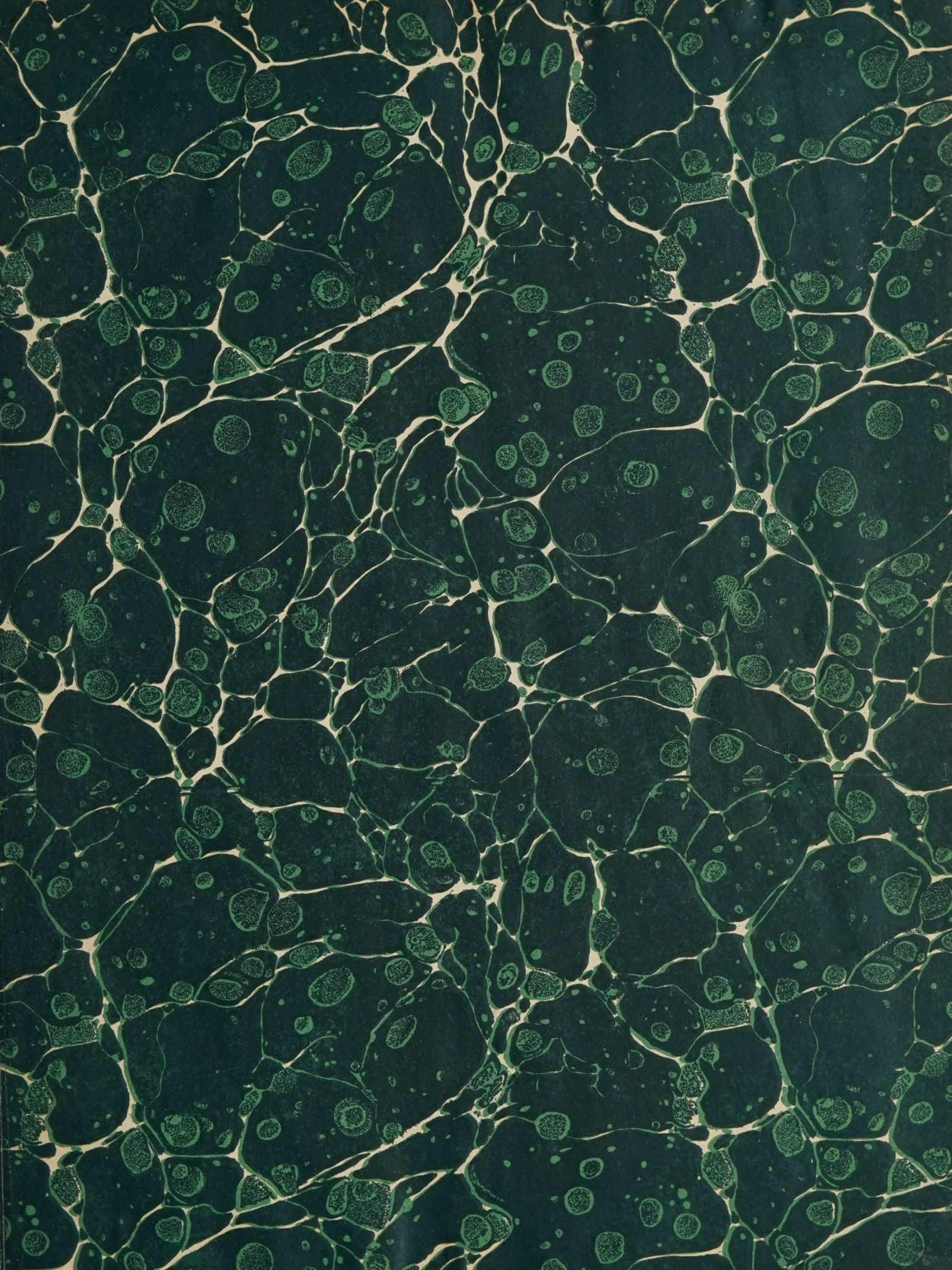


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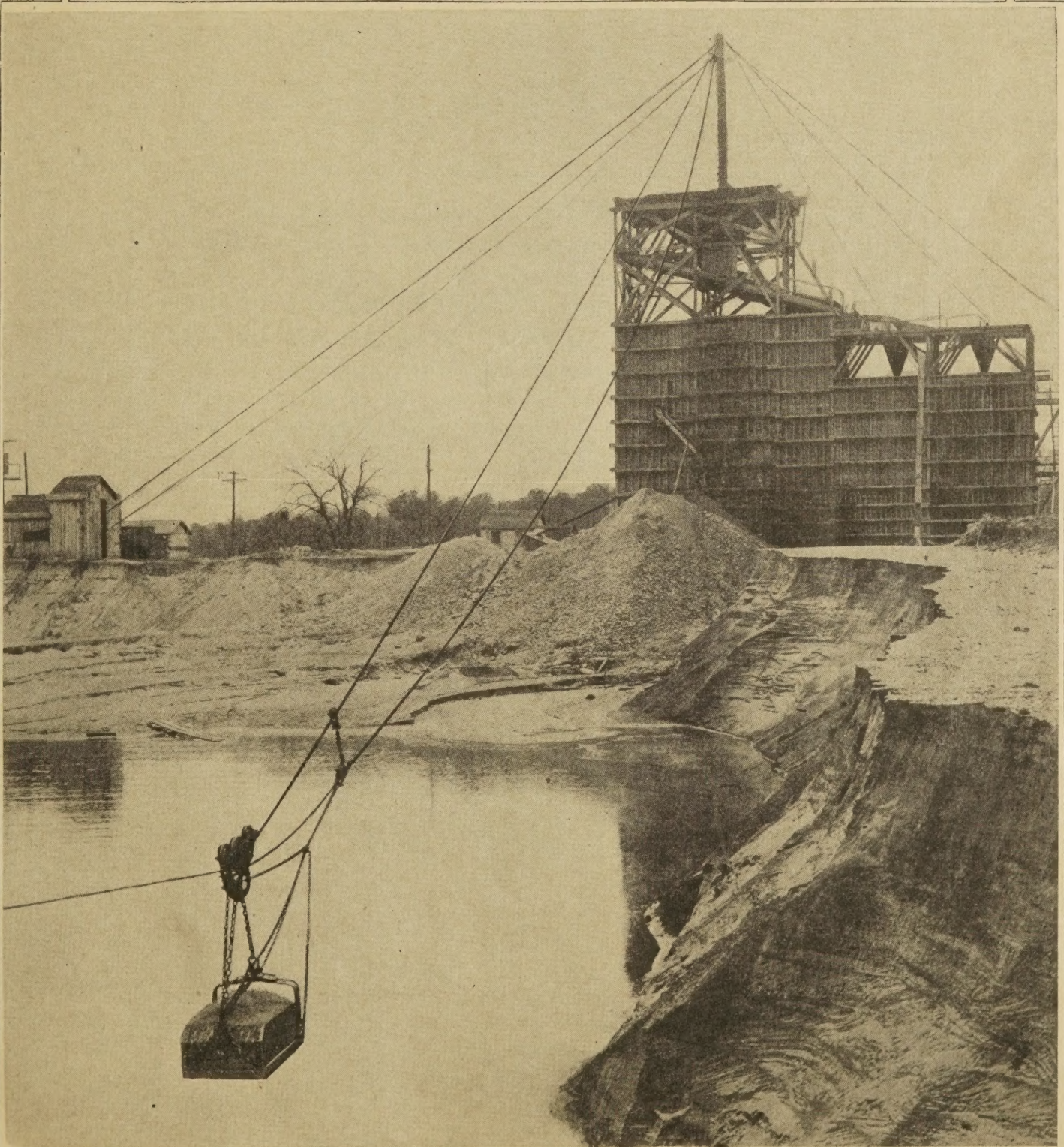
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CABLEWAY DRAGLINE IN OPERATION AT ILLINOIS SAND AND GRAVEL PLANT

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PUBLIC ROADS

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CRUSHED STONE AND GRAVEL ROADS

By C. L. McKESSON, Senior Highway Engineer, and A. F. MORRIS, Highway Engineer, Bureau of Public Roads.

THE fact that for many years an extensive mileage of highways must of necessity be surfaced with crushed stone or gravel seems to warrant a review of developments in this type of construction in the Pacific Northwest. This paper does not take into consideration macadam surfacing, which is an altogether different type.

Many miles of crushed stone or gravel surfacing are now under construction. Due to a lack of water in most localities where this type is being built, water has been used on only a few projects and rolling is seldom resorted to. The general practice now in this section is to use much finer material than heretofore, both in bottom and top courses. The maximum size of material used is 2 inches, and on many of the most satisfactory pieces of construction $1\frac{1}{2}$ inches was fixed as the maximum. The ease with which such a surfacing may be maintained and the smooth, uniform roadway resulting seem to justify the small additional cost involved in producing the finer material.



FEDERAL-AID PROJECT NO. 44, IN GILLIAM COUNTY, OREG., SURFACED WITH CRUSHED GRAVEL

The more recent specifications for crushed stone or crushed gravel surfacing usually require the material to be screened into two bins, one receiving the material from 2 inches or $1\frac{1}{2}$ inches, the maximum size, down to 1 inch or $\frac{7}{8}$ inch, and the other containing the finer material. The material is spread in 2 courses, each approximately one-half of the total thickness, but the exact thickness is regulated in such a way as to use all

of the material between $1\frac{1}{2}$ inches and 1 inch (or $\frac{7}{8}$ inch) for the bottom course and the finer material for the top course. The base course is usually spread about 500 feet in advance of the top course, but this is varied in order to prevent the overflow of either of the bins.

SPECIFICATIONS GIVE SATISFACTORY RESULTS.

The results obtained under these specifications have been satisfactory, but it has been noted that the stone from some quarries has set up into a smooth, hard roadway much more quickly than that from others. In some cases stone



WASHINGTON FEDERAL-AID PROJECT NO. 14, IN OKANOGAN COUNTY, SURFACED WITH SCREENED GRAVEL

which screening and abrasive tests indicated as being of superior quality did not form as satisfactory road material as a softer stone on which a rather adverse report had been made by the testing engineer. It has been demonstrated that a small amount of soft stone in a quarry provides a binder which is far more desirable than earth or clay, which it is sometimes necessary to add to the base where the material is a particularly hard clean basalt.

On one project in Central Oregon the specifications call for crusher-run material of a maximum size of $1\frac{1}{2}$ inches laid in one course of 5-inch thickness and leveled up with a top course of approximately 1-inch thickness. The results are not as satisfactory as on other projects where the material is separated into two grades and laid in two courses. When laid in deep courses, the material does not compact as well as when laid in lighter courses and the operation of spreading and dragging the stone tends to sift the screenings to the bottom and leave the larger fragments on top—exactly the reverse of the ideal condition.

In some specifications an attempt is made to specify percentages of material passing a series of screens between the maximum and minimum sizes. There appears to be little or no justification in practice for this attempted refinement. A gravel or broken-stone type of surfacing is at best only a light traffic surfacing and every effort should be made to use suitable materials locally available. In many cases splendid pieces of work have been constructed with material which would not comply with a specification requiring an ideal grading with a minimum percentage of voids. The maximum size should be specified at $1\frac{1}{2}$ or 2 inches. The maximum and minimum percentages of sand should be specified between liberal limits. The proportions passing and retained on a $\frac{7}{8}$ -inch or 1-inch screen should also be specified. These proportions can easily be checked on a large scale during the progress of the work by noting the relative output from each of the bins. The various pits should be carefully examined and average grading of the material, apparent cementing qualities, percentage of oversize particles and availability of material should all be considered in the selection of pits. The best material that can be obtained within reasonable costs should always be selected. In some cases it will be found necessary to use gravel little of which is coarser than $\frac{3}{4}$ inch or 1 inch, and some very satisfactory results have been obtained with such gravel, which of course requires no separation of sizes.

CRUSHED GRAVEL MOST SATISFACTORY FOR DRY-BUILT ROADS.

