cost differential, it may be advisable under some circumstances to vary the alternate features in such manner that they will have approximately equal total costs.

5. PRECONSTRUCTION PROCEDURES

a. When a State contemplates undertaking experimental construction as a part of a Federal-aid project, it should submit its proposal to the division engineer. The Washington office is to be informed, through the regional office, of the subject and nature of the proposed experiment. The subject matter will be considered by the interested divisions of the Offices of Engineering and Research, after which the Washington office will furnish such information on the subject as it may have from other sources.

Suggestions may be given as to factors for consideration: (1) in determining whether sufficient information has already been accumulated to make additional experimental work of this kind unnecessary, in whole or in part; and (2) in planning and constructing the project to the end that, in addition to serving its intended purpose with respect to the particular problems of the State in which it is located, the project may also provide data needed in connection with similar problems elsewhere.

b. The division engineer should present the suggestions of the Washington office to the State for the purpose of arriving at a mutually satisfactory understanding for use in preparing the necessary plans, specifications, and estimates. In some cases, it may be desirable to have representatives from the Washington office present during this planning stage.

c. As soon as the planning and designing of the project have become sufficiently advanced and firmly established, a preconstruction report is to be made to the Washington office giving a detailed description of the nature of the experiment, its objective, the proposed layout, materials, equipment, and methods to be used, the anticipated traffic and other conditions having a bearing on the project. The comments of the division and regional offices are to be included in or accompany the report.

6. PROJECT INSPECTIONS AND REPORTS

a. As the construction of the project progresses, inspections are to be made of both experimental sections and the control sections by division office representatives and reports submitted through the regional office to the Washington office to the extent necessary to keep all concerned fully informed regarding the progress, the problems and interesting developments encountered, and the results. When the project is of sufficient importance or interest, representatives of the regional and Washington offices may also inspect the project during construction operations and during the post construction period.

b. The reports should follow the attached outlines which have been developed as a general checklist and aid for developing uniform, accurate and complete reporting of experimental construction projects. Uniform headings and descriptions of the project should be used to facilitate subsequent review, evaluation and summarization of the data presented. The text of the reports should follow the lettered subject headings only as the sequence, paragraph development, and suggested content may be pertinent.

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c. The first progress report should be submitted as soon as possible after start of the construction. Subsequent reports should be numbered consecutively. A complete initial progress report obviates the need for repeating basic information in subsequent reports.

d. After completion of the construction, periodic inspections are to be made and reports submitted as often as warranted by conditions developing on the project. In general, reports should be submitted at least once a year even though they merely report that no change has occurred. A final report is to be submitted as soon as it becomes evident that no additional information of interest or experimental value is likely to develop.

e. Inspections should be made and reports prepared by engineers having sufficient knowledge and understanding of the objectives and controlling conditions of the experiment that they can accurately appraise the results and draw conclusions therefrom. The items to be reported will vary from job to job but the reports are to adequately describe all conditions developing during or after the construction that have a bearing on the results of the experiment. The reports should include discussion of any significant differences in maintenance requirements and costs. The final report should include a discussion of the conclusions reached, and recommendations with respect to further experimentation along the same or related lines. If, during the inspections, significant features are found that were not contemplated as a part of the experimental construction as originally planned, they should also be reported with all pertinent data.

7. SUBJECT SUMMARIES

The data contained in the experimental project reports will be analyzed and evaluated in the Washington office. Subject summaries will then be prepared by the Office of Engineering with the cooperation of the Office of Research, consolidating for each experimental subject the findings on all projects in which comparable experimental features or alternate features have been incorporated. These summaries will include final or tentative conclusions on the merits of the experimental feature to whatever extent such conclusions are justified on the basis of evaluation of the data. Recommendations with respect to desirable further experimentation regarding the subject will also be included in the summary reports. Copies will then be distributed to Public Roads offices and to the State highway departments for consideration in connection with the use of the experimental feature in subsequent highway construction and in connection with undertaking further experimentation or research on the same or related subjects.

8. FINANCING

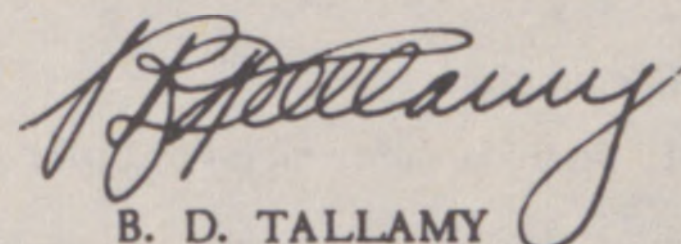
a. Experimental construction on Federal-aid projects shall be financed in the same manner as regular Federal-aid projects. The nature, type, and extent of the work shall be described in the PS&E, included in the advertising for bids, and made a part of the contract.

b. Observations and recording of data requiring instrumentation or expense in collection and assembly of information, including analysis, interpretation, and reporting of data, may be considered for inclusion in the program of engineering and economic investigations financed with 1-1/2 percent funds.

9. ADDITIONAL EXPERIMENTAL PROJECTS

a. Division and regional offices should constantly be on the alert for new ideas that show promise of developing improved practices, methods, designs, materials, and equipment and of improving the quality or the economy of the highway construction produced, or both. It is also their responsibility to encourage the State highway departments to undertake experimental construction projects for the purpose of ascertaining the merits of such features.

b. Experimental construction on projects financed under the 1954 Secondary Road Plan and on non-Federal-aid highway projects should also be reported. Data reported and procedures followed should be the same insofar as practicable as for regular Federal-aid experimental projects.



B. D. TALLAMY
Federal Highway Administrator

Attachments

PPM 60-2, Attachment, page 1
June 22, 1959

U. S. DEPARTMENT OF COMMERCE
Bureau of Public Roads

EXPERIMENTAL PROJECT (type of experiment involved)
(Example: EXPERIMENTAL PROJECT-DIAGONAL JOINTS IN CONCRETE PAVEMENT)
INITIAL-PRECONSTRUCTION REPORT

Report No. 1

Date _____

Reported by _____ Division _____
County _____ State _____
U. S. or State Route, County _____ Project No. _____
Route or Street name _____ Type Code _____
Termini by description _____
Station Numbers and exceptions _____
Mileage _____

A. Nature and objective of experiment.

1. Purpose of the experiment and feasible application of results that may be developed from the experiment.
2. Outline of essential features in the experiment.
3. Design—attach typical cross sections.
 - a. Description of replaced and new facilities.
 - b. Drainage.
4. Plan of study and evaluation.
5. Frequency of inspection—annual, seasonal, other specific times.

B. Construction Methods.

1. Methods and means to be used in constructing the experimental features.
2. Materials to be used.
 - a. Source—Producer and Location.
 - b. Test data.
 - c. Subgrade, subbase, surfacing, structures.
3. Equipment to be used.
4. Estimated cost of experimental design and standard design.

C. Traffic

1. Volume
 2. Character
- } Past, present and estimated future.
- a. Loading

D. Discussion.

1. Include references to other projects involving the same or similar experimental features.

E. Estimated construction starting date.

F. Attachments:

1. Sketch Map, in such detail that experimental sections will be clearly shown.
2. Typical cross sections.

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June 22, 1959

(This report is to be separate and distinct from
regular Construction Inspection Report Form 33-A)

U. S. DEPARTMENT OF COMMERCE
Bureau of Public Roads

EXPERIMENTAL PROJECT (type of experiment involved)
(Example: EXPERIMENTAL PROJECT-DIAGONAL JOINTS IN CONCRETE PAVEMENT)
CONSTRUCTION REPORT

Report No. _____

Inspection Date _____

Inspection made by: _____ Division _____

_____ State _____

In company with: _____ Project No. _____

_____ Type Code _____

- A. Nature and objective of experiment. (A brief statement is desired here.)
- B. Construction Methods. (Supplementing and amending information given in the Initial-Preconstruction Report.)
- C. Discussion.
1. Conditions likely to influence service behavior which were not mentioned in the Initial-Preconstruction Report.
- D. Attachments such as photographs, charts, tabulations, etc.



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June 22, 1959U. S. DEPARTMENT OF COMMERCE
Bureau of Public RoadsEXPERIMENTAL PROJECT (type of experiment involved)
(Example: EXPERIMENTAL PROJECT-DIAGONAL JOINTS IN CONCRETE PAVEMENT
CONDITION-POSTCONSTRUCTION REPORT)

Report No. _____

Inspection Date _____

Inspection made by: _____

Division _____

State _____

In company with: _____

Project No. _____

Type Code _____

Date Construction _____

Completed _____

Type of Inspection: Routine or Special (If special state purpose):

A. Nature and objective of experiment. (A brief statement is desired here.)

B. Condition of project. (A brief statement summarizing the condition of the project at the time of inspection and the amount of change that has occurred since the previous inspection. Complete details should be given further in report.)

C. Conclusions

1. Conclusions should be reported in earliest report after they become apparent.
2. Indications pointing toward conclusions that may be drawn after further observations should be reported as soon as they become apparent.

D. Condition and Maintenance Record

1. Comparison of Experimental and Control Sections

a. Riding quality of pavement

- (1) Influence of experimental features
- (2) Influence of other factors
- (3) Change since previous report

b. State of preservation

- (1) Influence of experimental features
- (2) Influence of other factors
- (3) Change since previous report

c. Maintenance received since previous report

E. Discussion

1. Comparison with standard or current design, construction and maintenance features with respect to:

- a. Strength
- b. Durability
- c. Cost
- d. Maintenance

2. Results of experiment

F. Attachments not previously submitted such as photographs, charts, tabulations, which should be included with report when available.

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U. S. DEPARTMENT OF COMMERCE
Bureau of Public Roads

EXPERIMENTAL PROJECT (type of experiment involved)
(Example: EXPERIMENTAL PROJECT-DIAGONAL JOINTS IN CONCRETE PAVEMENT)
FINAL CONDITION REPORT

Report No. _____

Inspection Date _____

Inspection made by: _____

Division _____

State _____

In company with: _____

Project No. _____

Type Code _____

Date Construction _____

Completed _____

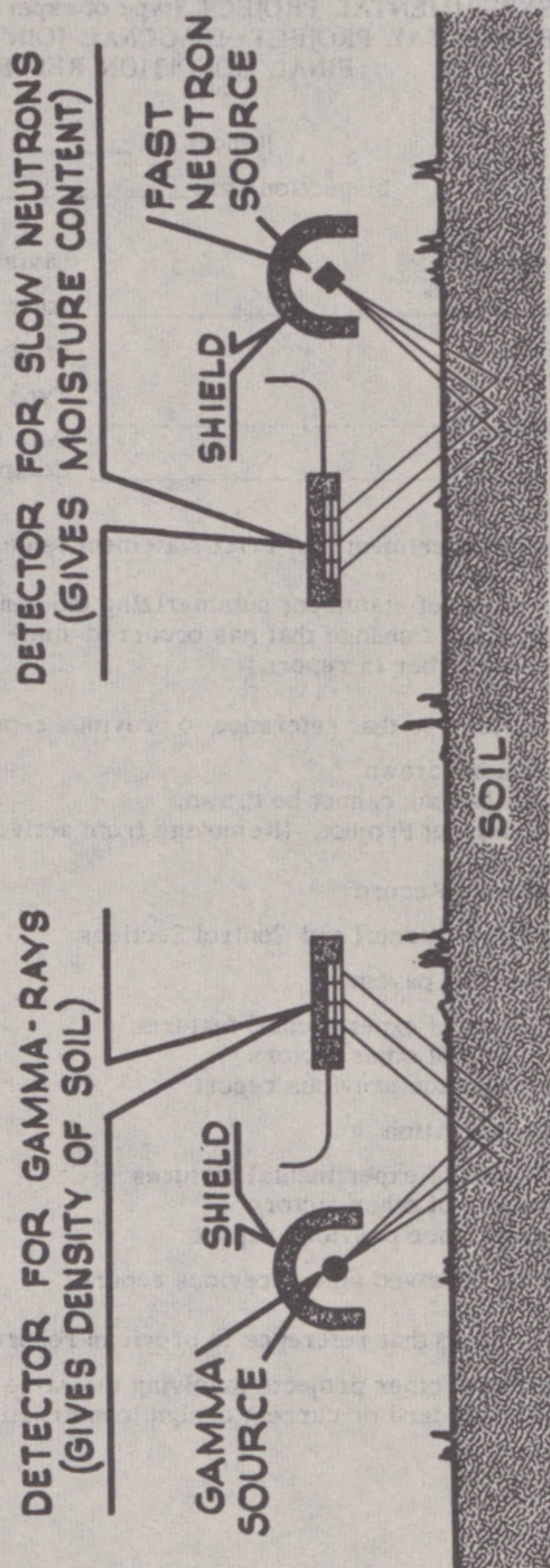
- A. Nature and objective of experiment. (A brief statement is desired here.)
- B. Condition of project. (A brief statement summarizing the condition of the project at the time of inspection and the amount of change that has occurred since the previous inspection. Complete details should be given further in report.)
- C. Conclusions. (Summarized so that reference to previous reports will be unnecessary.)
1. Basis for conclusions drawn.
 2. Reasons why conclusions cannot be drawn.
 3. Reasons for closing out Project. (Removing from active list.)
- D. Condition and Maintenance Record
1. Comparison of Experimental and Control Sections
 - a. Riding quality of pavement
 - (1) Influence of experimental features
 - (2) Influence of other factors
 - (3) Change since previous report
 - b. State of preservation
 - (1) Influence of experimental features
 - (2) Influence of other factors
 - (3) Change since previous report
 - c. Maintenance received since previous report
- E. Discussion. (Summarize so that reference to previous reports will be unnecessary.)
1. Include references to other projects involving the same or similar experimental features.
 2. Comparison with standard or current design, construction and maintenance features with respect to:
 - a. Strength
 - b. Durability
 - c. Cost
 - d. Maintenance
 3. Results of experiment
- F. Attachments such as photographs, charts, tabulations, which should be included with report when available.

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EXHIBIT D

Density and Moisture in Soil

AN INDUSTRIAL USE OF RADIOISOTOPES
IN ROAD BUILDING



- 1- DATA OBTAINED WITHOUT MOVING SOIL
- 2- GAMMA-RAY DETECTOR MEASURES DENSITY
- 3- SLOW NEUTRON DETECTOR SHOWS MOISTURE

EXHIBIT E

U.S. DEPARTMENT OF COMMERCE

Luther H. Hodges, Secretary

BUREAU OF PUBLIC ROADS

Rex M. Whitton,
Federal Highway Administrator

PRICE TRENDS for FEDERAL-AID HIGHWAY CONSTRUCTION

1957-59 BASE**FOURTH QUARTER 1961****(Construction and Maintenance Division)**

The Bureau of Public Road has just completed a revision of the base and the weighting structure of the highway construction bid price index, "Price Trends for Federal-aid Highway Construction."

The new index is composed of six indicator items and is based on total quantities used during the 1957-59 period. These items are common excavation, to indicate the price trend for all roadway excavation; portland cement concrete pavement and bituminous concrete pavement, to indicate the price trend for all surfacing types; and reinforcing steel, structural steel, and structural concrete, to indicate the price trend for structures.

The old index, which has been in use for many years, was composed of five indicator items and was based on average quantities used per mile during the 1925-29 period. The same items were used as in the new index, except that surfacing was represented by portland cement concrete pavement only.

The index based on 1925-29 base quantities and also converted to 1940 and 1946 bases will be published through calendar year 1961. In order to provide a suitable transition in use, the new index will also be published for the third and fourth quarters of 1961. Thereafter the 1925-29 index report will be discontinued.

Use of the new base is in conformance with the effort of the Federal Government to prepare all index studies on a standard 1957-59 base period.

Development of the new index is discussed in some detail in an article in Public Roads magazine, volume 31, No. 10, October 1961, available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 20 cents per copy.

FOR OFFICIAL DISTRIBUTION

PRICE TRENDS FOR FEDERAL-AID HIGHWAY CONSTRUCTION
1957-59 Base¹

Year	Common excavation		Surfacing						Structures						Com- posite index
			Portland cement concrete		Bituminous concrete		Surfac- ing index	Reinforcing steel		Structural steel		Structural concrete		Struc- tures index	
	Bid price (cu.yd.)	Index	Bid price (sq.yd.)	Index	Bid price (ton)	Index	Bid price (lb.)	Index	Bid price (lb.)	Index	Bid price (cu.yd.)	Index			
1922.....	\$0.40	102.5	\$2.28	56.9	.....	.....	56.9	\$0.050	38.1	\$0.074	37.3	\$20.18	36.6	63.2	
1923.....	.47	119.3	2.43	60.6	.....	.....	60.6	.057	43.4	.078	39.4	23.37	42.4	70.4	
1924.....	.43	109.4	2.40	59.9	.....	.....	59.9	.057	43.4	.077	38.8	22.91	41.6	67.6	
1925.....	.39	98.5	2.36	58.9	.....	.....	58.9	.056	42.6	.067	33.8	22.53	40.9	64.2	
1926.....	.36	92.8	2.29	57.1	.....	.....	57.1	.053	40.3	.074	37.3	22.76	41.3	61.8	
1927.....	.35	89.8	2.29	57.1	.....	.....	57.1	.051	38.8	.071	35.8	22.65	41.1	60.9	
1928.....	.34	85.9	2.10	52.4	.....	.....	52.4	.049	37.3	.067	33.8	21.22	38.5	56.9	
1929.....	.32	80.6	2.05	51.1	.....	.....	51.1	.048	36.5	.059	29.8	21.58	39.2	55.0	
1930.....	.30	77.3	1.86	46.4	.....	.....	46.4	.045	34.2	.061	30.8	20.08	36.4	51.2	
1931.....	.27	69.5	1.68	41.9	.....	.....	41.9	.040	30.4	.054	27.2	18.02	32.7	45.9	
1932.....	.18	49.2	1.44	35.9	.....	.....	35.9	.034	25.9	.046	23.2	15.33	27.8	36.4	
1933.....	.26	66.2	1.67	41.6	.....	.....	41.6	.038	28.9	.046	23.2	16.15	29.3	45.8	
1934.....	.29	74.6	1.90	47.4	.....	.....	47.4	.043	32.7	.053	26.7	17.73	32.2	50.2	
1935.....	.26	65.6	1.90	47.4	.....	.....	47.4	.044	33.5	.052	26.2	17.78	32.3	48.1	
1936.....	.26	67.0	1.91	47.6	.....	.....	47.6	.046	35.0	.060	30.3	20.25	36.8	49.5	
1937.....	.24	61.8	1.89	47.1	.....	.....	47.1	.048	36.5	.066	33.3	19.76	35.9	47.4	
1938.....	.21	53.5	1.72	42.9	.....	.....	42.9	.045	34.2	.063	31.8	19.06	34.6	43.5	
1939.....	.21	53.5	1.73	43.1	.....	.....	43.1	.044	33.5	.059	29.8	19.13	34.7	43.4	
1940.....	.21	53.0	1.68	41.9	.....	.....	41.9	.045	34.2	.063	31.8	19.17	34.8	42.8	
1941.....	.24	62.0	1.87	46.6	.....	.....	46.6	.054	41.1	.076	38.3	21.44	38.9	48.6	
1942.....	.37	93.2	2.39	59.6	.....	.....	59.6	.065	49.5	.090	45.4	26.16	47.5	65.0	
1943.....	.44	111.0	2.71	67.6	.....	.....	67.6	.067	51.0	.095	47.9	30.19	54.8	74.6	
1944.....	.37	95.4	2.45	61.1	.....	.....	61.1	.064	48.7	.089	44.9	31.94	58.0	67.6	
1945.....	.36	91.0	2.38	59.4	.....	.....	59.4	.062	47.2	.077	38.8	31.62	57.4	65.1	
1946.....	.35	88.7	2.65	66.1	.....	.....	66.1	.075	57.1	.113	57.0	38.79	70.4	71.1	
1947.....	.38	97.0	3.01	75.1	.....	.....	75.1	.093	70.8	.132	66.6	45.84	83.2	80.6	
1948.....	.42	106.8	3.37	84.0	.....	.....	84.0	.108	82.2	.158	79.7	51.00	92.6	90.3	
1949.....	.38	96.2	3.40	84.8	.....	.....	84.8	.104	79.1	.146	73.7	47.36	86.0	87.1	
1950.....	.33	84.6	3.32	82.8	.....	.....	82.8	.100	76.1	.139	70.1	44.62	81.0	82.3	
1950.....	.32	75.7	3.62	82.7	\$5.89	88.5	85.7	.099	76.2	.129	66.1	42.62	78.7	78.3	
1951.....	.40	96.2	3.92	89.6	7.33	110.1	100.3	.119	92.0	.176	90.4	50.72	93.6	96.1	
1952.....	.43	102.4	4.19	95.7	6.98	104.8	100.5	.119	92.4	.178	91.3	52.24	96.4	98.9	
1953.....	.40	96.2	4.07	93.0	6.53	98.1	95.6	.121	93.8	.172	88.6	52.82	97.5	95.3	
1954.....	.38	91.4	3.98	90.9	5.97	89.7	90.3	.112	86.7	.159	81.5	50.15	92.6	89.9	
1955.....	.35	84.0	3.96	90.5	6.07	91.2	90.8	.110	85.2	.157	80.9	50.01	92.3	87.3	

1956.....	.40	96.0	4.26	97.3	6.58	98.8	98.1	.127	97.9	.212	108.9	53.74	99.2	102.0	98.8
1957.....	.42	100.7	4.34	99.2	6.75	101.4	100.3	.134	104.0	.228	117.0	55.98	103.3	107.8	103.1
1958.....	.43	102.9	4.41	100.8	6.67	100.2	100.5	.129	99.9	.186	95.7	54.10	99.9	98.5	100.6
1959:															
First quarters...	.43	102.6	4.26	97.3	6.50	97.6	97.5	.125	97.1	.181	93.1	53.53	98.8	96.7	98.9
Second quarter...	.40	94.0	4.33	98.9	6.31	94.8	96.8	.123	94.9	.165	84.6	51.19	94.5	91.4	94.0
Third quarter...	.40	95.2	4.38	100.1	6.82	102.4	101.3	.124	96.3	.160	82.3	52.59	97.1	92.2	96.1
Fourth quarter...	.38	90.7	4.64	106.0	6.70	100.6	103.2	.130	100.7	.170	87.1	54.67	100.9	96.5	96.6
Average.....	.40	95.7	4.40	100.5	6.58	98.8	99.6	.126	97.2	.169	86.8	53.00	97.8	94.2	96.4
1960:															
First quarter....	.37	86.9	4.36	99.6	6.11	91.8	95.5	.125	97.0	.178	91.6	53.98	99.6	96.6	93.0
Second quarter...	.38	91.2	4.35	99.4	6.20	93.1	96.1	.121	93.3	.155	79.7	50.20	92.7	88.7	91.9
Third quarter....	.42	100.2	4.27	97.6	6.71	100.8	99.2	.114	87.8	.167	85.7	50.97	94.1	90.3	96.5
Fourth quarter...	.41	96.4	4.33	98.9	6.44	96.7	97.8	.116	90.1	.166	85.1	51.71	95.5	91.2	95.0
Average.....	.39	93.8	4.33	98.9	6.37	95.7	97.2	.119	92.1	.167	85.6	51.72	95.5	91.7	94.1
1961:															
First quarter....	.41	98.3	4.18	95.5	6.19	93.0	94.2	.115	89.0	.162	83.4	52.14	96.2	90.8	94.4
Second quarter...	.39	92.6	4.13	94.4	6.38	95.8	95.1	.116	89.6	.163	83.9	53.25	98.3	92.2	93.2*
Third quarter....	.41	98.1	4.16	95.0	6.47	97.2	96.2	.113	87.4	.161	82.8	52.96	97.8	91.1	95.1
Fourth quarter...	.41	98.6	4.38	100.1	6.34	95.2	97.5	.116	89.5	.172	88.5	55.40	102.3	95.6	97.2
Average.....	.41	96.7	4.20	96.0	6.35	95.4	95.7	.115	88.9	.165	84.8	53.38	98.5	92.4	94.9
1957-59 base.....	0.42	100.0	4.38	100.0	6.66	100.0	100.0	0.129	100.0	0.195	100.0	54.18	100.0	100.0	100.0

PREVIOUS QUARTER BASE--index for each quarter as compared with 100.0 for each preceding quarter.

1960:															
First quarter....	95.8	94.0	91.2	92.6	96.3	105.2	98.7	100.1	96.2						
Second quarter...	104.9	99.8	101.5	100.6	96.2	87.0	93.0	91.8	98.8						
Third quarter....	109.9	98.2	108.2	103.3	94.1	107.5	101.5	101.8	105.0						
Fourth quarter...	96.2	101.4	96.0	98.5	102.6	99.3	101.5	101.0	98.5						
1961:															
First quarter....	102.0	96.5	96.1	96.3	98.8	98.0	100.8	99.6	99.4						
Second quarter...	94.2	98.8	103.0	101.0	100.7	100.6	102.2	101.5	98.7						
Third quarter....	105.9	100.7	101.4	101.1	97.5	98.7	99.5	98.9	102.0						
Fourth quarter...	100.5	105.3	98.0	101.4	102.5	106.8	104.6	104.9	102.3						

¹Base for composite index, 1957-59, involves 3,641,885,000 cubic yards of roadway excavation 154,953,000 square yards of Portland cement concrete surfacing with an average thickness of 9.1 inches, 111,516,000 tons of bituminous concrete surfacing, 2,206,879,000 pounds of reinforcing steel for structures, 2,581,462,000 pounds of structural steel and 14,583,000 cubic yards of structural concrete.