Where surfacing is laid without water and without rolling, crushed gravel has generally been found to be the most satisfactory material. The selection of gravel pits requires care and experience on the part of the

engineer. As a rule any gravel which is found cemented together in the pit will form an excellent road metal when crushed and properly laid, while gravel which lies loose in its natural state, as in beds of streams or which carries a large amount of sand, can not be expected to set up rapidly when deposited on a road, though there have been some exceptions to this rule. The gravel, though lying loose and free in the bank, may carry enough soft granite or other soft stone to form a natural binder when crushed, but as a general rule, unless the material is found well cemented in the pit, it will not prove satisfactory as a surfacing material where the oversize gravel and excess sand is screened out and no crusher used. Such material will not compact into a good wearing surface in dry weather without the addition of clay or earth binder. Where such binder is used the results usually appear to be satisfactory in the summer, but, when the clay which acted as a binder in August becomes a lubricant in January, the results are apt to be far from satisfactory. It is very desirable to crush oversize material rather than to screen and waste it. Any gravel which contains 15 to 20 per cent of oversize material will justify the use of a crusher.

A number of projects have been constructed with gravel spread in two layers each of approximately one-half the total thickness, the material in both the top and bottom courses being required to pass a $1\frac{1}{2}$ -inch screen. In Washington it has been the general rule to specify "one-course" gravel of a maximum size of $1\frac{1}{2}$ inches. While the specifications permit laying the total thickness (which varies from 6 to 8 inches) in one course, it has been the general practice to spread a base course of approximately one-half the total thickness and follow with a second layer of the same size material, as it has been found easier to operate trucks in this way than to plow through 6 or 8 inches of loose gravel.

THE MOST SATISFACTORY METHOD.

After observing the methods employed in the construction of the various types of crushed rock and gravel surfacing on many Federal-aid jobs in district 1 and the results obtained, we are convinced that the most satisfactory road surface has been secured where the crushed gravel was placed in two courses; the bottom course consisting of material passing a screen with circular openings of not more than 2 inches, preferably $1\frac{1}{2}$ inches, and retained on a screen having openings of 1 inch or $\frac{7}{8}$ -inch diameter and the top course consisting of all material passing the smaller screen.

There is some difference of opinion as to the merits of this method of screening into two sizes before laying. Some engineers argue that it is better to use crusher run material in both courses on the theory that in this

way the voids in the base are filled better than if the fines are screened out. If it were possible to obtain a uniform mixture and to maintain this uniformity through the various stages of crushing, screening, hauling, and spreading the rock, there would be no doubt that the crusher-run method would be the more desirable, but it is not possible to secure the desired uniformity when all the output of the plant falls into one bin.

When the material falls from the screen, the fines cling together in a pyramid, while the larger pebbles and fragments roll down and outward to the sides of the bin. The result is that some loads hauled to the road contain practically all fines, while others consist almost entirely of the larger size stone; so that the theoretically uniform mixture actually consists of a patch of coarse and a patch of fine, with the fines on the bottom and the coarse material on top quite as frequently as otherwise, which is exactly the reverse of what it should be.

Even if every load were uniformly graded and mixed when deposited on the road, which they never are, the process of spreading and dragging necessary to secure a true and uniform surface would tend to work the fine material to the bottom, leaving the coarser particles on top, thus again producing a condition exactly opposed to the ideal, which is more nearly obtained by first laying the heavy rock on the bottom and spreading a top course of fine material.

IMPORTANCE OF DRAGGING DURING CONSTRUCTION.

The great importance of constantly dragging and maintaining the surface of the roadway during construction is frequently overlooked. Surfacing is usually begun at the source of supply, so that hauling and trucking of material will be carried on over the newly placed stone until the job is completed. With proper dragging a smooth, uniform surface can be obtained by the time the project is completed, but without dragging the road becomes badly rutted and a rough, unsatisfactory job results. In dragging it has been found advisable to use a light-drag in the early stages, gradually filling the ruts as they are formed. If a heavy drag is used which entirely fills the ruts, the trucks are obliged to plow new ruts, and a constant repetition of this operation results principally in an excessive cost for hauling and leaves a poorly compacted surface. With light drags gradually filling the ruts, the ruts are built up and soon traffic can be distributed over the surface.

On one Oregon project it was necessary to truck material over the new surfacing up to a distance of 11 miles from the pit. Without proper dragging or water this job made a very poor showing for several months.

Two water tanks were then provided, the gravel was kept damp and dragged with light drags, and the job carried to a most satisfactory completion. The cost for watering in this case was about \$250 per mile, but upon completion a smooth and well compacted surface was turned over to the public in spite of the heavy trucking during construction. A blade or road planer is necessary to finish such a surface after it has begun to compact under the light drags.

On one project heavy wagon tires dragged over the ruts behind the trucks assisted in filling and compacting the material and in eliminating the ruts.

The advisability of continuing the practice of laying screened or pit-run gravel surfacing without sprinkling and continuous dragging is seriously questioned, except in the rare instances where water can not be obtained. It is true that in nearly every case a fairly good road surface has been secured after properly maintaining it through a winter, with the usual amount of moisture from rain and melting snow; but it is very seldom that such a surface becomes really satisfactory until it has been thoroughly wet down, either by natural means or by the use of sprinklers in the course of construction.

Where water is available the cost per mile for sprinkling and dragging is usually very small as compared with the satisfaction of having a firm, smooth surface as soon as the road is completed. The inconvenience of a loose, ratty surface for the first season, as is so often the case where water and drag are not used, may thus be avoided. The reduced cost of maintenance for the first year where a road is properly compacted during construction will probably offset the cost of water used.

The illustrations show the difference between a crushed gravel surface and one of screened gravel, both laid without water or rolling and under practically the same weather conditions.

BRITISH ROAD CLASSIFICATION.

The classification of roads under the British ministry of transports' scheme is nearing completion, and when the schedules reach their final form it is the intention of the ministry to distinguish each first and second class road by an individual number. Another feature of the scheme is the standardization of warning signs and road direction posts; provision has been made for indicating the route numbers on the arms of posts in the belief that "the universal adoption of this practice would be of the greatest service to road users generally." These details are included in a letter from the ministry to the highway authorities in England. The letter concludes by saying that Sir Eric Geddes is not advocating "any wholesale replacement of serviceable signs at the present time."

CAPILLARY MOISTURE AND ITS EFFECT ON HIGHWAY SUBGRADES

By W. W. McLAUGHLIN, Senior Irrigation Engineer, Bureau of Public Roads.

ONE of the basic necessities in a pavement is a dry, well drained foundation or subgrade. The prevailing practice is to provide drainage by means of open ditches, covered drains, or both, for the removal of free surface or free ground water. Even where this precaution has been taken, many highway pavements have failed because of wet bases. In other instances, in the arid sections of the country, pavements have at least partially failed where drainage was not thought to be necessary, and these partial failures have resulted, as far as could be determined, because of moisture distribution in the subgrades.

Why do these highways fail? Why do the foundations become wet and unstable in the face of accepted drainage methods? These are live questions bothering many highway engineers and now causing much concern in connection with highway pavement construction.

That capillary moisture may be the cause of some highway troubles and even failures has but recently been suspected. The writer's interest has been aroused in this question by investigations of the movement of soil moisture by capillarity by the division of irrigation investigations of the Bureau of Public Roads. It is the purpose of this article to present briefly a few of the data which may have a bearing upon the subject.

The force of capillarity acts equally in all directions, while the force of gravity acts only in a direction vertically downward. These two forces are at work all the time upon any moisture which may be within the soil. Capillarity is augmented by gravity when working in a direction downward from the horizontal and is reduced by that amount when working in a direction upward from the horizontal.

The following table indicates the relative effects of these two forces:

TABLE NO. 1.—Capillary movement of soil moisture from a free water surface into a lava ash soil column for various periods of time, and the total quantity of water moved.

Distance moved.....	Time in days.	Direction moisture moved.			
		Vertically upward.	Horizontal.	Downward 15° from horizontal.	Downward 30° from horizontal.
		Inches.	Inches.	Inches.	Inches.
	1	16.25	22.9	24.80	26.20
	2	23.59	30.85	34.05	38.05
	3	27.67	37.55	41.70	42.35
	7	37.42	57.40	63.40	66.25
	15	46.92	81.45	95.25	99.70
	30	54.50	109.90	137.10	150.10
Water moved in acre-inches, per acre.....	1	0.403	0.605	0.655	0.605
	2	.554	.806	.907	.857
	3	.706	1.008	1.109	1.058
	7	.907	1.562	1.764	1.764
	15	1.169	2.369	2.722	3.024
	30	1.320	3.58	4.334	5.141

The table shows clearly the effect of gravity on the capillary movement of soil moisture, both as to the distance the latter will reach in a given time and the total quantity of water moved. Expressed in round numbers and based upon the figures for the vertical column the moisture had moved downward at the end of 30 days two and one-half times as far in the soil column inclined downward at an angle of 15° and two and three-fourths times as far in the soil inclined downward at an angle of 30°, as it had moved upward in the vertical column. At the end of 30 days, three and one-fourth times as much water had moved down the 15° incline and three and nine-tenths times as much water had moved down the 30° incline as had climbed upward in the vertical column.

The table also shows that the quantity of water per unit over the entire wetted length is greater for the columns inclined downward than for the horizontal or vertical columns. That some idea may be obtained of the unit distribution of moisture in a vertical soil column and in a column inclined downward at an angle of 30° the following table is given:

TABLE NO. 2.—Distribution of moisture in soil columns by 2-inch sections from the water surface.

[Yolo gravel-clay loam.]

Distance from water surface.	Percentage of moisture in the soil.	
	Vertical column.	Column inclined downward 30°.
	Per cent.	Per cent.
2 inches.....	37.48	36.03
4 inches.....	36.72	35.92
6 inches.....	37.31	35.00
8 inches.....	37.68	34.39
10 inches.....	35.85	34.74
12 inches.....	32.35	34.28
14 inches.....	30.60	33.61
16 inches.....	28.20	32.30
18 inches.....	26.05	31.00
20 inches.....	23.25	29.94
22 inches.....	20.18	28.70
Average.....	31.45	35.99

In the table the average percentage of moisture per inch in the inclined column is greater by 4½ per cent than that in the vertical column. The per cent of moisture in the end of the column away from the body of free water is 42 per cent greater in the inclined column than in the vertical column. This circumstance is of the greatest importance, because the supporting strength of the subgrade depends upon the percentage of water in the soil.

The percentage of moisture found in a vertical soil column is not related directly to the height above the ground water except at the upper end, and then in only a very general way. The maximum percentage of moisture may be found and, in the clays and loams,

usually is found several inches above the water surface. This point is illustrated by figure 1.

From the figure it is seen that in the Riverside soil the greatest per cent of moisture is found about 15 inches above the water surface. In the Idaho lava ash about one-half of the soil column is up to capillary saturation. In other words, there would be little difference from the standpoint of moisture content whether the pavement was 6 inches or 24 inches above the water surface.

EFFECT OF GRAVEL SUB-BASE INDICATED.

Stratified soils of different types are usually found in the alluvial areas and the relative percentage of moisture in the several strata is of interest. Several soil columns were made up of sand, loam, and clay in alternate layers, differently arranged. These columns after having stood for several days were analyzed for moisture. It was found that, at the same height, the

In a soil column made up of 16 inches of clay on the bottom and sand on top, the moisture had not moved up into the sand more than 3 inches after standing 20 days. There was only 5 per cent of moisture in the sand, although there was 39 per cent in the top of the clay. Other similar tests indicated the advantage of a top layer of sand or gravel in keeping the moisture percentage low near the upper end of the soil column. The top layer of sand also seems to permit only slow movement of the moisture from the clay upward into the sand. Generally speaking, if the sand or gravel is placed at the bottom and a topping of clay or loam provided, the sand or gravel must be thick enough to prevent the rise of moisture to its upper edge to be effective. While the sand layer may transmit the moisture slowly, the clay or loam will readily take it up. Retardation of the movement within the limits of a few weeks is not of material importance or advantage in pavement work.