Index figures for 1922 through 1950 are simple mathematical conversions from the 1925-29 base to the 1957-59 base. They were derived from the previously computed figures, using 1925-29 base quantities and prices, and dividing the figures for each year by the average of the figures for the years 1957, 1958, and 1959. Revisions for 1950 and figures subsequent thereto are computed from 1957-59 base quantities and prices. The breaks in the curves indicate indexes for 1950 computed by both methods. Prices for Portland cement concrete surfacing reflect adjustments to base period thicknesses in each state and do not include costs for reinforcing steel and joints.

PRICE TRENDS FOR FEDERAL-AID HIGHWAY CONSTRUCTION

1957-1959=100

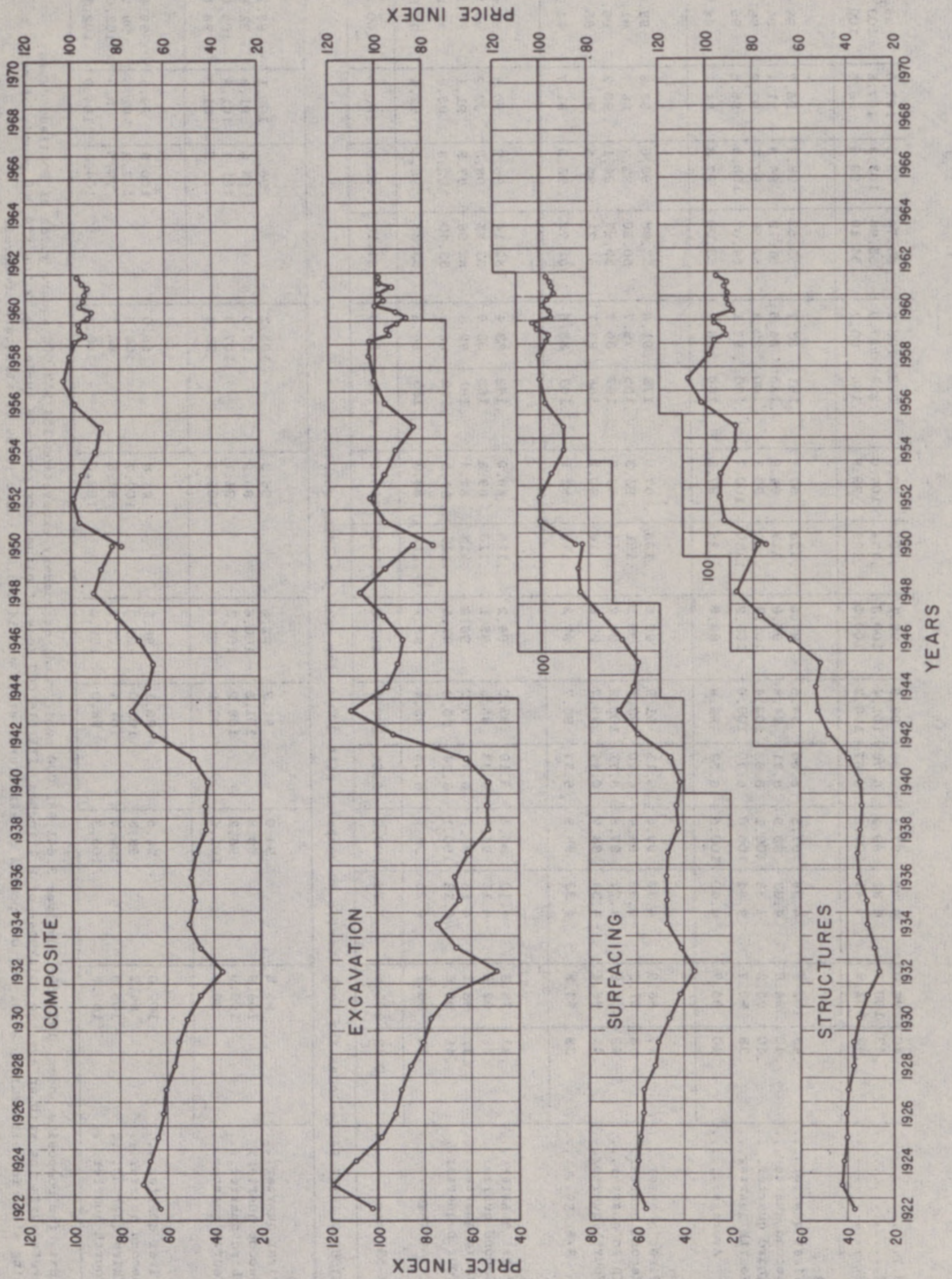


EXHIBIT F

DEPARTMENT OF COMMERCE,
BUREAU OF PUBLIC ROADS,
Washington, D.C., June 23, 1958.

Circular memorandum to: Regional and division engineers.

From: G. M. Williams, Assistant Commissioner; by M. B. Christensen, Chief,
Construction and Maintenance Division.

Subject: Availability of aggregates for construction.

Replies have been received in accordance with the memorandum of November 5, 1957, same subject. They have been very helpful in reviewing the situation with regard to the supply of aggregates and in some cases actions have been initiated that will assist in increasing the known sources of supply and thereby facilitating the highway construction program and possibly reducing the cost thereof.

A brief summary of the replies is as follows:

1. "Is the known supply of aggregates ample to take care of the anticipated needs for highway purposes for at least the next 15 years?"

The supply is not considered adequate in Colorado, Mississippi, or Oklahoma. In Florida it is adequate for at least 10 years; Kansas adequate in the eastern one-third of the State; Nebraska is short on crushed rock; New Hampshire expects a gravel shortage; New York expects a shortage of fine aggregate and bank-run gravel; Oregon short in the southwest and northwest part of the State; Pennsylvania short of coarse aggregate in the northwest part of the State and fine aggregate in the central part; Virginia short of coarse aggregate in Suffolk district; other States have minor shortages of certain types of aggregates in small areas.

2. "Are the sources of available aggregates within economical shipping distances?"

The replies were most interesting to study in regard to what is considered an economical shipping distance. In States with plentiful aggregate sources, 2 to 5 miles might be considered the limit, while a State with general shortage or large shortage areas might consider up to 100 miles economical. It would seem that where the longer hauls are required the States should consider every alternate means of upgrading, stabilizing, or other means of reducing the quantity needed for these long hauls.

3. "What action has been taken or is planned to inventory existing supplies of aggregates and to find and explore new sources?"

Most States have kept some records of the known and used sources of supply. Many have kept such records and also have done some exploring for new sources in the vicinity of proposed construction; among them are Arizona, Arkansas, Colorado, Florida, Georgia, Idaho, Illinois, Indiana, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, Nevada, New Hampshire, New Mexico, North Carolina, Oklahoma, Oregon, Texas, Utah, Vermont, Virginia, Washington, and Wisconsin. Commercial producers are active with or without State assistance in Alabama, Arkansas, Florida, Iowa, Maryland, New Jersey, New York, North Carolina, Ohio, Hawaii, and the District of Columbia.

4. "Would the State be interested in undertaking a comprehensive cooperative survey of existing and potential aggregate sources?"

Some interest in a cooperative survey has been expressed in Arizona, Colorado, Connecticut, Florida, Idaho, Iowa, Kansas, Louisiana, Minnesota, Mississippi, New Hampshire, New York, Oklahoma, Oregon, South Dakota, Utah, Vermont, Washington, and Hawaii.

Cooperative soil surveys have been completed in New Jersey and Rhode Island. Cooperative surveys of aggregates are now underway in Maine, North Dakota, Oklahoma, Oregon, Washington, and West Virginia. It is anticipated that cooperative surveys will soon be started in Arizona, Vermont, and Utah. Rather complete independent surveys have been made in Michigan, North Carolina, Virginia, and Wyoming among others.

5. "What measures have been or can be taken to conserve the best quality aggregates by making maximum use of those of lower quality?"

The most common reply to this query and mentioned by 25 States was the use of medium quality material for subbase and conserving high quality material for bases and surfaces where greater shear strength is required. Several States advised that this was done for economy rather than for conservation. The net result in either case is the same—smaller quantities of higher quality material are required and the construction cost is lowered without reducing the strength of the pavement.

Several States reported using their better materials from excavation for topping the fills, thereby reducing the needed thickness of pavement. Twenty-one States advised that they were using or considering some stabilizing of fine-grained soils with lime, portland cement, or asphalt, or upgrading a gravel of doubtful quality due to excess plasticity into higher quality by cement or lime treatment. Three States used blending of long-haul high quality material to convert doubtful local gravel into satisfactory high quality base material.

It would appear that of the many methods reported as being used or studied above, the most promising from the standpoint of conservation of aggregates and for economy are the selection of high bearing value materials from excavation for use in topping fills thereby reducing the required thickness, and the use of medium quality material for subbase reserving the higher quality materials for base and surface.

In general, commercial producers serving both the general construction industry and highway construction concentrate their efforts toward producing high quality materials suitable for concrete or bituminous concrete. They find very little market in the general construction industry for the medium quality materials suitable for highway subbase. The result is that sources of local materials suitable for subbase only are not usually sought and developed by commercial producers and may have to be located by soil or material surveys conducted by the State highway departments if a source of low-cost materials is to be provided for the highway contractor.

EXHIBIT G

HIGHWAY CONSTRUCTION USAGE FACTORS FOR AGGREGATES, 1958-60

DISCUSSION

This is the sixth in a series of tabulations showing highway construction usage factors for aggregates covering 3-year periods. The first of the series was based on the period 1953-55 and the fifth of the series covered the period 1957-59.

An important phase in highway construction planning is the estimating of future material requirements in order that industry may be geared to supply such materials. Of the various materials used in highway construction, aggregates comprise the largest item of cost, averaging somewhat over 30 percent of the cost of all materials and supplies and slightly over 15 percent of the contract construction cost.

The usage factors for aggregates are intended to aid commercial pit and quarry operators as well as highway contractors, engineers, and economists in planning to meet the needs of the expanded highway construction program in the United States. These factors, when applied to expected contract construction expenditures for both Federal-aid and non-Federal-aid highway construction, will generally result in reasonably accurate estimates of requirements.

The data used in the development of the usage factors are supplied by contractors for projects on the Federal-aid primary system. Investigations have indicated that for comparable standards of design, material usage factors for non-Federal-aid work do not differ appreciably from those developed for Federal-aid construction. Information for computing Federal-aid secondary factors, by States, is not currently reported. It is recommended, therefore, that the State secondary factors on the tabulation of October 1957, covering the years 1954, 1955, and 1956, be used for reasonably accurate estimating purposes. It should be recognized that factors shown for individual States, in some instances, may not be truly representative of normal usage because of being based on low volumes of work and/or temporary disproportionate percentages of the three major types of highway construction; i.e., grading, surfacing, and structures. In most States, however, during the 3-year period, the volume of work is large enough and the type distribution is of proper proportion to reflect representative usage factors.

As in previous tabulations of the series, the elimination of data for the first year of the last edition and the inclusion of data for the most current complete year have resulted in some significant changes in the factors for some States. Changes in all U.S. average factors, however, are insignificant.

The U.S. average factors for all Federal-aid systems combined, including estimated secondary system factors for the years 1958, 1959, and 1960, are as follows:

Aggregate purchased by contractors: 48,000 tons per million dollars contract construction cost.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

HIGHWAY CONSTRUCTION USAGE FACTORS FOR AGGREGATES¹ (Including Sand, Gravel, Clay Gravel, Crushed Gravel, Slag, Crushed Stone, etc.)

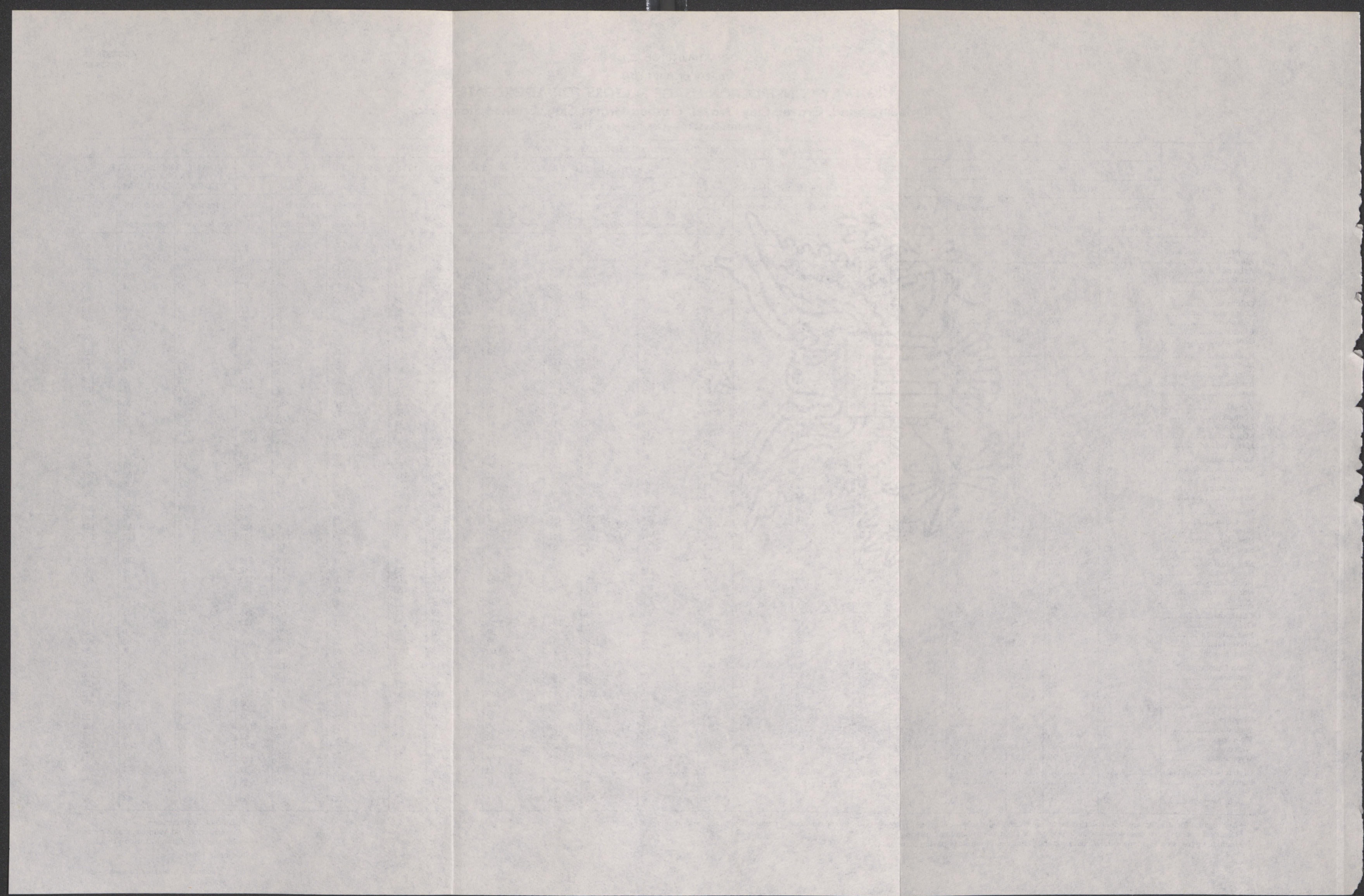
WEIGHTED AVERAGE—1958, 1959 AND 1960

AGGREGATES
1958-59-60

STATE	THOUSANDS OF TONS OF AGGREGATE PER MILLION DOLLARS CONTRACT CONSTRUCTION COST ²																				
	INTERSTATE SYSTEM									FEDERAL-AID PRIMARY SYSTEM (EXCLUSIVE OF INTERSTATE)									ALL INTERSTATE AND OTHERS FEDERAL-AID PRIMARY		
	RURAL			URBAN			RURAL AND URBAN			RURAL			URBAN			RURAL AND URBAN			Purchased by contractor ³	Produced by contractor	Total
	Purchased by contractor ³	Produced by contractor	Total	Purchased by contractor ³	Produced by contractor	Total	Purchased by contractor ³	Produced by contractor	Total	Purchased by contractor ³	Produced by contractor	Total	Purchased by contractor ³	Produced by contractor	Total	Purchased by contractor ³	Produced by contractor	Total			
Alabama.....	55	7	62	15	0	15	54	7	61	73	15	88	52	27	79	69	17	86	66	14	80
Alaska.....																					
Arizona.....	4	84	88	10	4	14	5	73	78	9	84	93	31	34	65	15	71	86	10	72	82
Arkansas.....	80	21	101	95	9	104	85	17	102	83	109	192	44	28	72	73	88	161	78	59	137
California.....	34	44	78	40	13	53	37	28	65	36	62	98	55	19	74	45	42	87	40	34	74
Colorado.....	26	54	80	17	17	34	23	39	62	11	101	112	95	13	108	20	92	112	21	65	86
Connecticut.....	24	102	126	30	21	51	27	67	94	50	41	91	28	18	46	38	28	66	33	46	79
Delaware.....	6	0	6				6	0	6	49	0	49	53	0	53	49	0	49	48	0	48
Florida.....	100	0	100	25	0	25	41	0	41	97	12	109	81	1	82	10	103	65	4	69	
Georgia.....	54	32	86	40	0	40	46	12	58	98	7	105	99	0	99	98	6	104	88	7	95
Hawaii.....										26	5	31	162	0	162	110	2	112	110	2	112
Idaho.....	7	115	122	21	0	21	8	111	119	46	167	213	22	131	153	43	162	205	24	135	159
Illinois.....	68	4	72	37	0	37	52	2	54	84	3	87	48	2	50	72	3	75	64	2	66
Indiana.....	32	12	44	47	0	47	35	10	45	139	5	144	58	1	59	123	5	128	102	6	108
Iowa.....	46	3	49				46	3	49	104	19	123	45	5	50	93	17	110	91	16	107
Kansas.....	51	36	87	27	27	54	44	33	77	52	55	107	40	9	49	50	48	98	47	40	87
Kentucky.....	19	23	42	31	0	31	21	19	40	89	6	95	60	0	60	83	4	87	55	11	66
Louisiana.....	52	0	52	28	5	33	43	2	45	99	16	115	41	1	42	74	9	83	63	7	70
Maine.....	135	26	161	111	22	133	134	25	159	115	97	212	65	9	74	104	77	181	114	60	174
Maryland.....	51	68	119	20	0	20	39	43	82	71	53	124	41	7	48	59	35	94	48	39	87
Massachusetts.....	79	6	85	61	0	61	71	4	75	80	0	80	51	0	51	63	0	63	66	1	67
Michigan.....	46	9	55	30	1	31	39	5	44	68	37	105	48	4	52	60	23	83	48	13	61
Minnesota.....	17	130	147	14	43	57	15	81	96	23	216	239	21	98	119	23	182	205	21	160	181
Mississippi.....	14	0	14	47	0	47	19	0	19	54	105	159	61	6	67	56	73	129	37	36	73
Missouri.....	32	13	45	31	10	41	32	11	43	50	30	80	39	4	43	47	24	71	39	17	56
Montana.....	57	301	358	12	0	12	54	285	339	27	219	246	10	125	135	25	210	235	34	232	266
Nebraska.....	48	1	49				48	1	49	98	51	149	42	5	47	94	49	143	86	40	126
Nevada.....	1	177	178				1	177	178	3	186	189	0	0	0	3	186	189	2	182	184
New Hampshire.....	115	90	205	139	57	196	123	79	202	34	157	191	70	91	161	43	141	184	79	113	192
New Jersey.....	30	0	30	26	0	26	27	0	27	38	24	62	38	4	42	38	14	52	34	10	44
New Mexico.....	6	176	182	18	85	103	7	169	176	16	217	233	18	127	145	16	203	219	10	180	190
New York.....	20	37	57	17	8	25	18	19	37	46	23	69	25	8	33	34	14	48	28	16	44
North Carolina.....	67	2	69	111	0	111	78	1	79	109	15	124	104	6	110	108	14	122	93	8	101
North Dakota.....	35	59	94	34	43	77	35	56	91	14	385	399	11	145	156	14	364	378	26	194	220
Ohio.....	43	17	60	27	3	30	38	13	51	56	16	72	45	7	52	52	13	65	42	13	55
Oklahoma.....	37	30	67	54	29	83	41	29	70	52	73	125	56	35	91	53	62	115	47	45	92
Oregon.....	16	119	135	23	29	52	18	95	113	32	92	124	55	60	115	39	83	122	27	90	117
Pennsylvania.....	40	0	40	18	0	18	25	0	25	56	0	56	27	0	27	40	0	40	33	0	33
Rhode Island.....	10	2	12	27	17	44	25	15	40	78	156	234	59	76	135	78	152	230	43	62	105
South Carolina.....	14	3	17	7	0	7	14	3	17	71	0	71	60	3	63	68	1	69	58	1	59
South Dakota.....	37	116	153	12	0	12	35	109	144	6	370	376	44	112	156	14	317	331	21	245	266
Tennessee.....	29	1	30	25	0	25	27	1	28	126	16	142	69	3	72	110	12	122	90	10	100
Texas.....	54	90	144	62	31	93	57	64	121	39	113	152	55	56	111	48	83	131	52	74	126
Utah.....	4	128	132	27	2	29	13	79	92	5	208	213	140	10	150	15	194	209	14	143	157
Vermont.....	53	74	127	18	45	63	36	60	96	62	38	100	168	10	178	66	37	103	50	49	99
Virginia.....	63	36	99	65	0	65	63	30	93	87	3	90	48	0	48	72	2	74	68	14	82
Washington.....	13	91	104	34	49	83	22	73	95	11	148	159	29	29	58	17	106	123	20	88	108
West Virginia.....	7	0	7				7	0	7	46	12	58	33	0	33	43	9	52	42	9	51
Wisconsin.....	93	99	192	18	22	40	81	87	168	77	152	229	54	47	101	69	117	186	73	107	180
Wyoming.....	18	79	97	12	24	36	17	72	89	26	138	164	15	113	128	26	137	163	21	101	122
District of Columbia.....				18	0	18	18	0	18				33	4	37	33	4	37	31	3	34
Puerto Rico.....										46	0	46	41	0	41	44	0	44	44	0	44
U. S. averages.....	40	50	90	33	12	45	38	34	72	60	68	128	44	19	63	55	50	105	47	43	90

¹ Aggregates for all highway construction including bases, sub-bases, concrete surfaces, bituminous surfaces, structural concrete and drainage work.² Contract construction cost does not include costs of right-of-way and engineering.³ Include aggregates in ready-mixed concrete and premixed bituminous paving materials.Office of Engineering
Construction and Maintenance Division
Construction Administration Branch