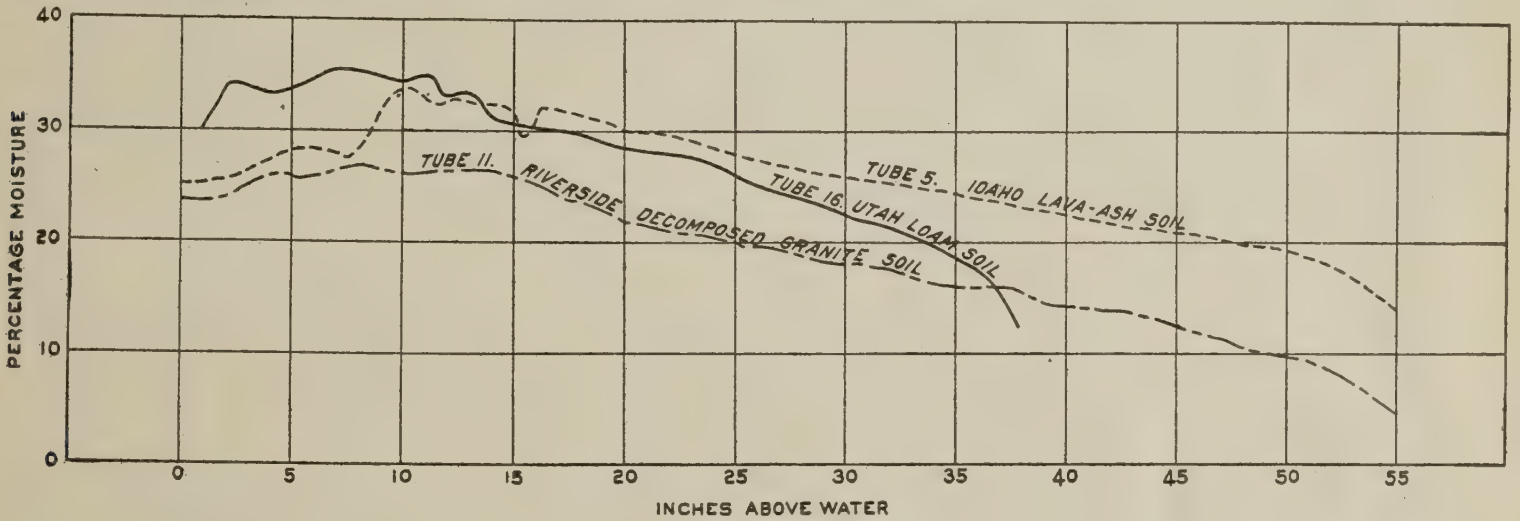


FIGURE 1.

several strata contained approximately the same percentage of moisture as a column of one type representing the various soils mingled. Table 3 gives the results of a typical instance. The made-up soil column has 6 inches of clay on the bottom, then 4 inches of river sand, and then a layer of clay, 6 inches thick, of the same type as the bottom layer. The second column of the table gives the percentage of moisture at various heights in a soil column made up as described above, and column 3 gives the percentage of moisture found at the corresponding heights in a uniform soil column of the type found in the made-up column at the respective heights.

TABLE No. 3.—Distribution of moisture in soil column of uniform type and in a stratified column of different soil types.

Distance above the water.	Percentage of moisture.	
	Made-up column.	Uniform column.
	Per cent.	Per cent.
Average from 0 to 6 inches.....	44.39	47.95
6 to 10 inches.....	13.46	16.10
10 to 12 inches.....	43.52	40.78
12 to 14 inches.....	14.89	14.21
18 inches.....	13.72	12.19

EXTENT AND RATE OF CAPILLARY MOVEMENT.

Questions often arise as to how far moisture will be brought up in different soils by capillarity from a body of free water, and at what rate the water will reach points at various heights above the water surface. Table 4 gives some indication of the answers.

TABLE No. 4.—Rise of capillary moisture in soils for different periods of time and rate of movement of the moisture.

Distance above water surface.	Light clay loam.		Lava ash soil.		Sandy loam.	
	Time in days.	Acre-inches per day.	Time in days.	Acre-inches per day.	Time in days.	Acre-inches per day.
12 inches.....	1 1/2	0.193	1/2	0.193	3/8	0.151
24 inches.....	6 1/2	.0035	2	.116	37	.0001
36 inches.....	55	.0018	6 1/2	.035	.....	None.
48 inches.....	219	.0001	17	.009	.....	.....
60 inches.....	.....	None.	50	.005	.....	.....
72 inches.....	.....	.....	200	.0001	.....	.....

The table but emphasizes the fact that the finer the soil texture the greater its capillary power, and it also shows the fallacy of attempting to keep the subgrade dry by shallow drainage or the building of low fills over soil saturated with water or where the underground water table is nearer than 5 or 6 feet to the surface,

unless the soil be sandy. The table shows that in lava ash soil of the type used in the experiment there will be brought to the surface through 5 feet of soil 1.8 acre-inches of water in a year, and through 4 feet of this soil there would be brought to the surface in the same time 3.3 acre-inches. Five and one-half inches of water would be brought up through 1 foot of sand, but through 2 feet of sand only one-half acre-inch of water would be brought up in a year.

It is difficult to estimate the amount of the evaporation of moisture from below the midpoint of a paved highway. Near the outer edge of the pavement the rate of evaporation may be very rapid, but in the center the moisture would first have to move horizontally to a crack or through 8 or 10 feet of soil to the outer edge of the pavement. On the deserts of the West the rate of evaporation from a wet soil may be one-half inch per day, and under some conditions even more. The rapid evaporation of the moisture near the outer edge of the pavement might, and sometimes does, result in a dry subgrade at and near the outer edge of the pavement and a wet subgrade in the center. In the heavier soils this would result in a subgrade of unequal supporting power and, through contraction and expansion resulting from unequal moisture content, leave an unsupported outer edge of the pavement or a mushy yielding subgrade center. According to Prof. William H. Burr, M. Am. Soc. C. E., the safe-bearing power of dry clay is 4 to 6 tons per square foot; that of moderately dry clay 2 to 4 tons; and that of soft, moist clay 1 to 2 tons. Hool and Johnson give as the safe-bearing power of quicksand $\frac{1}{2}$ to 1 ton per square foot, gravel and coarse sand well cemented 8 to 10 tons, and clean dry sand 2 to 4 tons. These figures indicate the effect of moisture in the subgrade in its relation to load-bearing strength.

CAPILLARY SYPHON MAY CAUSE WATER-LOGGING.

Where a highway is built through a country having a transverse slope of 15 degrees or more the movement of moisture down this slope by capillarity is relatively very rapid and extensive. If a sand or gravel stratum is present (especially if it be on top of a clay or other impervious or semi-impervious layer) then the capillary movement of moisture is much more rapid and will extend for great distances. Such soil conditions are not at all uncommon in an alluvial country and afford ideal conditions for the capillary syphoning of water.

The capillary movement of soil moisture from a free water surface is very rapid for the first 48 hours, and for that reason, shallow side drain ditches are not effective in preventing the capillary movement of moisture into subgrades, especially if these ditches are at all near the pavement. Deep drains are not effective against capillary moisture unless placed below the limit of capillary rise of moisture in the soil under consideration.

That capillary moisture has caused soggy, wet subgrades is beyond question and unless effective preventive measures are taken it will continue to cause highway troubles. Just what these protective measures should be and remain within reasonable cost limits has not yet been ascertained.

The data outlined above were obtained from experiments conducted on the capillary movement of soil moisture where the source of the moisture was free water. The capillary movement of soil moisture from a wet soil to a soil containing a smaller percentage of water differs from what has been shown only in quantity. However, the rate and extent of movement of the moisture under the last named condition is relatively so little as to be almost negligible in highway pavements.

SCHOLARSHIP ESSAY CONTEST ANNOUNCED.

A national essay contest, open to all pupils of high-school grade, with a 4-years' scholarship in any college or university as the prize for the successful contestant, was announced recently by the Highway and Highway Transport Education Committee. The subject prescribed by the committee is "Good Roads and Highway Transport." At the request of the committee Mr. H. S. Firestone, of Akron, Ohio, has consented to furnish the scholarship, which is valued at about \$5,000. This is a repetition of Mr. Firestone's offer of last year, which resulted in the awarding of a scholarship to Miss Katharine F. Butterfield, of Weiser, Idaho.

United States Commissioner of Education Dr. P. P. Claxton has requested the superintendents of education of the various States to name State committees to pass upon the essays that are written in each of the States, and the best essay from each State will be sent to Washington, where the national prize winner will be decided by a committee to be appointed by the Commissioner of Education.

The essays must not exceed 500 words in length and must be in the hands of the local committees not later than June 15, or the date of the closing of school in each locality.

Members of the Highway and Highway Transport Education Committee are: Dr. P. P. Claxton, United States Commissioner of Education, chairman; Thomas H. MacDonald, Chief Bureau of Public Roads; Col. Mason M. Patrick, Corps of Engineers, United States Army; Roy D. Chapin, National Automobile Chamber of Commerce; W. S. Keller, president American Association of State Highway Officials; H. S. Firestone, Rubber Association of America; Dean F. L. Bishop, Society for the Promotion of Engineering Education; Dr. Walton C. John, United States Bureau of Education, secretary; and Prof. C. J. Tilden, Yale University, director.

BITUMINOUS PAVEMENTS LAID ON OLD MACADAM STREETS IN DENVER

By J. W. JOHNSON, Senior Highway Engineer, Bureau of Public Roads.

THE city and county of Denver, during the past 10 years, have paved a number of streets with various types of bituminous surfaces on old macadam bases. The different types laid to date are asphaltic concrete, tar concrete, "Amiesite," sheet asphalt, and "Willite." The first attempt at this construction was made by the city in 1910, when four blocks on Speer Boulevard were paved. Three types of pavement were laid in the following order, each type being used throughout one block: Asphalt concrete, tar concrete, "Amiesite," and tar concrete. In 1912 the paving on this street was continued for a distance of eight blocks, using asphalt concrete. In the same year a block on Eighteenth Avenue, from Sherman to Grant, was paved with "Amiesite." In 1913 the block between Sherman and Lincoln on Eighteenth Avenue was paved with asphalt concrete.

In 1916, 1917, and 1918, 35 to 40 blocks were paved with sheet asphalt and asphalt concrete. One block of "Willite" was laid in 1919. In 1920 a total of 112,920 square yards of asphalt concrete and "Willite" pavement was laid.

All of the streets paved in this manner had previously been improved by grading, curbing, and gutter and surfacing. The surfacing originally placed varied in different parts of the city. Disintegrated granite, slag, and oil macadam were used.

The width of the streets varied from 30 to 40 feet between curbs. The width of the gutter was usually 2 feet. The crown varied from 8 to 12 inches. All of the streets had previously been supplied with storm sewers. Intakes to sewers were provided at intervals so that the maximum length of run-off of surface water was about 600 feet.

Owing to the light annual precipitation (an average of about 14 inches), the high crown on pavements, and the short distances that surface water has to travel before entering sewers, there is very little opportunity for the subgrade to become wet so long as the pavement is in good condition. Only a very few places



REMOVING THE EXCESS MATERIAL AFTER SCARIFYING THE OLD MACADAM.

where settlement of the subgrade has occurred are in evidence. Practically all of these defects occur under the earlier pavements.

With the exception of a small amount of "Willite," all of the 1920 construction was asphaltic concrete, 1½ inches thick on a 1½-inch binder course. Both Mexican and California asphalt, with a penetration of from 50 to 60, were used. The binder course was mixed in the proportion of 50 pounds of asphaltic cement to 250 pounds of sand and 750 pounds of smelter slag (maximum size 1 inch). The surface course was mixed in the proportion of 80 pounds of asphaltic cement to 85 pounds of limestone dust, 300 pounds of slag (maximum size ½ inch), and 535 pounds of sand.