October 1961



U.S. DEPARTMENT OF COMMERCE

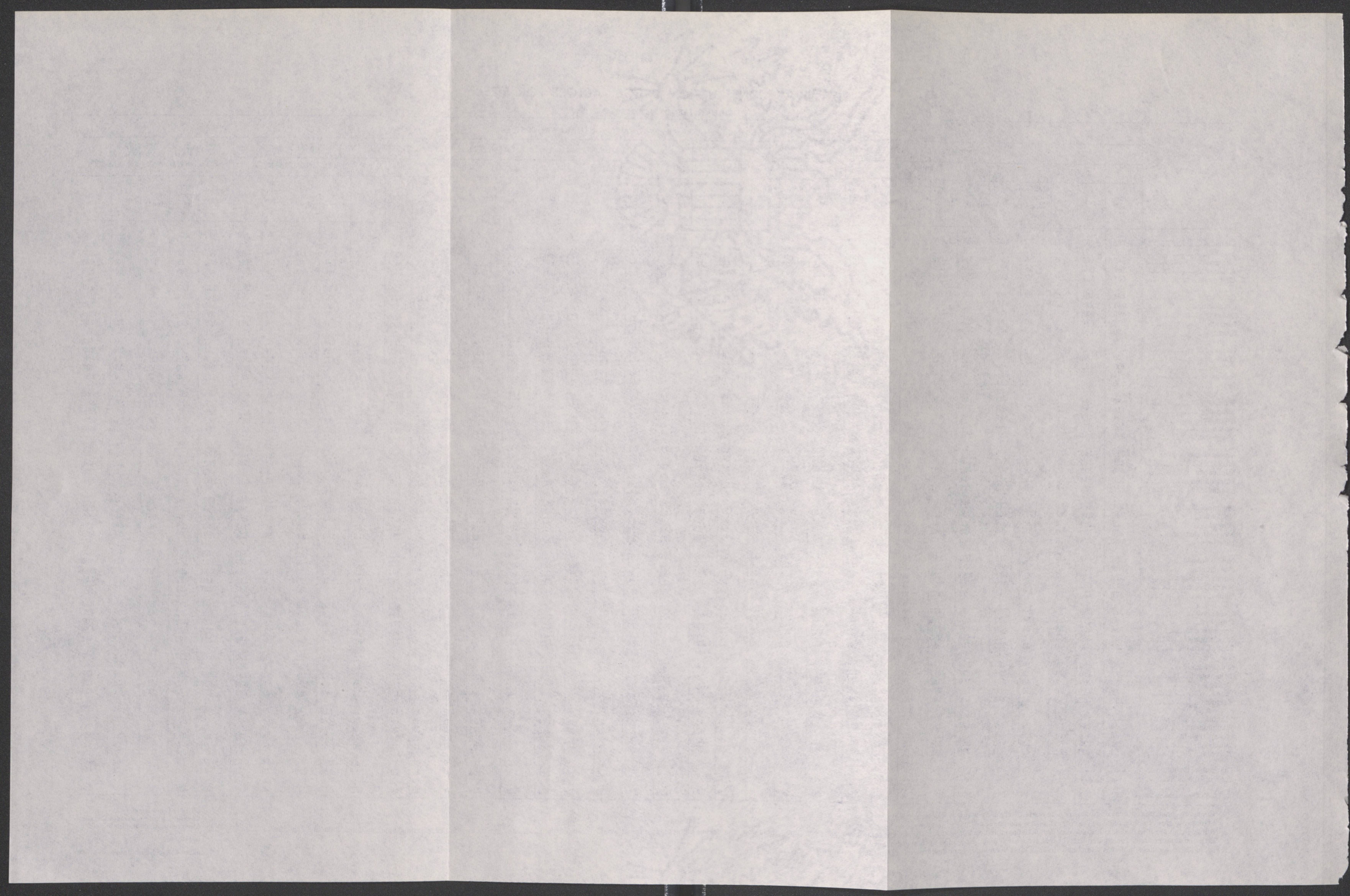
BUREAU OF PUBLIC ROADS

HIGHWAY CONSTRUCTION USAGE FACTORS FOR STEEL

WEIGHTED AVERAGE—1958, 1959 AND 1960

STEEL
1958-59-60

STATE	TONS OF STEEL PER MILLION DOLLARS CONTRACT CONSTRUCTION COST ¹																																		
	INTERSTATE SYSTEM															FEDERAL-AID PRIMARY SYSTEM (EXCLUSIVE OF INTERSTATE)										ALL INTERSTATE AND OTHER FEDERAL-AID PRIMARY									
	RURAL					URBAN					RURAL AND URBAN					RURAL					URBAN					RURAL AND URBAN									
	Struc-tural ²	Rein-forc-ing ³	Cul-vert pipe ⁴	Mis-cel-lane-ous ⁵	Total	Struc-tural ²	Rein-forc-ing ³	Cul-vert pipe ⁴	Mis-cel-lane-ous ⁵	Total	Struc-tural ²	Rein-forc-ing ³	Cul-vert pipe ⁴	Mis-cel-lane-ous ⁵	Total	Struc-tural ²	Rein-forc-ing ³	Cul-vert pipe ⁴	Mis-cel-lane-ous ⁵	Total	Struc-tural ²	Rein-forc-ing ³	Cul-vert pipe ⁴	Mis-cel-lane-ous ⁵	Total	Struc-tural ²	Rein-forc-ing ³	Cul-vert pipe ⁴	Mis-cel-lane-ous ⁵	Total					
Alabama.....	88	269	44	2	403	55	1,491	0	0	1,546	87	296	43	2	428	82	208	29	1	320	135	165	17	1	318	91	201	27	1	320	90	223	31	1	343
Alaska.....																																			
Arizona.....	48	139	75	68	330	350	189	4	38	581	90	146	65	64	365	173	130	73	62	438	114	158	26	32	330	158	137	60	54	409	123	142	63	59	387
Arkansas.....	389	302	3	26	720	213	371	4	120	708	335	323	3	55	716	56	97	19	17	189	373	322	8	46	749	136	154	16	25	331	220	225	11	37	493
California.....	101	167	26	47	341	204	408	9	73	694	155	293	17	61	526	103	190	25	69	387	134	516	15	75	740	117	344	20	72	553	139	315	18	66	538
Colorado.....	101	204	25	62	392	390	328	11	124	853	220	255	19	87	581	37	61	70	44	212	58	302	19	117	496	39	87	65	52	243	133	173	41	70	417
Connecticut.....	624	215	23	57	919	837	258	30	79	1,204	715	233	26	66	1,040	122	139	46	56	363	642	180	17	132	971	412	162	29	99	702	547	194	28	85	854
Delaware.....	896	328	0	244	1,468						896	328	0	244	1,468	8	101	14	20	143	0	21	25	21	67	7	89	16	20	132	36	97	15	27	175
Florida.....	70	76	1	40	187	192	313	1	8	514	166	262	1	15	444	105	83	7	12	207	85	148	1	45	279	100	97	6	20	223	136	187	3	17	343
Georgia.....	126	142	65	33	366	528	325	6	86	945	373	255	29	65	722	29	115	14	3	161	74	76	24	32	206	38	107	17	9	171	105	136	19	21	281
Hawaii.....																																			
Idaho.....	25	80	61	80	246	28	710	0	30	768	25	105	59	78	267	12	272	2	13	299	4	114	8	86	214	7	174	6	60	247	7	174	6	60	247
Illinois.....	230	382	9	55	676	322	248	5	109	684	275	316	7	82	680	81	127	19	27	254	167	204	6	45	422	109	152	15	33	309	176	218	11	52	457
Indiana.....	414	381	17	72	884	45	344	22	127	538	343	374	17	83	818	141	181	16	61	399	157	195	22	69	443	144	183	17	63	407	192	230	17	68	507
Iowa.....	150	296	8	0	454						150	296	8	0	454	48	111	10	4	173	382	161	7	4	554	108	119	10	4	241	111	130	9	4	254
Kansas.....	97	448	18	30	593	127	476	15	79	697	106	456	17	45	624	52	242	38	19	351	135	300	19	34	488	66	252	35	21	374	86	352	26	33	497
Kentucky.....	116	286	12	55	469	309	298	0	17	624	149	288	10	49	496	21	134	19	66	240	103	248	1	61	413	38	158	15	65	276	89	218	13	57	377
Louisiana.....	391	213	1	13	618	582	431	0	79	1,092	460	292	1	37	790	196	68	4	42	310	539	241	4	138	922	346	144	4	84	578	388	197	3	67	655
Maine.....	265	108	30	37	440	277	107	29	18	431	266	108	30	36	440	145	32	77	37	291	193	144	41	28	406	156	58	68	35	317	193	75	55	35	358
Maryland.....	298	201	18	33	550	569	319	15	53	956	400	246	17	41	704	118	147	39	42	346	358	236	21	38	653	213	182	32	40	467	314	217	24	40	595
Massachusetts.....	359	145	17	78	599	689	173	3	43	908	503	158	11	63	735	177	94	13	96	380	395	117	6	81	599	306	108	9	87	510	383	127	10	78	598
Michigan.....	211	340	2	39	592	223	204	17	83	527	216	278	9	59	562	92	242	4	17	355	285	295	1	41	622	174	264	2	28	468	197	272	6	45	520
Minnesota.....	696	203	16	35	950	714	253	20	94	1,081	706	231	18	69	1,024	72	82	43	12	209	195	102	14	16	327	107	88	35	13	243	240	119	31	26	416
Mississippi.....	108	434	0	23	565	44	440	1	2	487	99	434	0	20	553	89	218	0	2	309	21	209	0	8	238	67	215	0	4	286	83	328	0	12	423
Missouri.....	356	271	8	68	703	245	341	7	38	631	301	306	7	53	667	76	260	15	44	395	105	259	7	48	419	84	260	12	45	401	205	286	10	49	550
Montana.....	101	70	78	24	273	23	460	19	92	594	96	91	75	28	290	173	54	94	21	342	204	77	35	36	352	175	56	89	23	343	152	66	84	25	327
Nebraska.....	740	216	22	127	1,105						740	216	22	127	1,105	161	124	75	29	389	241	178	3	41	463	166	127	71	30	394	269	143	62	47	521
Nevada.....	26	159	42	122	349						26	159	42	122	349	35	43	66	53	197						35	43	66	53	197	31	96	55	84	266
New Hampshire.....	253	170	30	31	484	413	143	11	121	688	311	160	23	64	558	144	68	62	33	307	301	113	13	24	451	182	79	50	31	342	240	115	38	46	439
New Jersey.....	174	275	13	84	546	142	207	20	64	433	152	229	17	71	469	327	135	17	48	527	309	142	12	58	521	318	139	14	53	524	262	169	15	59	505
New Mexico.....	58	169	34	53	314	142	356	30	61	589	65	184	33	54	336	79	107	135	37	358	60	134	18	10	222	76	111	117	33	337	68	161	60	47	336
New York.....	409	181	10	56	656	503	220	5	58	786	467	205	6	58	736	107	122	30	63	322	291	155	40	117	603	216	142	36	95	489	315	167	24	80	586
North Carolina.....	312	276	47	23	658	453	229	8	16	706	347	264	38	21	670	134	182	25	1																



Aggregates produced by contractors: 56,000 tons per million dollars contract construction cost.

Where the factor "0" appears in the tabulation it indicates that none or a negligible quantity of aggregates was reported. The dotted lines indicate that no work was reported on the particular system for the State shown.

EXHIBIT H

HIGHWAY CONSTRUCTION USAGE FACTORS FOR STEEL, 1958-60

DISCUSSION

This is the sixth in a series of tabulations showing highway construction usage factors for steel covering 3-year periods. The first of the series was based on the years 1953, 1954, and 1955 and the fifth of the series covered the years 1957, 1958, and 1959.

An important phase in highway construction planning is the estimating of future requirements for materials in order that industry may be geared to supply such materials. Of the various materials used in highway construction steel constitutes one of the largest items of cost, amounting to nearly 15 percent of the total construction cost (not including the costs of right-of-way and engineering) and more than 25 percent of the cost of all materials and supplies.

The usage factors for steel are intended to aid mills, fabricators, and related industries, as well as highway engineers and economists, in planning to meet the needs of the expanded highway construction program in the United States. These factors, when applied to expected contract construction expenditures for both Federal-aid and non-Federal-aid highway construction will generally result in reasonably accurate estimates of requirements.

The data used in the development of the usage factors are supplied by contractors for projects on the Federal-aid primary system. Investigations have indicated that for comparable standards of design, material usage factors on non-Federal-aid work do not differ appreciably from those developed for Federal-aid construction. Information for computing Federal-aid secondary factors, by States, is not currently reported. It is recommended, therefore, that the State secondary factors on the tabulation of October 1957, covering the years 1954, 1955, 1956, be used for reasonably accurate estimating purposes.

It should be recognized that the factors shown for individual States, in some instances, may not be truly representative of normal usage because of being based on low volumes of work and/or temporary disproportionate percentages of the three major types of highway construction; i.e., grading surfacing and structures. In most States, however, during the 3-year period, the volume of the work is large enough and the type distribution is of proper proportion to reflect representative usage factors.

As in previous tabulations of the series, the elimination of data for the first year of the last edition and the inclusion of data for the most current complete year have resulted in some significant changes in the factors for some States. Changes in all U.S. average factors, however, are insignificant.

The U.S. average factors for all Federal-aid systems combined, including estimated secondary factors, for the years 1958, 1959, and 1960 are as follows:

<i>Item</i>	<i>Tons per million dollars contract construction cost</i>
Structural steel.....	185
Reinforcing steel.....	190
Metal culvert pipe.....	38
Miscellaneous steel.....	50

Where the factor "0" appears in the tabulation it indicates that none or a negligible quantity of steel was reported. The dotted lines indicate that no work was reported on the particular system for the State shown.

EXHIBIT I

HIGHWAY CONSTRUCTION USAGE FACTORS FOR CEMENT, BITUMENS, CONCRETE PIPE, AND CLAY PIPE, 1958-60

DISCUSSION

This is the sixth in a series of tabulations showing highway construction usage factors for cement, bitumens, concrete pipe, and clay pipe for 3-year periods. The first of the series was based on the years 1953, 1954, and 1955 and the fifth of the series covered the years 1957, 1958, and 1959.

An important phase in highway construction planning is the estimating of future requirements for materials in order that industry may be geared to supply such materials. Of the various materials used in highway construction, steel and aggregates constitute the largest elements of cost, together amounting to more than 50 percent of the cost of all materials and supplies and about 30 percent of the total construction cost (not including the cost of right-of-way and engineering). The approximate comparable percentages for the materials in this tabulation are as follows:

Item	Percent of materials and supplies cost	Percent of construction cost
Cement.....	10.....	5.
Bitumens.....	10.....	5.
Concrete pipe.....	3 to 4.....	2.
Clay pipe.....	Less than 1.....	Less than 1.

The usage factors for cement, bitumens, and the pipe items are intended to aid producers, manufacturers, and suppliers of these commodities and related industries, as well as highway contractors, engineers, and economists in planning to meet the needs of the expanded highway construction program in the United States. These factors when applied to expected contract construction expenditures for both Federal-aid and non-Federal-aid highway construction, will generally result in reasonably accurate estimates of requirements.

The data used in the development of the usage factors are supplied by contractors for projects on the Federal-aid primary system (including Interstate). Investigations have indicated that, for comparable standards of design, material usage factors for non-Federal-aid work do not differ appreciably from those developed for Federal-aid construction. Information for computing Federal-aid secondary factors, by States, is not currently reported. It is recommended, therefore, that the State secondary factors on the tabulation of November 1957, covering the period 1954-56, be used for reasonably accurate estimating purposes.

It should be recognized that the factors shown for individual States, in some instances, may not be truly representative of normal usage because of being based on low volumes of work and/or temporary disproportionate percentages of the three major classifications of highway construction, i.e., grading and drainage, surfacing, and structures. An outstanding and unusual example of this is shown for concrete pipe on the Interstate Urban System in Arizona, where there were a relatively small number of projects, all of which consisted primarily of drainage work. In most States, however, during the 3-year period, the volume of work is large enough and the type distribution is of proper proportion to reflect fairly representative usage factors.

As in previous tabulations of the series, the elimination of data for the first year of the last edition and the inclusion of data for the most current complete year resulted in some significant changes in the factors for some States. Generally the U.S. average factors for cement, bitumens, and concrete pipe have decreased to some extent as compared to the previous issue, while those for clay pipe have increased.

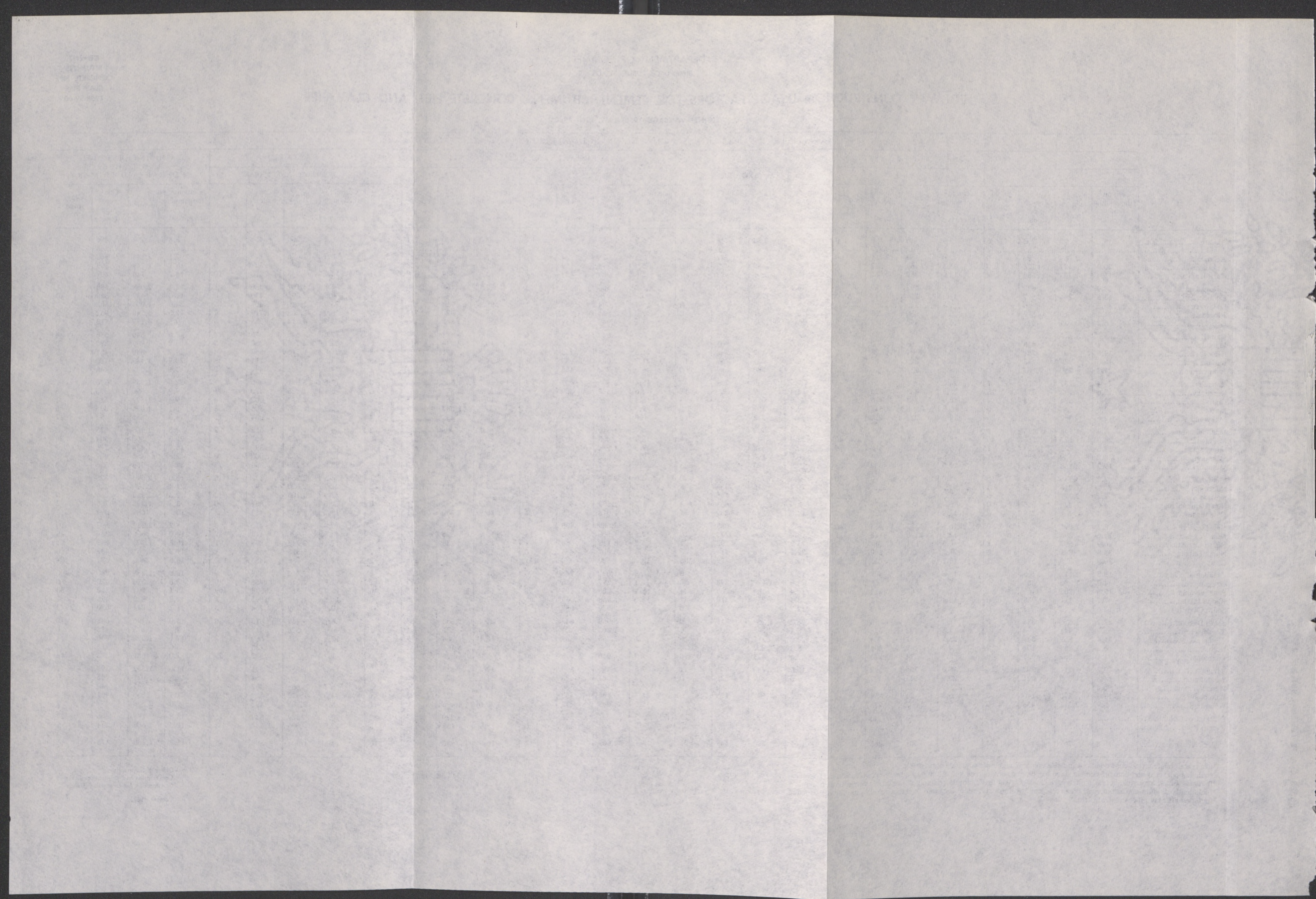
U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

HIGHWAY CONSTRUCTION USAGE FACTORS FOR CEMENT, BITUMENS, CONCRETE PIPE, AND CLAY PIPE

WEIGHTED AVERAGE—1958, 1959, AND 1960

CEMENT
BITUMENS
CONCRETE PIPE
CLAY PIPE
1958-59-60

STATE	QUANTITIES OF MATERIALS PER MILLION DOLLARS CONTRACT CONSTRUCTION COST ¹																											
	INTERSTATE SYSTEM												FEDERAL-AID PRIMARY SYSTEM (EXCLUSIVE OF INTERSTATE)												ALL INTERSTATE AND OTHER FEDERAL-AID PRIMARY			
	RURAL				URBAN				RURAL AND URBAN				RURAL				URBAN				RURAL AND URBAN							
	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)	Cement ² (thousands of barrels)	Bitu- mens ³ (tons)	Con- crete ⁴ pipe (tons)	Clay ⁵ pipe (tons)
Alabama.....	18.0	90	253	6	13.9	0	0	0	17.9	88	248	6	6.3	2,293	401	8	4.7	2,370	731	7	6.1	2,306	454	8	8.8	1,787	406	8
Alaska.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Arizona.....	5.5	2,763	33	0	7.0	168	12,251	0	5.7	2,404	1,727	0	7.2	2,028	24	0	12.7	1,457	481	6	8.7	1,876	146	2	7.1	2,148	960	1
Arkansas.....	20.9	427	378	0	35.5	469	537	0	25.4	440	427	0	6.9	3,294	189	0	17.0	917	734	0	9.5	2,692	327	0	16.1	1,749	369	0
California.....	15.4	753	368	4	14.0	462	482	10	14.6	601	428	7	13.6	1,204	434	8	13.9	649	319	11	13.7	943	380	10	14.2	746	407	8
Colorado.....	24.9	1,330	525	0	8.5	692	1,139	3	18.1	1,067	778	1	5.0	3,303	255	1	12.1	1,461	1,490	8	5.8	3,107	386	1	12.1	2,058	588	1
Connecticut.....	13.6	284	327	0	11.8	209	242	0	12.9	252	291	0	10.8	978	567	0	8.5	284	318	1	9.5	591	430	0	11.0	439	368	0
Delaware.....	5.5	4	0	0	.....	.....	.....	.....	5.5	4	0	0	25.7	1,094	1,550	6	25.1	717	557	17	25.6	1,040	1,407	8	24.9	1,007	1,362	7
Florida.....	21.3	910	579	0	13.9	250	255	0	15.5	391	324	0	7.0	2,654	1,420	2	15.4	928	2,749	25	8.9	2,265	1,719	7	12.5	1,248	962	3
Georgia.....	6.2	3,929	593	0	16.9	453	527	0	12.8	1,795	553	0	7.1	4,949	642	0	14.5	3,842	1,166	0	8.7	4,714	753	0	9.5	4,129	713	0
Hawaii.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.9	647	426	0	8.6	484	667	7	7.6	546	576	4	7.6	546	576	4
Idaho.....	3.1	1,340	418	0	13.7	155	0	0	3.6	1,293	401	0	1.5	2,856	319	0	10.0	2,424	619	0	2.7	2,796	360	0	3.2	1,997	382	0
Illinois.....	19.8	201	261	3	13.3	81	325	30	16.6	142	292	17	21.5	1,724	282	2	22.5	471	1,128	8	21.8	1,316	557	4	19.7	846	451	9
Indiana.....	16.6	230	83	11	16.4	320	81	29	16.5	247	82	14	21.7	2,083	153	38	24.5	769	464	38	22.3	1,836	211	38	20.9	1,449	180	32
Iowa.....	21.3	230	509	0	.....	.....	.....	.....	21.3	230	509	0	46.6	1,252	458	11	35.0	322	371	2	44.5	1,085	442	10	43.1	1,032	446	9
Kansas.....	29.4	1,157	226	1	24.6	168	269	5	27.9	859	239	2	16.4	3,306	409	1	22.7	1,586	933	0	17.5	3,021	496	1	22.6	1,959	370	2
Kentucky.....	15.6	193	374	15	8.5	483	320	2	14.4	242	365	13	4.6	1,827	409	1	11.8	855	462	0	6.1	1,625	420	1	9.9	990	395	6
Louisiana.....	29.0	634	593	4	16.9	343	476	1	24.6	528	551	3	15.3	3,429	467	0	17.8	561	775	0	16.4	2,173	602	0	19.4	1,577	583	1
Maine.....	9.6	256	350	0	3.8	1,196	547	0	9.3	309	361	0	2.7	1,625	321	1	3.7	1,087	252	34	2.9	1,504	306	8	5.1	1,096	325	6
Maryland.....	12.6	366	465	26	12.8	222	222	5	12.7	312	373	18	10.0	1,240	608	23	25.5	233	675	4	16.1	842	634	15	14.3	555	493	17
Massachusetts.....	4.9	1,146	473	1	4.9	726	329	11	4.9	962	409	5	4.4	1,619	792	0	4.1	908	488	3	4.2	1,198	612	2	4.5	1,106	533	3
Michigan.....	24.6	123	366	46	18.9	178	372	40	22.0	148	369	44	18.9	1,463	567	16	27.4	506	803	40	22.5	1,057	667	26	22.3	560	504	36
Minnesota.....	14.5	728	304	1	6.5	323	312	0	10.0	498	309	0	19.5	1,984	368	1	16.6	1,169	472	6	18.6	1,752	397	3	16.7	1,474	378	2
Mississippi.....	8.2	139	855	1	20.5	199	604	1	10.0	148	817	1	9.7	828	988	0	28.3	686	1,045	0	15.8	782	1,006	0	12.8	456	909	0
Missouri.....	19.2	158	246	3	19.6	87	352	3	19.4	123	299	3	25.9	897	315	2	25.5	230	580	4	25.8	725	383	2	22.2	389	336	3
Montana.....	2.2	3,945	338	0	13.0	36	0	0	2.8	3,737	320	0	4.6	2,304	314	0	3.5	1,820	447	1	4.5	2,258	327	0	4.0	2,696	325	0
Nebraska.....	20.3	216	359	3	.....	.....	.....	.....	20.3	216	359	3	21.1	2,773	129	0	29.8	313	1,256	15	21.7	2,620	199	1	21.4	2,190	228	1
Nevada.....	2.2	2,777	145	0	.....	.....	.....	.....	2.2	2,777	145	0	2.4	3,106	405	0	.....	.....	.....	.....	2.4	3,106	405	0	2.3	2,956	286	0
New Hampshire.....	4.6	1,274	655	0	5.4	880	678	8	4.9	1,131	663	3	1.7	1,599	831	1	3.2	1,177	911	0	2.0	1,497	851	0	3.3	1,332	766	2
New Jersey.....	20.4	251	278	0	12.2	295	295	2	14.8	281	289	1	9.9	1,018	455	1	16.9	760	451	4	13.2	897	453	3	13.7	688	397	2
New Mexico.....	8.2	2,091	702	0	16.5	332	453	0	8.9	1,953	683	0	3.7	3,559	405	0	24.4	1,080	438	0	6.8	3,179	410	0	8.2	2,339	597	0
New York.....	14.6	296	349	14	12.3	140	148	17	13.2	200	225	16	12.8	1,806	396	14	15.7	396	425	22	14.5	970	413	19	14.0	666	339	18
North Carolina.....	20.9	607	953	2	40.5	811	314	0	25.9	658	792	1	5.8	3,112	666	1	13.4	938	2,015	0	7.1	2,743	895	1	16.5	1,700	843	1
North Dakota.....	33.3	881	326	0	27.0	433	800	0	32.1	798	414	0	2.6	8,607	453	0	13.4	5,233	590	7	3.6	8,313	465	1	19.3	4,164	437	0
Ohio.....	20.9	258	514	131	15.1	169	433	50	19.1	231	489	105	18.7	800	484	111	14.0	759	395	77	17.1	786	453	100	18.5	405	477	104
Oklahoma.....	15.3	1,112	165	0	15.2	1,131	477	0	15.2	1,115	224	0	16.8	1,692	248	0	31.4	726	562	1	21.0	1,412	339	0	18.0	1,258	280	0
Oregon.....	4.2	1,396	351	0																								