The mixing was done at stationary plants and the material was transported to the job in auto trucks. The mixing plants and trucks are owned and operated by the city. All of the work, including the grading and preparation of the subgrade, is done by the city by day labor. No contracts are let for any portion of the work of this character.

PREPARATION OF SUBGRADE.

The surface of the street selected for paving is scarified by the use of a scarifier attached to a heavy blade machine and pulled by a 10-ton caterpillar tractor. The depth and amount of scarifying depends on the condition of the old macadam and the amount necessary to be removed. As all of the streets paved

have either brick or concrete gutters, it becomes necessary to remove 3 inches of old material at the junction of pavement and gutter. From this point the amount of material removed is decreased to the center of the road, where only the amount necessary to bring the road to a uniform crown is taken off.

The material loosened by the scarifier is bladed into windrows, about 6 feet wide and 3 feet high, and then loaded into wagons by means of a traveling bucket loader. After the excess material is removed the roadbed is thoroughly rolled until hard and firm. All depressions are then filled with good material and again rolled and brought to a uniform grade and cross section.

Upon this subgrade the asphalt binder course and surface course are laid in accordance with usual practice in laying asphalt pavement.

COST OF PAVEMENT.

The number of square yards of pavement of this character laid during the season of 1920 was 112,920. The total cost of this work was \$127,768.77, which is at the rate of \$1.13 per square yard. This price included the grading necessary to prepare the subgrade.

The average cost of grading amounted to \$0.15 per square yard of pavement. In other words, the pavement cost an average of \$0.98, and the grading \$0.15 per square yard.

The items of cost of the work done in 1920 are as follows:

Item.	Cost per square yard.
Surface mixture.....	\$0.281
Binder mixture.....	.210
Fuel.....	.071
Expense.....	.010
Tools and sundries.....	.023
Plant repairs.....	.030
Depreciation plant.....	.013
General salaries.....	.040
General labor.....	.013
Plant labor.....	.115
Street labor.....	.088
Hauling.....	.086
Total for surfacing.....	.980
Grading.....	.150
Total.....	1.13

The various charges entering into the above items are explained as follows: Surface and binder mixture include the cost of asphalt, limestone dust, sand and slag which are used in them.

Fuel covers all coal used at plant and on steam rollers on job and fuel oil in the dryer and electric power for derrick.

Expense includes insurance, taxes, printing, automobile and miscellaneous expenditures.

Tools and sundries include the purchase of tools and miscellaneous plant supplies, water rental, horse feed and shoeing, lubricating oil and grease.

Plant repairs include repairs and replacements to plant and roller parts; also labor in getting plant in shape before starting up in the spring.

Depreciation is 20 per cent of the cost of new equipment purchased.

General salaries include those of the superintendent, bookkeeper at plant, clerk at administrative office, and an inspector.

General labor includes labor in building addition to plant, assembling derrick and any other work not properly chargeable to operation.

Plant labor includes all labor used in operating the plant.

Street labor includes all labor used on the street in laying the binder and top.

Hauling includes the cost of trucks and drivers, and street rollers and operators.

Grading includes all labor in preparing subgrade.

PRESENT CONDITION OF PAVEMENT.

The most noticeable defects in the present condition of these pavements are sunken spots, roughness or waves in the surface, and surface cracks. The sunken places are all on work done in 1910 and 1912. The largest of these have a diameter of from 8 to 10 feet, and are possibly 8 to 12 inches below grade. This condition is caused by settlement of the subgrade, which was on a comparatively new fill of from 4 to 10 or 12 feet. The street on which these sunken places occur was built along the bank of Cherry Creek, parallel to new retaining walls built to confine the water course of the creek. The surfacing was placed on this fill within two years after it was constructed, and evidently prior to the time of complete settlement.

Roughness and waves are in evidence on a number of streets laid during the early period of this construction. Apparently this condition is caused by insufficient care in laying the pavement, or insufficient rolling of the subgrade. This condition does not exist to any extent in work done since 1916.

Transverse cracks in the pavement laid in 1916, 1917, and 1918 are in evidence throughout a large portion of the work. These cracks are usually at right angles to the center line of roadway. Sometimes they extend entirely across the pavement from gutter to gutter, and sometimes they extend only a distance of 6 or 8 feet each side of the center. Apparently they are caused by contraction and do not indicate any serious permanent defect in the wearing qualities. The distance between them varies considerably; ordinarily they are not less than 30 feet apart.

One block of surfacing laid in 1919 shows the worst cracking of any so far laid. This pavement is so badly cracked that it will undoubtedly have to be replaced in a very short time. In fact it should be replaced this season. This cracking was apparently

caused by the pavement being mixed with too small a percentage of asphalt. The resulting mixture was too brittle, and severe cracking was evident after the first cold weather in the fall after the pavement was laid.

One disadvantage in this method of constructing pavements is the high crown which very often obtains. This result is caused from the desire to use all of the old macadam possible in the center of the road, and the necessity of meeting the gutter already in place. As the macadam has usually been given a good crown for drainage, the addition of 3 inches of bituminous pavement will as a rule result in 1 or 2 inches of additional crown. This result would be more undesirable in a wet, cold climate than under the climatic conditions usual in Denver.

Acknowledgment is made to Mr. C. H. Draney, superintendent of the paving division of the city and county of Denver, for his courtesy and assistance in supplying information and data relative to this work.

THE PRESIDENT'S MESSAGE ON FEDERAL HIGHWAY POLICIES.

President Harding's first message to Congress, delivered April 12, contains the following statement with regard to Federal participation in highway construction:

Transportation over the highways is little less important [than railway transportation], but the problems relate to construction and development, and deserve your most earnest attention, because we are laying a foundation for a long time to come, and the creation is very difficult to visualize in its great possibilities.

The highways are not only feeders to the railroads and afford relief from local burdens, they are actually lines of motor traffic in interstate commerce. They are the smaller arteries of the larger portion of our commerce, and the motor car has become an indispensable instrument in our political, social, and industrial life.

There is begun a new era in highway construction, the outlay for which runs far into hundreds of millions of dollars. Bond issues by road districts, counties, and States mount to enormous figures, and the country is facing such an outlay that it is vital that every effort shall be directed against wasted effort and unjustifiable expenditure.



LAYING THE SHEET ASPHALT TOPPING.

The Federal Government can place no inhibition on the expenditure in the several States, but since Congress has embarked upon a policy of assisting the States in highway improvement, wisely, I believe, it can assert a wholly becoming influence in shaping policy.

With the principle of Federal participation acceptably established, probably never to be abandoned, it is important to exert Federal influence in developing comprehensive plans looking to the promotion of commerce, and apply our expenditures in the surest way to guarantee a public return for money expended.

Large Federal outlay demands a Federal voice in the program of expenditure. Congress can not justify a mere gift from the Federal purse to the several States, to be prorated among counties for road betterment. Such a course will invite abuses which it were better to guard against in the beginning.

The laws governing Federal aid should be amended and strengthened. The Federal agency of administration should be elevated to the importance and vested with authority comparable to the work before it. And Congress ought to prescribe conditions to Federal appropriations which will necessitate a consistent program of uniformity which will justify the Federal outlay.

I know of nothing more shocking than the millions of public funds wasted in improved highways; wasted because there is no policy of maintenance. The neglect is not universal, but it is very near it. There is nothing the Congress can do more effectively to end this shocking waste than condition all Federal aid on provisions for maintenance. Highways, no matter how generous the outlay for construction, can not be maintained without patrol and constant repairs. Such conditions insisted upon in the grant of Federal aid will safeguard the public which pays and guard the Federal Government against political abuses, which tend to defeat the very purposes for which we authorize Federal expenditure.

SAND AND GRAVEL PRODUCTION SURVEY OF TWENTY-TWO STATES.

By GEORGE E. LADD, Economic Geologist, Bureau of Public Roads.

IN spite of the fact that the United States has under way a vast road-building program, except in very few States no systematic survey of road materials has been undertaken. The United States Bureau of Public Roads has records of thousands of tests of road materials, and State highway organizations have similar records, for their own territories, respectively, but field information is lacking. Testing records are worthless in themselves unless it is known that the sample collected represents an average of a workable deposit. The information needed is much broader in scope. The highway engineer must know where material is available, the nature of the occurrence, extent, thickness, accessibility, transportation facilities, conditions affecting production—in short availability for roads, and the necessary costs involved in getting the materials, in desired form and condition, to the roads.

The Dominion of Canada has long conducted systematic surveys of its road materials. A few of our own States are compiling and publishing information on this subject, but very little indeed has been done in the way of systematic surveys undertaken and conducted with the needs of the highway engineer in mind. The Bureau of Public Roads has carried on economic studies of rock excavation and the production of broken stone. It has compiled lists of broken stone, and sand and gravel producers in the United States, and has assembled all available information on the occurrence of road materials from publications and records of geological surveys, university geological departments, mining bureaus and State highway commissions.

SURVEY OF 536 PLANTS.

During the field season of 1920, because of problems arising in the administration of the Federal aid road act, a survey of producing sand and gravel plants in the United States was begun and work was completed in 22 States. During the progress of this work, as much general information as possible was obtained, collaterally, about the distribution and quality of sand and gravel deposits in the area covered; and so far as possible our list of broken stone producers was revised. A detailed study was made of the sand and gravel industry as a source of road materials. Approximately 1,000 pits and plants were visited in the area under consideration.

The tabulated information which follows pertains to 536 plants, at which 13 different methods of excavation were noted.

These tables do not include data on molding, glass or other special sands, crushed sandstone, or hand

excavating plants at sand and gravel pits, unless the latter have a capacity of at least 300 tons per day. It should be borne in mind, therefore, that table No. 2, totals the production figures only of the plants under consideration in this paper. Many States possess widespread gravel deposits of excellent quality which occur so generally, and from which material is so readily obtained for local use, that permanent-type plants are few in number or entirely absent. This is noticeable especially in the New England States, where the scarcity of sand and gravel plants of the types included in the tables below is not the result of the absence of sand and gravel deposits, but, on the contrary, because they may be found wherever need occurs.

Lest the terms "wet" and "dry" as used in the following tables be misunderstood, the reader's attention is called to the fact that these terms are used in reference to excavating conditions only, and not to screening methods. As a matter of fact very few plants listed are dry plants in the latter sense.

When the survey was started car shortage was acute, and information on that subject was gathered. Although there has been a complete reversal of that condition within the past few months, results of car shortage as they affected this industry are indicated in Table No. 2.

Information obtained by field men on this survey was embraced in a questionnaire and instructions which covered the following points: Name and address of the operator; location of plant; transportation facilities; geological occurrence of the deposit; amount of stripping; thickness of deposit where obtainable; thickness worked; kind and character of material; notes on percentage of sizes; variations throughout the bed; mechanical analysis of the commercial product; uses of the products; sand and gravel production for 1919 and 1920; tonnage sold for road purposes; daily capacity of plants; length of operating season; effect of car shortage on production; sketch of plant arrangement; description of plant and method of operation, with flow sheet; kind and amount of power used; details of screening operation; storage arrangements; labor employed at each unit of operation.

Many photographs were taken and samples of sand products were collected and sent to the bureau laboratory for mechanical analysis and microscopic examination.

FEW COMMERCIAL PLANTS IN NEW ENGLAND.

In the New England States, Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island, glacial gravel and sand beds are widespread. They are mostly worked in original deposits, bu

stream gravels are used, particularly in Vermont, where so many roads are built in the narrow valleys of the Green Mountains.

Clamshell dredges operate from Boston for sea sand, and dredging boats sometimes operate from points in Maine. For a generation past great quantities of sharply angular quartz sand have been taken from the harbor at Newburyport, Mass., at the mouth of the Merrimac River. Throughout New England local pits are worked for road material as needed, and all the cities and towns of consequence have sand and gravel beds within or near them, from which material is hand excavated and used as "bank run," or as dry screened sand and gravel. The total output from such pits is large.