U.S. DEPARTMENT OF COMMERCE

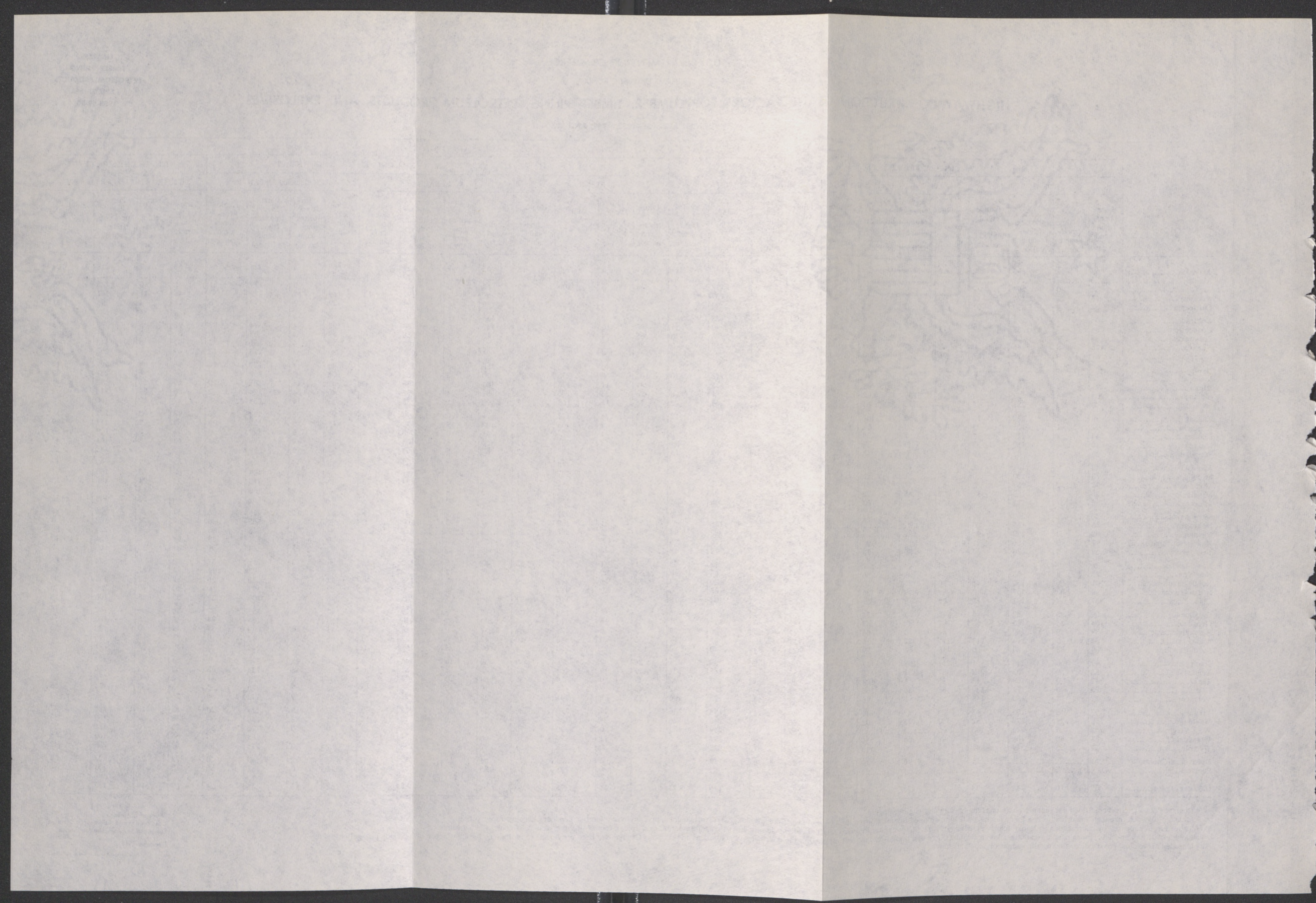
BUREAU OF PUBLIC ROADS

HIGHWAY CONSTRUCTION USAGE FACTORS FOR LUMBER, TIMBER PILING, PETROLEUM PRODUCTS, AND EXPLOSIVES

WEIGHTED AVERAGE—1958, 1959, AND 1960

LUMBER
TIMBER PILING
PETROLEUM PRODUCTS
EXPLOSIVES
1958-59-60

STATE	QUANTITIES OF MATERIALS PER MILLION DOLLARS CONTRACT CONSTRUCTION COST ¹																											
	INTERSTATE SYSTEM												FEDERAL-AID PRIMARY SYSTEM (EXCLUSIVE OF INTERSTATE)												ALL INTERSTATE AND OTHER FEDERAL-AID PRIMARY			
	RURAL				URBAN				RURAL AND URBAN				RURAL				URBAN				RURAL AND URBAN							
	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)	Lum- ber ² (thou- sand bd.ft.)	Tim- ber ³ piling (thou- sand bd.ft.)	Petro- leum ⁴ products (thou- sand gallons)	Explo- sives ⁵ (thou- sand pounds)
Alabama	63	11	185	222	268	278	33	0	68	16	182	217	61	3	236	78	65	9	189	23	62	4	228	69	63	7	218	104
Alaska .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Arizona	38	0	197	77	31	0	50	0	37	0	177	67	48	0	200	63	47	0	123	19	48	0	179	51	42	0	178	59
Arkansas	43	14	136	3	56	0	145	4	47	10	139	3	43	14	195	36	69	2	127	12	49	11	178	30	48	11	161	19
California	67	4	110	21	126	0	73	8	98	2	90	15	79	3	125	10	186	10	69	1	129	7	99	5	111	4	94	11
Colorado	105	9	173	9	98	1	76	4	102	6	133	7	51	1	242	57	135	18	63	0	60	3	223	51	82	5	177	28
Connecticut	84	7	83	17	77	7	100	1	81	7	90	11	88	10	111	155	115	0	80	34	103	4	94	87	93	5	92	53
Delaware	184	129	28	0	.....	.....	.....	.....	184	129	28	0	65	4	64	0	13	1	53	0	58	3	62	0	62	7	61	0
Florida	175	0	146	0	48	9	100	0	75	7	110	0	35	3	204	3	34	6	103	0	35	4	181	2	57	5	143	1
Georgia	87	0	471	167	96	13	97	16	93	8	241	74	43	4	273	5	24	0	281	44	39	3	275	13	49	4	268	26
Hawaii .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	151	0	155	31	60	6	110	4	95	4	127	14	95	4	127	14
Idaho	25	12	226	115	225	0	18	0	33	11	218	110	109	0	275	88	70	2	162	41	104	0	259	82	66	6	237	97
Illinois	63	9	100	0	101	19	43	4	82	14	72	2	41	11	125	1	102	23	65	0	61	15	106	0	69	15	92	1
Indiana	204	46	79	0	110	108	92	0	186	58	81	0	38	25	133	2	81	21	85	3	46	24	124	2	80	32	114	1
Iowa	0	93	251	2	.....	.....	.....	.....	0	93	251	2	16	15	168	2	29	11	88	16	18	14	154	5	17	19	160	5
Kansas	99	44	172	13	118	50	101	10	105	46	150	12	94	124	212	28	75	170	90	3	91	132	192	23	98	90	171	18
Kentucky	92	1	105	93	143	0	64	2	101	0	98	78	64	2	133	120	133	19	77	14	78	5	122	98	89	3	111	89
Louisiana	43	2	116	0	56	5	38	0	48	3	88	0	44	4	177	0	41	10	45	0	43	6	120	0	45	5	108	0
Maine	48	3	130	75	80	0	51	5	50	2	126	71	30	3	201	37	66	8	104	23	39	4	179	34	42	3	161	47
Maryland	46	0	81	19	79	0	48	5	58	0	69	14	27	5	123	12	187	5	61	1	91	5	99	7	73	2	83	11
Massachusetts	43	9	101	25	32	11	47	0	38	10	77	14	50	5	119	17	54	4	84	21	52	5	98	19	47	7	90	17
Michigan	70	41	130	0	67	1	49	0	69	23	93	0	43	8	137	2	57	81	71	0	49	39	109	1	60	30	100	1
Minnesota	72	12	139	0	63	47	87	8	67	32	109	5	17	12	245	21	38	30	124	3	23	17	210	16	33	21	188	13
Mississippi	128	14	150	11	209	45	172	0	140	19	154	9	78	5	201	0	43	9	138	0	67	7	180	0	104	13	167	5
Missouri	55	37	111	40	134	88	60	10	94	62	86	25	101	68	165	51	87	0	57	4	97	51	137	39	96	57	108	31
Montana	35	22	262	62	249	174	22	0	46	30	249	59	65	18	227	27	31	1	137	16	62	16	219	26	57	20	228	36
Nebraska	58	0	155	0	.....	.....	.....	.....	58	0	155	0	73	31	169	0	47	0	102	0	71	30	165	0	69	24	163	0
Nevada	62	0	220	94	.....	.....	.....	.....	62	0	220	94	54	7	223	86	.....	.....	.....	.....	54	7	223	86	58	4	222	89
New Hampshire	97	0	136	11	106	1	108	2	100	0	126	8	71	5	179	14	69	0	146	7	70	4	171	13	84	2	151	10
New Jersey	52	0	70	34	86	90	73	10	75	61	72	18	58	38	54	1	48	5	54	0	53	22	54	1	61	35	60	7
New Mexico	98	7	220	90	224	44	122	0	109	9	212	83	51	1	265	35	41	15	163	10	50	3	249	31	90	8	224	66
New York	43	8	53	18	33	123	36	5	37	78	43	10	38	2	103	34	85	12	52	3	65	8	73	16	54	36	61	14
North Carolina	101	66	150	44	70	26	70	1	93	56	130	33	73	16	248	29	66	197	158	10	72	47	233	26	82	52	181	30
North Dakota	54	63	167	0	49	64	156	0	53	63	165	0	19	9	410	0	69	36	200	0	23	12	392	0	40	40	266	0
Ohio	37	4	121	12	96	7	67	15	55	5	104	13	49	4	113	21	46	5	101	51	48	4	109	32	53	5	106	18
Oklahoma	69	5	182	6	76	2	154	1	71	4	177	5	40	11	166	36	42	0	129	6	41	8	155	27	56	6	167	16
Oregon	164	25	180	63	197	44	167	54	173	30	176	61	71	16	215	63	200	50	116	0	110	27	184	44	147	28	180	54
Pennsylvania	39	0	130	41	51	0	68	37	47	0	86	39	29	0	124	44	51	0	68	22	41	0	93	32	44	0	90	35
Rhode Island	84	0	114	113	115	22	36	5	111	19	47	19	66	0	43	10	42											



The U.S. average factors for all Federal-aid systems combined, including estimated secondary factors, for the years 1958, 1959, and 1960 are as follows:

	Material	Quantities per million dollars contract con- struction cost
Cement-----	barrels--	12, 600, 000
Bitumens-----	tons----	1, 423
Concrete pipe-----	do-----	534
Clay pipe-----	do-----	16

Where the factor "0" appears in the tabulation it indicates that none or a negligible quantity of the material was reported. The dotted lines indicate that no construction was reported on the particular system for the State shown.

EXHIBIT J

HIGHWAY CONSTRUCTION USAGE FACTORS FOR LUMBER, TIMBER PILING, PETROLEUM PRODUCTS, AND EXPLOSIVES, 1958-60

DISCUSSION

This is the sixth in a series of tabulations showing highway construction usage factors for lumber, timber piling, petroleum products, and explosives for 3-year periods. The first of the series was based on the years 1953, 1954, and 1955 and the fifth of the series covered the years 1957, 1958, and 1959.

An important phase in highway construction planning is the estimating of future requirements for materials in order that industry may be geared to supply such materials. Of the various materials used in highway construction, steel and aggregates constitute the largest elements of cost, together amounting to more than 50 percent of the cost of all materials and supplies and about 30 percent of the total construction cost (not including the cost of right-of-way and engineering). The approximate comparable percentages for the materials in this tabulation are as follows:

Item	Percentage of materials and supplies cost	Percent of con- struction cost
Lumber-----	2-----	1-----
Timber piling-----	Less than 1 (0.5)-----	Less than 1 (0.2).
Petroleum products-----	8-----	4-----
Explosives-----	1-----	Less than 1 (0.5).

The usage factors for lumber, timber piling, petroleum products, and explosives are intended to aid producers, manufacturers, and suppliers of these commodities and related industries, as well as highway contractors, engineers, and economists in planning to meet the needs of the expanded highway construction program in the United States. These factors when applied to expected contract construction expenditures for both Federal-aid and non-Federal-aid highway construction, will generally result in reasonably accurate estimates of requirements.

The data used in the development of the usage factors are supplied by contractors for projects on the Federal-aid primary system (including interstate). Investigations have indicated that for comparable standards of design, materials usage factors for non-Federal-aid work do not differ appreciably from those developed for Federal-aid construction. Information for computing Federal-aid secondary factors, by States, is not currently reported. It is recommended, therefore, that the State secondary factors on the tabulation of January 1958, covering the period 1954-56, be used for reasonably accurate estimating purposes.

It should be recognized that the factors shown for individual States, in some instances, may not be truly representative of normal usage because of being based on low volume of work and/or temporary disproportionate percentages of the three major classifications of highway construction, i.e. grading and drainage, surfacing and structures. In some States, however, during the 3-year period, the volume of work is large enough and the type distribution is of suitable proportion to reflect fairly representative usage factors.

As in previous tabulations of the series, the elimination of data for the first year of the last edition and the inclusion of data for the most current complete year resulted in some significant changes in the factors for some States. Generally

the U.S. average factors for timber piling and explosives have increased to some extent as compared to the previous issue, while those for lumber and petroleum products have decreased.

The U.S. average factors for all Federal-aid systems combined, including estimated secondary factors, for the years 1958, 1959, and 1960 are as follows:

<i>Item</i>	<i>Quantities per million dollars contract con- struction cost</i>
Lumber.....	board feet..... 69, 000
Timber piling.....	do..... 20, 000
Petroleum products.....	gallons..... 145, 000
Explosives.....	pounds..... 24, 000

Where the factor "0" appears in the tabulation it indicates that none or a negligible quantity of the material was reported. The dotted lines indicate that no construction was reported on the particular system for the State shown.

EXHIBIT K

TABLE 1.—*Estimate of annual highway material usage, 1962-72*

Description	Unit	1962			1962-72 total
		Construction (\$5,600,000,000 net construction) ¹	Maintenance (\$2,800,000,000 program)	Total	
Steel (incorporated in high-ways):					
Structural steel.....	Thousand tons.....	1, 036	52	1, 088	13, 200
Reinforcing steel.....	do.....	1, 064	56	1, 120	13, 600
Steel culvert pipe.....	do.....	213	52	265	3, 100
Miscellaneous.....	do.....	280	46	326	3, 900
Subtotal.....	do.....	2, 593	206	2, 799	33, 800
Estimated concrete pipe reinforcement.	do.....	40	2	42	490
Total.....	do.....	2, 633	208	2, 841	34, 290
Steel (indirect):					
Construction machinery replacements.	do.....			710	7, 900
Motor vehicle replacements.	do.....			308	3, 450
Repair parts (all equipment), including cutting edges.	do.....			285	3, 180
Subtotal.....	do.....			1, 303	14, 530
Grand total.....	do.....			4, 144	48, 820
Aluminum: All mill shapes, castings, and forgings.	Thousand pounds.	31, 100	6, 100	37, 200	510, 000
Cement:					
Portland cement.....	Thousand barrels.	70, 600	2, 100	72, 700	887, 200
Estimated cement in R.C.P. culverts.	do.....	4, 000	200	4, 200	46, 400
Total.....	do.....	74, 600	2, 300	76, 900	933, 600
Bitumens.....	Thousand tons.....	8, 000	5, 700	13, 700	172, 000
Aggregates: Sand, gravel, and crushed stone.	do.....	582, 000	172, 000	754, 000	9, 040, 000
Lumber: Lumber and plywood.	Million feet board measure.	386	480	866	10, 320
Timber piling.....	do.....	112, 000	19, 600	131, 600	1, 474, 500
Concrete culvert pipe.....	Thousand tons.....	3, 000	265	3, 265	40, 500
Clay pipe and tile.....	Tons.....	89, 600	3, 700	93, 300	1, 030, 600
Petroleum products.....	Million gallons.....	812	520	1, 332	15, 400
Explosives.....	Million pounds.....	134	7	141	1, 550
Paints:					
Structural and other.....	Thousand gallons.....	1, 580	1, 930	3, 510	40, 200
Traffic.....			8, 300	8, 300	94, 800
Metallic.....		355	405	760	8, 600
Total.....		1, 935	10, 635	12, 570	143, 600

¹ Not including right-of-way and engineering expenditures.

EXHIBIT L

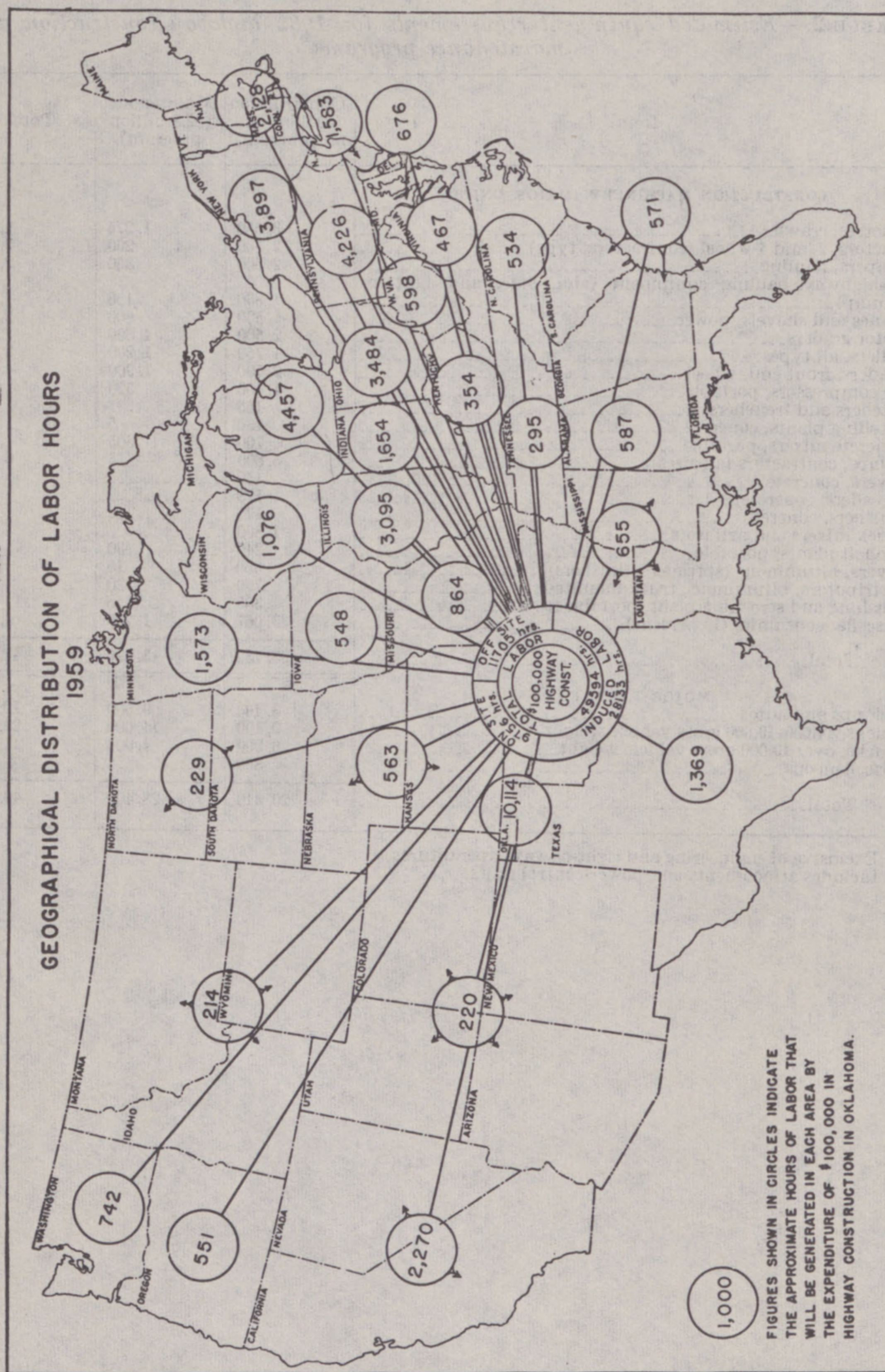
TABLE 2.—*Estimated equipment requirements for 1962 highway construction and maintenance programs*

Item	Construction (\$5.6 billion net program) ¹	Maintenance (\$2.8 billion program)	Total
CONSTRUCTION MACHINERY (MAJOR UNITS)			
Tractors, crawler ²	3,550	1,275	4,825
Tractors, 2- and 4-wheel (contractors' type)	2,700	260	2,960
Scrapers, hauling	2,500	350	2,850
Off-highway hauling equipment (end, side, and bottom dump)	1,830	150	1,980
Cranes and shovels, power	1,500	800	2,300
Motor graders	2,500	4,600	7,100
Rollers, all types	1,750	1,200	2,950
Loaders, front end, wheel	2,100	1,900	4,000
Air compressors, portable	1,460	520	1,980
Ditchers and trenchers	155		155
Batching plants, concrete	430	5	435
Concrete mixers, portable	700	305	1,005
Pumps, contractors (all sizes)	5,600	775	6,375
Pavers, concrete	150		150
Spreaders, concrete	175		175
Finishers, concrete	175		175
Truck mixers and agitators	1,800		1,800
Asphalt plants, portable	240	30	270
Pavers, bituminous (spreaders, finishers)	350	15	365
Distributors, bituminous, truck mounted	700	20	720
Crushing and screening plant, portable	300	155	455
Miscellaneous units (10 percent)	3,067	1,236	4,303
Total	33,732	13,596	47,328
MOTOR VEHICLES			
Pick ups and autos	3,460	9,500	12,960
Trucks, 14,000-19,000 gross vehicle weight	9,100	14,000	23,100
Trucks, over 19,000 gross vehicle weight	6,900	4,900	11,800
Miscellaneous	850		850
Total	20,310	28,400	48,710

¹ Exclusive of engineering and right-of-way expenditures.² Includes attachments and power-control units.

EXHIBIT M

GEOGRAPHICAL DISTRIBUTION OF LABOR HOURS 1959



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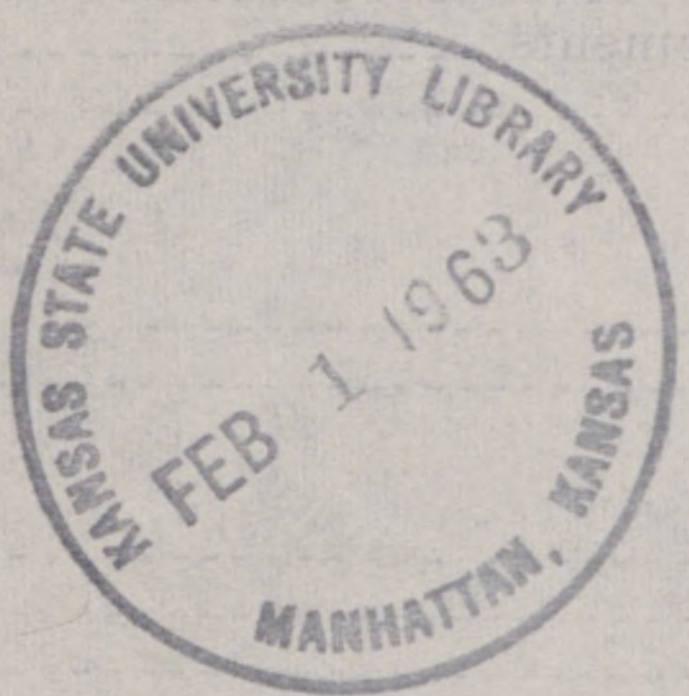
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