In Maine and New Hampshire, mechanical-power excavation is confined to steam shovels. In Massachusetts and Connecticut steam shovels, derricks, locomotive crane clamshells, and centrifugal pumping are the methods used for excavating. At West Peabody, Mass., there is a pumping plant which is unique in that it delivers its product to the screens by two stages; a centrifugal pump on a boat in a pond delivers the material by a 12-inch pipe line to a hopper on shore, whence it is boosted by another centrifugal pump up a 400-foot incline to the top of the screening plant 100 feet above.

The States of Vermont and Rhode Island use local-type pits only.

THE MIDDLE ATLANTIC STATES.

In New York State, most of the plants produce their sand and gravel from banks of glacial origin, but dredges are operated in Long Island Sound and in the Niagara River. The land plants in this State excavate with steam shovels, mechanical diggers, derricks, and locomotive crane clamshells and cableway draglines. The Niagara River dredges, operating near Buffalo, are centrifugal-pump boats and one ladder dredge, with gravity screens which separate the sand and gravel. The product is brought to yards at Buffalo, where it is unloaded by clamshell cranes. The Long Island Sound plants use clamshell dredges, and the material is towed to screening and washing plants on shore.

Land plants in New Jersey operate in banks sand and gravel by means of steam shovels, mechanical diggers, derricks, locomotive crane clamshells and cableway draglines, and by pump boats with pipe lines which discharge to gravity or cylindrical screening plants. Operations in the Delaware River are confined to ladder dredges, which work between Philadelphia and Trenton.

There are many gravel banks in New Jersey which are operated by hand, and in which the material is loaded directly from the bank to wagons, trucks, and railroad cars.

In Pennsylvania, most of the sand and gravel plants occur in the glacial deposits of the northern part of the State. A few land plants occur elsewhere, in old river terraces. Much sand and gravel is also taken from the Delaware, Allegheny, Monongahela, Ohio and Susquehanna Rivers. In this State, four hand-operated plants have a sufficiently large production to justify their inclusion in the tables which follow. Of the plants which operate by strictly dry excavation methods the majority use steam shovels. One locomotive-crane clamshell is in operation and three cableway draglines. Two plants use cableway draglines for excavating from small streams. The 20 plants obtaining their material from the larger rivers are evenly divided between pumping boats and ladder dredges. In the Pittsburgh district, ladder dredges are used exclusively for river work. Revolving cylindrical screens are used on the dredges and the products delivered to barges alongside, the latter being towed to yards along the river bank.

In the Williamsport district, centrifugal pump boats are used exclusively, all material being otherwise handled as in the Pittsburgh district, except that a few use gravity screens only. In the Philadelphia district, both ladder and clamshell dredges are used for river work. Material is screened on the dredges and delivered by barges to storage yards in Philadelphia and other points. There are no pipeline, pump-boat plants operating in Pennsylvania.

The States of Delaware, Maryland, and the District of Columbia may be considered together. In this area, the sand and gravel is obtained locally, mostly from old river terraces and small streams. The Delaware plant operates on a large scale, excavating with derrick clamshell, in sand dunes, originating from beaches on the Delaware Bay. In Chesapeake Bay and the Potomac River, ladder dredges are used. The material is usually washed and screened on the boat, and the product delivered to barges. Excess sand is discharged from the side of the boat. Unloading on shore is done with the use of derrick clamshells. Some dredges, however, deliver by barge to washing and screening plants on shore. Among the inland deposits of sand and gravel, other than the sand dunes referred to above, sand and gravel deposits, varying in thickness from 12 feet to 30 feet, are worked by steam shovels and derrick clamshells.

Some gravel and an abundance of sand, of excellent grade, occur in the Cretaceous, Tertiary, and Quaternary formations on the eastern shore, and in the Palæozoic formation of western Maryland. Sand also occurs in the tidal streams and estuaries, from which it is extensively dredged. A short account of sand and gravel in this State may be found in the Maryland Geological and Economic Survey, Report of 1908, Part II, Volume VIII.

VIRGINIA AND WEST VIRGINIA.

In Virginia, there are 14 sand and gravel producers of the class under discussion in this article. Sand and gravel deposits may be found along many streams and in river terraces. Land deposits are mostly worked by dragline excavators—two plants use cableway draglines and two plants use steam shovels. River and bay work is conducted by pumping plants or ladder dredges. These are found on Little River, 12 miles northeast of Richmond, and on the James River and Chesapeake Bay. A Baltimore corporation, which operates from Norfolk, Va., on the James River, and at Petersburg, Va., is reported as using ladder type dredges in addition to pump boats. Land deposits are relatively thin. None of those at present being worked exceed 25 feet in thickness. Operation in these deposits is therefore relatively expensive. Plants operate the year round in this State.

In West Virginia, sand and gravel deposits are comparatively scarce. Exclusive of small hand-operated pits only six land deposits are worked. Operations at these are conducted by derrick clamshells, cableway draglines, steam shovels, and horse scrapers. River deposits are worked by 14 producers, the operations of which are equally divided between centrifugal pumps and ladder dredges. Land plants use gravity screens only. Ninety-five per cent of the sand¹ produced in West Virginia is dredged from the Ohio and Elk Rivers or pumped from smaller streams. The ladder dredges on the Ohio and Elk Rivers are equipped with screening plants, whence material is towed to shore in barges. It is then delivered to storage piles or hoppers for truck and railroad car, loading by clamshells. A few plants further subdivide their material by shore screening. The stream pumping plants in West Virginia operate with 6 and 10 inch centrifugal pumps, some of which discharge to barges, and others, by pipe lines, to gravity screens on shore.

OHIO AND INDIANA HAVE MANY LARGE PLANTS.

In Ohio, sand and gravel beds are widely distributed and, over much of the State, are of glacial origin. Forty-five land plants are included in the list of this survey. Twenty-seven of these are operated by steam shovels. There are no mechanical diggers or dragline scrapers in operation in the State.

All other methods of excavation, however, are used, there being a greater variety of methods of operation found in Ohio than in any other State studied. Large, modern-type plants are common.

Pumping and dredging plants operate in Lake Erie, the Ohio River, and in some of the smaller rivers of the State. The three types of dredges (ladder, dipper, and clamshell) are found in this State. Eighteen plants excavate by centrifugal pumps. Some

¹ Consideration of crushed sandstone plants, which are numerous in both West Virginia and Pennsylvania, is omitted in this paper.

screening is done immediately on the dredges, but some pump boats deliver by pipe lines to screening plants on shore. On Lake Erie, the method of operation is pumping, the material being delivered to barges.

The State of Indiana is remarkably well supplied with sand and gravel, and commercial, permanent-type plants are found in all parts of the State with the exception of a portion of its southern extremity, which was unglaciated, and a few counties in the north-western part of the State. Southern Indiana is well served with these road materials through deposits taken from the Ohio and Wabash Rivers. For local use in the southern part of the State there are widespread deposits of stream gravels mixed with iron carbonate nodules, which are residual from the decomposition of shale and clay strata. Stream gravels occur generally over the State, and consist mostly of reassorted materials from glacial drift. The sand and gravel land plants in this State number 52. The majority of these excavate with cableway draglines and steam shovels; a few use the dragline excavators; and a few others derrick and locomotive-crane clamshells. Excavation from the Wabash and Ohio Rivers is accomplished almost entirely by centrifugal pumps. No ladder dredges are used, and only one clamshell dredge. Hydraulic stripping was noted at a number of plants in Indiana. The operating season varies from 7 to 10 months. In 1905 the Geological Survey of Indiana published an exhaustive report on the occurrence and distribution of road materials in the State.

In Illinois, gravel deposits are scarce in the central, eastern, and southern portions of the State, and these districts are served through plants on the Mississippi River, at the mouth of the Ohio River, and on the Wabash River. This statement, while true in general, applies specifically to deposits suitable for commercial development on a large scale. There are 55 permanent-type sand and gravel plants in Illinois. Of these, 32 are land plants, 5 of which operate by dragline method below water level. Sixteen of this class of plants excavate by steam shovels; two use mechanical diggers, while others use dragline cableways, excavators, and scrapers, and both derrick and locomotive crane clamshells.

The State highway department of this State has published, in its Bulletin No. 14, a report on "Materials Available for Highway Construction in Illinois." The Illinois Sand and Gravel Producers Association has a comprehensive report on the sands and gravels of the State, which is known as "General Letter No. 24."

MICHIGAN'S GLACIAL GRAVELS INEXHAUSTIBLE.

Michigan, like New England, has an apparently inexhaustible supply of glacial gravels, occurring in the form of ridges, known as "hog-backs" and eskers, in irregular hills called "kames" and in outwash plains and deltas. There are enormous deposits of gravels

also in the old beach ridges in Presque Isle and Alpena Counties, bordering on Lake Huron. The latter gravels, however, are chiefly of limestone and of low grade. Sand and gravel plants occur wherever there is demand for material. Most of them are in the southern half of the State. There are 57 plants in Michigan, two of which use more than one method of excavation; 50 of these are dry land plants. The steam shovel and cableway dragline methods of excavation prevail. One plant uses a dragline scraper; six, dragline excavators; seven, locomotive-crane clamshells; and three, derrick clamshells. In this State, many of the plants using cableway dragline excavators deliver to a stock pile over a tunnel which feeds to conveyer belts leading to screens. Of the seven distinctly wet-class plants in Michigan, one should perhaps be included in the class of land plants, as its operations are in a glacial deposit, and the sand and gravel is pumped through a 15-inch pipe line from an artificial lake. This plant is operated as is one, described above, in Massachusetts. At the Michigan plant material is picked up in the lake by a centrifugal pump, which is driven by a 400-horsepower electric motor. It is then conducted 300 feet through a 15-inch pipe line laid on pontoons. A booster pump on shore delivers the material up a 200-foot incline of 20° to screens.

In the St. Clair, Detroit, and St. Joe Rivers and Lakes St. Clair and Erie, operators excavate sand and gravel by means of clamshell dredges and centrifugal pumps. In this State, the stripping is comparatively thin and at most plants the overburden is carried to the plants, and eliminated by washing. The operating season varies from 75 to 250 days per year.

An account of the road materials of Michigan may be found in publication No. 27, Geological Series No. 22, of the Michigan Geological and Biological Survey for 1917 and prior years.

WISCONSIN WELL SUPPLIED.

Few States have a greater abundance of road material than has Wisconsin. Suitable materials are found in nearly every county. The southwestern quarter of the State is free from "drift." Elsewhere glacial sand and gravels are common. A great majority of the producing plants are located in the southeastern quarter. Thirty-one permanent-type sand and gravel producers operate in this State. One of these, only, produces from Lake Superior. This company excavates with clamshell dredges and occasionally takes gravel from beaches, bringing the material within reach of the clamshell by means of dragline scrapers. One plant operates a centrifugal pump boat in an artificial lake. At this plant the material is delivered through a 10-inch pipe line to a settling pit, whence it is loaded direct to cars, without screening, by clamshell. Eleven land plants excavate with steam shovels and eight with cableway draglines. Derrick clamshells, dragline

excavators, and scrapers are also used. In Wisconsin mechanical diggers are more extensively used than in any other State. The latter may be seen to good advantage at Janesville, where they are operated by electric power and deliver to conveyor belts from high banks of loose material—favorable conditions for these machines.

The Wisconsin deposits are especially free from clay, but in the Janesville district the overburden reaches a thickness of 6 feet. In other districts the amount of stripping is small.

Local pits supply road material in many parts of the State. A number of counties in Wisconsin own and operate sand and gravel plants.

The Wisconsin Geological and Natural History Survey has published a report on the natural road materials of Wisconsin. There is little reference to sand and gravel although the distribution of glacial drift is discussed and outlined by map.

Glacial drift covering Minnesota provides sand and gravel as needed. Most of the large producing plants are in the southeastern quarter of the State, and, naturally, many of these are grouped about the large centers of population at St. Paul and Minneapolis. A large number of plants in this State excavate with steam shovels and dragline cableways; others use mechanical diggers, derrick clamshells, dragline excavators and scrapers. Five plants excavate with centrifugal pumps. One company operates on the Mississippi River and another on the Minnesota River. The other three excavate from ponds located in glacial beds of sand and gravel. On Lake Superior, one company operates by pulling the material from beaches by means of steel scrapers. It is then picked up by clamshell dredges and transferred to barges. One company in the State uses bull jigs to separate shale from the gravel.

South Dakota commercial plants are but three in number, and are located near the eastern edge of the State. Data for our tables was therefore gathered by side trips from Minnesota. Methods of excavation were found to be cableway dragline, dragline excavator and steam shovel. Conditions in the rest of the State were not investigated.

IOWA IS COVERED WITH GLACIAL DRIFT.

Iowa is covered with glacial drift except for a small area in the northeastern part of the State, bordering the Mississippi River; consequently sand and gravels abound and are found, suitable for road work, in three-quarters of the counties of the State. In some counties the quantity is insufficient for more than the main roads, and the principal supply must be obtained from the larger streams or from terraces. River terrace gravels are of most importance along the streams flowing from the Wisconsin drift area in the north-central part of the State. Important pits in these terrace

gravels are at Mason City, Iowa Falls, Gifford, Belmond, Clemons, Des Moines, Grand Junction, Lake View, Spencer, Cherokee, Emmettsburg, and Estherville. Gravel hillocks and knobs, known as kames, are abundant in north-central Iowa. Several counties contain gravel plains of under-stream and outwash origin. The kame gravels contain considerable clay, and washing is necessary.

Among the land plants it is worthy of note that 12 cableway draglines are found and but 4 steam shovels. Two plants excavating by means of horse scrapers are included in our statistical tables because of the amount of their production. Four companies operate dragline scrapers; three, locomotive-crane clamshells, and one, derrick clamshell. The sand and gravel industry in Iowa is exceptional in that a large majority of the plants excavate by means of pumps. Forty-three companies use this method. There are a few large pumping plants which operate in artificial ponds in sand and gravel deposits. The majority of them, however, take their material from the Mississippi and Des Moines Rivers and some of the smaller streams.

The Iowa Geological Survey in volume 24, Annual Report, published a comprehensive account of the road materials of the State.

Kentucky, as compared with the States over which glacial drift is deposited, is greatly lacking in sand and gravel deposits. The Ohio River, however, is a source of supply for shipping purposes, and nearly all of the permanent-type plants of the State are located along this river. Many pits for local use occur in stream deposits over the State. Some of the deposits worked near Louisville and Ludlow may be of glacial origin, as a point of glacial drift penetrates a short distance into the State at this point. Some material is taken from the bed of the Kentucky River by pump dredges, and some from the old terraces along this stream. Tennessee River terraces furnish an abundance of coarse gravel as well as sand. Such a deposit has been worked up to a thickness of 50 feet, the total thickness being undetermined. Three companies in Kentucky excavate with steam shovels; one, with dragline excavator; seven, with centrifugal pumps; and one, with clamshell dredge. The river pumping plants clean and size the material on dredge boats, whence it is delivered by chute to barges, and finally unloaded on shore by clamshell or cableway dragline. The river pumping plants in this State operate about eight months in the year, while land plants occasionally operate throughout the year.

TABLE 1.—Permanent-type commercial sand and gravel plants.¹

MAINE.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Bangor Cast Stone Co.....	Bangor, Me.....	East Hampden, Me.....	Dry; steam shovel.
Maine Crushed Rock & Gravel Co.....	Portland, Me.....	Leeds, Me.....	Do.

NEW HAMPSHIRE.

Standard Sand & Gravel Co.....	Portland, Me.....	Milton, N. H.....	Dry; steam shovel.
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MASSACHUSETTS.

Bernie Sand & Gravel Co.....	Wilbraham, Mass.....	Wilbraham, Mass.....	Dry; steam shovel.
Boston Sand & Gravel Co.....	Boston, Mass.....	Scituate, Mass.....	Do.
Do.....	do.....	Greenbush, Mass.....	Do.
Connolly Co.....	do.....	Topsfield, Mass.....	Do.
Highland Sand & Gravel Co.....	West Roxbury, Mass.....	West Roxbury, Mass.....	Do.
John C. Kelly & Co.....	do.....	do.....	Dry; locomotive crane clamshell.
Massachusetts Sand & Gravel Co.....	Newton Upper Falls, Mass.....	Newton Upper Falls, Mass.....	Dry; derrick clamshell.
J. H. McNamara.....	Boston, Mass.....	Wellesley, Mass.....	Dry; locomotive crane clamshell.
Do.....	do.....	Watertown, Mass.....	Do.
New England Sand & Gravel Co.....	do.....	West Peabody, Mass.....	Wet; pump.
Do.....	do.....	Walpole Heights, Mass.....	Dry; dragline excavator.
George H. Noone Sand & Gravel Co.....	West Roxbury, Mass.....	West Roxbury, Mass.....	Dry; locomotive crane clamshell.

CONNECTICUT.

Atlas Sand & Gravel Co.....	Hartford, Conn.....	Farmington, Conn.....	Dry; steam shovel.
Edward Balf Co.....	do.....	Connecticut River.....	Wet; clamshell dredge.
Bridgeport Sand & Gravel Co.....	Bridgeport, Conn.....	Bridgeport, Conn.....	Dry; derrick clamshell.
F. W. Fuller.....	Torrington, Conn.....	Torrington, Conn.....	Dry; dragline excavator.
Iron Ledge Co.....	Bridgeport, Conn.....	Turnbull, Conn.....	Wet; dragline excavator.
New London Sand & Stone Co.....	New London, Conn.....	Massapeag, Conn.....	Dry; dragline excavator.
W. & W. Sand & Gravel Co.....	Ansonia, Conn.....	Seymour, Conn.....	Dry; locomotive crane clamshell.

¹ A few plants are included which, although not having a permanent type of plant, produce 300 tons or more daily.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

NEW YORK.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Allegheny Sand & Gravel Co.	Olean, N. Y.	Allegheny, N. Y.	Dry; steam shovel.
Apex Sand & Grit Co.	Buffalo, N. Y.	Williamsville, N. Y.	Do.
Buffalo Gravel Corporation.	do.	Buffalo, N. Y.	Wet; pump and ladder dredge.
J. E. Carroll Sand Co.	do.	Attica, N. Y.	Dry; locomotive crane clamshell.
Darwin Springs Sand & Gravel Co.	Syracuse, N. Y.	Darwin Springs, N. Y.	Dry; derrick clamshell.
George F. Dulin.	Mechanicsville, N. Y.	Willow Grove, N. Y.	Dry; locomotive crane clamshell.
Fredriks' Sand & Gravel Co.	Fishers, N. Y.	Fishers, N. Y.	Dry; steam shovel.
Goodwin-Gallagher Sand & Gravel Co.	New York City.	New York City.	Do.
Kieth O. Guthrie.	Schenectady, N. Y.	Yosts, N. Y.	Wet; pump.
Hill Sand & Gravel Co.	Fishers, N. Y.	Fishers, N. Y.	Dry; derrick clamshell.
Holloway Sand Co.	Buffalo, N. Y.	Buffalo, N. Y.	Wet; pump.
Machias Sand & Gravel Co.	do.	Machias, N. Y.	Dry; cableway dragline.
Marlboro Sand & Gravel Co.	New York City.	Marlboro, N. Y.	Dry; steam shovel.
Nassau Sand & Gravel Co.	do.	Roslyn, Long Island.	Do.
Niagara Sand Corporation.	Buffalo, N. Y.	Buffalo, N. Y.	Wet; pump.
Oak Corners Sand Co.	Geneva, N. Y.	Oak Corners, N. Y.	Dry; mechanical digger.
Perry-Beazel Sand Co.	Rochester, N. Y.	Pittsford, N. Y.	Dry; derrick clamshell.
Fred Pierce Sand Co.	Fulton, N. Y.	Arrowhead, N. Y.	Dry; steam shovel.
Scottsville Sand Co.	Scottsville, N. Y.	Scottsville, N. Y.	Do.
Henry Steers Sand & Gravel Co.	New York City.	Northport, N. Y.	Wet; clamshell dredge.

NEW JERSEY.

Absecon Sand Co.	Absecon, N. J.	Absecon, N. J.	
Albion Sand Co.	Yardville, N. J.	Yardville, N. J.	Dry; derrick clamshell.
Bennett Gravel Co.	Spring Lake, N. J.	Allenwood, N. J.	Dry; steam shovel.
Do.	do.	Farmingdale, N. J.	Do.
Cape May Sand Co.	Cape May, N. J.	Cape May, N. J.	Do.
C. W. Crane & Co.	New York City.	South Amboy, N. J.	Do.
Delaware River Sand & Dredging Co.	Bordentown, N. J.	Bordentown, N. J.	Wet; ladder dredge.
S. W. Downer.	Downer, N. J.	Downer, N. J.	Dry; steam shovel.
Daniel Goff & Co.	Philadelphia, Pa.	Millville, N. J.	Do.
Hainesport Mining & Transportation Co.	do.	Bridgeboro, N. J.	Do.
Do.	do.	do.	Wet; ladder dredge.
John G. Hodgson.	Stanhope, N. J.	Near Netcong, N. J.	Dry; derrick clamshell.
Lakewood Sand Co.	South Lakewood, N. J.	South Lakewood, N. J.	Dry; mechanical digger.
Menantico Sand & Gravel Co.	Millville, N. J.	Menantico, N. J.	Wet; pump.
William C. Moore.	Tuckahoe, N. J.	Tuckahoe, N. J.	Dry; steam shovel.
Morris County Crushed Stone Co.	Morristown, N. J.	Morristown, N. J.	Do.
New Jersey Sand & Gravel Co.	Yardville, N. J.	Yardville, N. J.	Dry; derrick clamshell.
Norcross & Edmunds.	Philadelphia, Pa.	Birmingham, N. J.	Dry; steam shovel.
Do.	do.	South Femberton, N. J.	Wet; locomotive crane clamshell.
Ridner Bros.	Succasunna, N. J.	Succasunna, N. J.	Wet; pump.
Seguine & Bogart.	Kenvil, N. J.	do.	Do.
Do.	do.	Kenvil, N. J.	Do.
J. M. Stokes.	Rancocas, N. J.	Rancocas, N. J.	Dry; steam shovel.
Succasunna Sand Co.	Morristown, N. J.	Succasunna, N. J.	Wet; pump.
Warren Sand & Gravel Co.	Easton, Pa.	Carpentersville, N. J.	Dry; cableway dragline.

PENNSYLVANIA.

Beaver Sand Co.	Beaver, Pa.	Beaver, Pa.	Dry; cableway dragline.
Crawford Sand & Gravel Co.	Meadville, Pa.	Meadville, Pa.	Dry; locomotive crane clamshell.
Curtis Hill Sand & Gravel Co.	Morrisville, Pa.	Morrisville, Pa.	Dry; steam shovel.
J. K. Davidson & Bros.	Pittsburgh, Pa.	Rivers near Pittsburgh.	Wet; ladder dredge.
Erie Sand & Gravel Co.	Erie, Pa.	Erie, Pa.	Wet; pump.
A. R. Gilmore Sand Co.	Linden, Pa.	Linden, Pa.	Do.
Griff Construction Co.	Erie, Pa.	Erie, Pa.	Dry; cableway dragline.
W. W. Gulick Sand Co.	Lime Ridge, Pa.	Lime Ridge, Pa.	Dry; steam shovel.
Hazen Sand Co.	Bangor, Pa.	Mount Bethel, Pa.	Do.
Iron City Sand Co.	Pittsburgh, Pa.	Rivers near Pittsburgh.	Wet; ladder dredge.
Keystone Sand & Supply Co.	do.	Near Neville Island, Pa.	Do.
Kincaid & Wade.	Warren, Pa.	Warren, Pa.	Wet; cableway dragline.
Lake Shore Sand Co.	Erie, Pa.	North East, Pa.	Wet; pump.
Lycoming Silica Sand Co.	Fairfield, Pa.	Fairfield, Pa.	Dry; steam shovel.
McClain Sand Co.	Point Marion, Pa.	Point Marion, Pa.	Wet; pump.
Moosie Sand Co.	Moosie, Pa.	Moosie, Pa.	Dry; hand.
Nickle Plate Gravel Co.	Erie, Pa.	Fairview, Pa.	Dry; steam shovel.
Ohio River Sand Co.	Pittsburgh, Pa.	Rivers near Pittsburgh.	Wet; ladder dredge.
Penn Sand & Gravel Co.	Philadelphia, Pa.	Wheatsheaf, Pa.	Dry; steam shovel.
Pittsburgh Sand & Supply Co.	Baden, Pa.	Baden, Pa.	Wet; ladder dredge.
Point Marion Sand Co.	Point Marion, Pa.	Point Marion, Pa.	Wet; pump.
Rock Point Sand Co.	Pittsburgh, Pa.	West Elwood June, Pa.	Wet; ladder dredge.
Rodgers Sand Co.	do.	Rivers near Pittsburgh.	Do.
Sayer Sand & Plaster Co.	Waverly, N. Y.	Sayer, Pa.	Dry; steam shovel.
Seguine & Co.	Portland, Pa.	Portland, Pa.	Do.
H. J. Stannert Sand Co.	Northumberland, Pa.	Northumberland, Pa.	Wet; pump.
Do.	do.	Lewistown, Pa.	Do.
D. N. Thomas Sand & Gravel Co.	Williamsport, Pa.	Williamsport, Pa.	Do.
United Ice & Coal Co.	Harrisburg, Pa.	Harrisburg, Pa.	Do.
Universal Sand Co.	New Castle, Pa.	New Castle, Pa.	Dry; steam shovel.
Valley Sand & Supply Co.	Parnassus, Pa.	Parnassus, Pa.	Wet; ladder dredge.
Van Brunt Sand Co.	Philadelphia, Pa.	Philadelphia, Pa.	Do.
Charles Warner Co.	do.	do.	Wet; ladder and dipper dredge.
Washed Sand & Gravel Co.	East Bangor, Pa.	Mount Bethel, Pa.	Dry; steam shovel.
Waid & Yeager.	Meadville, Pa.	Meadville, Pa.	Dry; hand.
Wayne Concrete & Sand Works.	Ariel, Pa.	Ariel, Pa.	Do.
West Branch Sand Co.	Duboisstown, Pa.	Duboisstown, Pa.	Wet; pump.
Williamsport Sand & Gravel Co.	Williamsport, Pa.	Williamsport, Pa.	Wet; cableway dragline.
Wyoming Clear Sand & Gravel Co.	Wyoming, Pa.	Wyoming, Pa.	Dry; hand.
Wyoming Sand & Stone Co.	Wilkes-Barre, Pa.	Wyonna, Pa.	Dry; steam shovel.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

DELAWARE.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Lewes Sand Co.	Lewes, Del.	Lewes, Del.	Dry; derrick clamshell.

MARYLAND AND DISTRICT OF COLUMBIA.

Arundel Corporation	Baltimore, Md.	Spring Grove, Md.	Wet; ladder dredge.
Builders Supply Co.	Cumberland, Md.	Cumberland, Md.	Dry; steam shovel.
Charleston Sand & Stone Corporation	Elkton, Md.	North East, Md.	Do.
R. F. Clark Sand Co.	Severn, Md.	Severn, Md.	Dry; derrick clamshell.
Columbia Granite & Dredging Co.	Washington, D. C.	Potomac River near Washington	Wet; ladder dredge.
E. M. Goode Sand & Gravel Co.	Havre de Grace, Md.	Charlestown, Md.	Dry; steam shovel.
L. E. Smoot	Washington, D. C.	River near Washington.	Wet; ladder dredge.

VIRGINIA.

Arundel Corporation	Baltimore, Md.	Petersburg, Va.	Wet; pump.
Do.	do.	Norfolk, Va.	Do.
Atlantic Sand Co.	Norfolk, Va.	Emmerson, Va.	Dry; cableway drag line.
J. V. Bickford	Hampton, Va.	Hampton, Va.	Wet; pump.
Dixie Sand & Gravel Co.	Petersburg, Va.	Prince George County, Va.	Dry; drag-line excavator.
Highland Park Sand & Gravel Co.	Richmond, Va.	Richmond, Va.	Dry; steam shovel.
James River Sand & Gravel Co.	Petersburg, Va.	Chesterfield County, Va.	Wet and dry; cableway drag line.
J. C. Jones Sand Co.	Norfolk, Va.	14 miles east of Norfolk, Va.	Dry; steam shovel.
Massaponax Sand & Gravel Co.	Fredericksburg, Va.	Massaponax, Va.	Dry; drag-line excavator.
Mercer & Miller (Inc.)	Richmond, Va.	Little River, Va.	Wet; pump.
Old Dominion Sand & Gravel Co.	do.	Petersburg, Va.	Dry; drag-line excavator.
Petersburg Sand & Gravel Corporation	Petersburg, Va.	Across river from Petersburg	Do.
Southern Sand & Gravel Co.	Richmond, Va.	Massaponax, Va.	Do.

WEST VIRGINIA.

Armstrong Sand Co.	Wheeling, W. Va.	Wheeling, W. Va.	Wet; ladder dredge.
Bridgeport Wall Plaster Co.	do.	Wheeling Island, W. Va.	Wet; pump.
Corliss Sand Co.	New Martinsville, W. Va.	New Martinsville, W. Va.	Wet; ladder dredge.
Crystal Sand Co.	Moundsville, W. Va.	Chestnut Hill, W. Va.	Dry; derrick clamshell.
Deckers Creek Stone & Sand Co.	Morgantown, W. Va.	Sturgison, W. Va.	Dry; steam shovel.
Kentucky & Ohio Transportation Co.	Carrolton, Ky.	Huntington, W. Va.	Wet; pump.
Laval Sand Co.	Hinton, W. Va.	Lavalette, W. Va.	Do.
New Martinsville Sand Co.	New Martinsville, W. Va.	New Martinsville, W. Va.	Wet; ladder dredge.
Moundsville Sand Co.	Moundsville, W. Va.	Moundsville, W. Va.	Dry; cableway drag line.
Ohio Valley Sand & Slag Co.	do.	Chestnut Hill, W. Va.	Dry; derrick clamshell.
Parkersburg Builders Material Co.	Parkersburg, W. Va.	Parkersburg, W. Va.	Dry; horse scraper.
Parkersburg Sand Co.	do.	do.	Wet; ladder dredge.
Pfaff & Smith Co.	Charleston, W. Va.	Charleston, W. Va.	Do.
Wells Pit Sand Co.	Proctor, W. Va.	Wells Pit, W. Va.	Dry; derrick clamshell.
Western Rivers Co.	Point Pleasant, W. Va.	Point Pleasant, W. Va.	Wet; pump and dipper dredge.
West Virginia Sand & Gravel Co.	Charleston, W. Va.	Rivers near Charleston	Wet; ladder dredge.
Wheeling Wall Plaster Co.	Wheeling, W. Va.	Wheeling, W. Va.	Do.
Wilson Sand & Gravel Co.	Huntington, W. Va.	Fork of Coals, W. Va.	Wet; pump.
Do.	do.	Huntington, W. Va.	Do.
Zenith Sand Co.	St. Albans, W. Va.	Fork of Coals, W. Va.	Do.

OHIO.

Aeme Coal & Builders Supply Co.	Toledo, Ohio.	River near Toledo, Ohio.	Wet; pump.
Akron Sand & Gravel Co.	Akron, Ohio.	Akron, Ohio.	Dry; steam shovel.
The Barnes Sand & Gravel Co.	Piketon, Ohio.	Near Wakefield, Ohio.	Do.
O. K. Barber Concrete Co.	Barberton, Ohio.	Barberton, Ohio.	Not operating 1920.
C. M. Boltz	Springfield, Ohio.	Springfield, Ohio.	Dry; horse scraper.
Buckeye Sand & Gravel Co.	Cincinnati, Ohio.	Hageman, Ohio.	Dry; cableway dragline.
Central Gravel & Sand Co.	Dayton, Ohio.	Dayton, Ohio.	Dry; steam shovel and cableway dragline.
M. A. Callahan	Cleveland, Ohio.	Willow, Ohio.	Wet; pump.
Chillicothe Sand & Gravel Co.	Chillicothe, Ohio.	Chillicothe, Ohio.	Dry; steam shovel.
Cleveland Builders Supply & Brick Co.	Cleveland, Ohio.	Aurora, Ohio.	Wet; pump.
Columbus Sand & Gravel Co.	Columbus, Ohio.	Columbus, Ohio.	Do.
Concrete Materials Co.	do.	do.	Wet and dry; dipper dredge and steam shovel.
Edward A. Davis	Bellair, Ohio.	Winding Hill, Ohio.	Dry; dragline excavator.
Dayton Sand & Gravel Co.	Dayton, Ohio.	Dayton, Ohio.	Wet; cableway dragline.
G. R. Deming Sand & Gravel Co.	Piqua, Ohio.	Rossville, Ohio.	Dry; hand.
Diamond Sand & Gravel Co.	Bedford, Ohio.	Garfield Heights, Ohio.	Dry; locomotive crane clamshell.
Do Ville Lake Sand & Gravel Co.	Toledo, Ohio.	Maumee River, Toledo, Ohio.	Wet; pump.
East End Sand & Gravel Co.	Chillicothe, Ohio.	Chillicothe, Ohio.	Dry; steam shovel.
East Liverpool Sand Co.	East Liverpool, Ohio.	East Liverpool, Ohio.	Wet; ladder dredge.
Fayette Sand & Gravel Co.	Washington Courthouse, Ohio.	Washington Courthouse, Ohio.	Wet; cableway dragline.
Franklin Bros.	Akron, Ohio.	Akron, Ohio.	Dry; steam shovel.
Garland Block & Sand Co.	Youngstown, Ohio.	Youngstown, Ohio.	Dry; locomotive crane clamshell.
Glacial Sand & Gravel Co.	Zanesville, Ohio.	Gilbert, Ohio.	Do.
Greenville Gravel Co.	Greenville, Ohio.	Fort Jefferson, Ohio.	Dry; steam shovel.
Do.	do.	Mechanicsburg, Ohio.	Do.
T. J. Hall & Co.	Cincinnati, Ohio.	Cincinnati, Ohio.	Wet; pump.
Home Sand Co.	Fremont, Ohio.	River near Fremont, Ohio.	Do.
Homegardner Sand Co.	Sandusky, Ohio.	Sandusky, Ohio.	Do.
The Island Sand & Gravel Co.	Columbus, Ohio.	Columbus, Ohio.	Wet; cableway dragline.
Kelly Island Lime & Transportation Co.	Sandusky, Ohio.	Sandusky, Ohio.	Wet; pump.
Killbuck Sand & Gravel Co.	Killbuck, Ohio.	Killbuck, Ohio.	Dry; steam shovel.
Lake Erie Sand Co.	Sandusky, Ohio.	Sandusky, Ohio.	Wet; pump.
Le Beau Wrecking Co.	Toledo, Ohio.	River near Toledo, Ohio.	Do.
Liberty Sand & Gravel Co.	Liberty, Ohio.	Liberty, Ohio.	Dry; cableway dragline.
Longaker & Hines	Pleasant Hill, Ohio.	Near Pleasant Hill, Ohio.	Dry; steam shovel.
Marietta Sand Co.	Marietta, Ohio.	Marietta, Ohio.	Wet; ladder dredge.
Marion Sand & Gravel Co.	Marion, Ohio.	Near Marion, Ohio.	Wet; derrick clamshell.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

OHIO—Continued.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Martin & Arnold.....	New Philadelphia, Ohio.....	New Philadelphia, Ohio.....	Dry; steam shovel.
Mount Calvary Sand & Gravel Co.....	Columbus, Ohio.....	Columbus, Ohio.....	Do.
Mulinix Brothers.....	Toledo, Ohio.....	Lake near Toledo, Ohio.....	Wet; pump.
Ohio Gravel Ballast Co.....	Cincinnati, Ohio.....	Miami Grove, Ohio.....	Wet; dipper dredge.
Do.....	do.....	Newtown, Ohio.....	Dry; steam shovel.
Do.....	do.....	Cleves, Ohio.....	Do.
Do.....	do.....	Miamiville, Ohio.....	Do.
Do.....	do.....	Trenton, Ohio.....	Do.
The Ohio River Sand & Gravel Co.....	do.....	Cincinnati, Ohio.....	Wet; pump.
Ohio Valley Sand & Gravel Co.....	Shadyside, Ohio.....	Dille, Ohio.....	Dry; cableway dragline.
David A. Onkst & Son.....	Dayton, Ohio.....	Dayton, Ohio.....	Dry; steam shovel.
G. W. Perry.....	Washington Courthouse, Ohio.....	Washington Courthouse, Ohio.....	Wet; pump.
Port Clinton Lumber & Coal Co.....	Port Clinton, Ohio.....	Port Clinton, Ohio.....	Do.
Portsmouth Sand & Gravel Co.....	Portsmouth, Ohio.....	Portsmouth, Ohio.....	Do.
The Queen City Crushed Stone & Sand Co.....	Cincinnati, Ohio.....	Miamiville, Ohio.....	Dry; steam shovel.
Radebaugh & Graham.....	St. Johns, Ohio.....	St. Johns, Ohio.....	Do.
The Red Bank Gravel Co.....	Cincinnati, Ohio.....	Cincinnati, Ohio.....	Dry; cableway dragline.
Richwood Sand & Gravel Co.....	Richwood, Ohio.....	Gallipolis, Ohio.....	Wet; derrick clamshell.
Reader Sand & Gravel Co.....	Canton, Ohio.....	Canton, Ohio.....	Dry; locomotive crane clamshell
The River Sand Co.....	Steubenville, Ohio.....	Steubenville, Ohio.....	Wet; ladder dredge.
The Rubber City Sand & Gravel Co.....	Akron, Ohio.....	Akron, Ohio.....	Dry; steam shovel.
John H. Schell.....	Martins Ferry, Ohio.....	Martins Ferry, Ohio.....	Dry; horse scraper.
Steubenville Sand Co.....	Steubenville, Ohio.....	Steubenville, Ohio.....	Dry; steam shovel.
Southern Sand, Gravel & Supply Co.....	Columbus, Ohio.....	Columbus, Ohio.....	Wet; clamshell dredge.
Tarco Construction Co.....	Cincinnati, Ohio.....	Cleves, Ohio.....	Dry; steam shovel.
Do.....	do.....	Willevs, Ohio.....	Do.
Toledo Builders Supply Co.....	Toledo, Ohio.....	Maumee River, Toledo, Ohio.....	Wet; pump.
Toledo Pulp, Plaster & Supply Co.....	do.....	do.....	Do.
Wiggins Sand & Gravel Co.....	Germantown, Ohio.....	Germantown, Ohio.....	Dry; steam shovel.
A. F. Wendling Co.....	Massillon, Ohio.....	Massillon, Ohio.....	Do.
Youngstown Silica Sand Co.....	Youngstown, Ohio.....	Youngstown, Ohio.....	Start operating 1921.
Zanesville Washed Gravel Co.....	Zanesville, Ohio.....	Dresden, Ohio.....	Dry; steam shovel.

KENTUCKY.

J. B. Blanton & Co.....	Frankfort, Ky.....	River near Frankfort, Ky.....	Wet; pump.
Breslin Sand Co.....	Louisville, Ky.....	Louisville, Ky.....	Dry; steam shovel.
T. A. Duke & Co.....	Maysville, Ky.....	Near Maysville, Ky.....	Dry; dragline excavator.
Evansville, Sand & Gravel Co.....	Henderson, Ky.....	Henderson, Ky.....	Dry; report missing.
Grobmyer Sand & Gravel Co.....	Carrollton, Ky.....	Carrollton, Ky.....	Wet; clamshell dredge.
Henderson Sand & Gravel Co.....	Henderson, Ky.....	Henderson, Ky.....	Wet; pump.
Ideal Supply Co.....	Ludlow, Ky.....	Ludlow, Ky.....	Dry; steam shovel.
Kentucky & Ohio Transportation Co.....	Carrollton, Ky.....	Carrollton, Ky.....	Wet; pump.
Memphis Stone & Gravel Co.....	Memphis, Tenn.....	Gravel Switch, Ky.....	Dry; steam shovel.
Nugent Stone Co.....	Louisville, Ky.....	River near Louisville, Ky.....	Wet; pump.
Ohio River Sand & Gravel Co.....	Paducah, Ky.....	River near Paducah, Ky.....	Do.
River Sand & Gravel Co.....	Owensboro, Ky.....	River near Owensboro, Ky.....	Do.
E. T. Slider Co.....	Louisville, Ky.....	River near Louisville, Ky.....	Do.

INDIANA.

Acme Gravel Co.....	Indianapolis, Ind.....	Near Indianapolis, Ind.....	Wet; cableway dragline.
Atlas Sand and Gravel Co.....	do.....	do.....	Do.
B. and B. Sand and Gravel Co.....	Fort Wayne, Ind.....	Near Fort Wayne, Ind.....	Do.
Baker Gravel Co.....	Noblesville, Ind.....	Near Noblesville, Ind.....	Wet and dry; cableway dragline.
Bedford-Nugent Sand and Gravel Co.....	Evansville, Ind.....	Near Evansville on L. and N.....	Wet; pump.
Bloomfield Washed Sand and Gravel Co.....	Bloomfield, Ind.....	Bloomfield, Ind.....	Do.
Bluffton-Lewisburg Stone Co.....	Lafayette, Ind.....	West Lafayette, Ind.....	Dry; steam shovel.
Brown-Huffstetter Sand Co.....	Indianapolis, Ind.....	Near Indianapolis, Ind.....	Wet and dry; cableway dragline.
Do.....	do.....	S. Harding and White River.....	Do.
Capital City Gravel Co.....	do.....	Indianapolis, Ind.....	Wet; cableway dragline.
Carmichael Gravel Co.....	Williamsport, Ind.....	Attica, Ind.....	Dry; steam shovel.
Do.....	do.....	Wolcottville, Ind.....	Dry; locomotive crane clamshell.
Columbus Gravel Co.....	Columbus, Ind.....	Columbus, Ind.....	Wet; cableway dragline.
Consumers Co.....	Chicago, Ill.....	South Bend, Ind.....	Dry; dragline excavator.
Covington Sand and Gravel Co.....	Covington, Ind.....	Covington, Ind.....	Dry; steam shovel.
Evansville Sand and Gravel Co.....	Evansville, Ind.....	Mount Vernon, Ind.....	Wet; pump.
Do.....	do.....	Evansville, Ind.....	Do.
Granite Gravel Co.....	Indianapolis, Ind.....	Indianapolis, Ind.....	Wet; pump.
Do.....	do.....	do.....	Wet; cableway dragline.
Do.....	do.....	do.....	Wet; clamshell dredge.
Do.....	do.....	Mohawk, Ind.....	Wet; cableway dragline.
Do.....	do.....	Morristown, Ind.....	Do.
Griffith Sand and Gravel Co.....	Griffith, Ind.....	Griffith, Ind.....	Start operating 1921.
Hazelton Gravel Co.....	Hazelton, Ind.....	Hazelton, Ind.....	Wet; pump.
Abe Hart.....	Sandborn, Ind.....	Worthington, Ind.....	Do.
Do.....	do.....	Emison, Ind.....	Do.
J. M. Hinderleiter.....	Medora, Ind.....	Medora, Ind.....	Do.
George J. Hoffman Co.....	South Bend, Ind.....	South Bend, Ind.....	Dry; derrick clamshell.
Do.....	do.....	Near South Bend, Ind.....	Dry; steam shovel.
Indiana Gravel Co.....	Indianapolis, Ind.....	Indianapolis, Ind.....	Wet; cableway dragline.
Interstate Gravel Co.....	Terre Haute, Ind.....	Covington, Ind.....	Dry; steam shovel.
John Jones and Sons.....	Indianapolis, Ind.....	Indianapolis, Ind.....	Wet; cableway dragline.
Kickapoo Sand and Gravel Co.....	Attica, Ind.....	Attica, Ind.....	Dry; steam shovel.
Kirkpatrick Sand and Gravel Co.....	Greenfield, Ind.....	Cambridge City, Ind.....	Wet; cableway dragline.
Lafayette Hydraulic Gravel Co.....	Lafayette, Ind.....	Lafayette, Ind.....	Dry; steam shovel.
Lenmane Brothers.....	Detroit, Mich.....	Pleasant Lake, Ind.....	Dry; dragline excavator.
Macksville Gravel Co.....	Terre Haute, Ind.....	Macksville, Ind.....	Wet; pump.
Martinsville Gravel Co.....	Martinsville, Ind.....	Martinsville, Ind.....	Wet; cableway dragline.
Merom Gravel Co.....	Indianapolis, Ind.....	Riverton, Ind.....	Do.
A. Miller and Sons.....	Clinton, Ind.....	Summit Grove, Ind.....	Dry; steam shovel.
Million Brothers Sand and Gravel Co.....	Lake Cicott, Ind.....	Lake Cicott, Ind.....	Do.
Montezuma Gravel Co.....	Terre Haute, Ind.....	Montezuma, Ind.....	Do.
Montezuma Road and Concrete Gravel Co.....	Montezuma, Ind.....	do.....	Dry; locomotive crane clamshell.
William Nading.....	Shelbyville, Ind.....	N. Pike and Blue River.....	Wet; cableway dragline.
Neal Gravel Co.....	Mattoon, Ill.....	Attica, Ind.....	Do.
Do.....	do.....	Covington, Ind.....	Do.
Do.....	do.....	Silverwood, Ind.....	Dry; steam shovel.
Newman and Kirkham Sand and Gravel Co.....	Lewisville, Ind.....	Beeson, Ind.....	Wet; cableway dragline.
Northern Construction Co.....	Elkhart, Ind.....	Elkhart, Ind.....	Do.

TABLE I.—Permanent-type commercial sand and gravel plants—Continued.

INDIANA—Continued.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Northern Indiana Sand and Gravel Co.	Wolcottville, Ind.	Wolcottville, Ind.	Wet and dry; derrick clamshell and steam shovel.
O'Keefe Gravel Co.	Plymouth, Ind.	Culver, Ind.	Wet; pump and cableway dragline.
Richmond-Greenville Gravel Co.	Greenville, Ohio	Richmond, Ind.	Dry; steam shovel.
Richmond Gravel Co.	Richmond, Ind.	do.	Dry; cableway dragline.
E. T. Slider.	New Albany, Ind.	New Albany, Ind.	Wet; pump.
Standard Sand and Gravel Co.	Clinton, Ind.	Clinton, Ind.	Dry; steam shovel.
Stilwell Sand and Gravel Co.	Anderson, Ind.	Anderson, Ind.	Dry; dragline excavator.
Do.	do.	Orestes, Ind.	Do.
Summit Sand and Gravel Co.	Terre Haute, Ind.	Terre Haute, Ind.	Dry; locomotive crane clamshell.
Do.	do.	Clinton, Ind.	Do.
Wabash Sand and Gravel Co.	do.	Terre Haute, Ind.	Do.
Do.	do.	Montezuma, Ind.	Do.
Wabee Sand and Gravel Co.	Milford, Ind.	Milford, Ind.	Dry; steam shovel.
Warsaw Sand and Gravel Co.	Warsaw, Ind.	Warsaw, Ind.	Do.
Western Indiana Gravel Co.	Terre Haute, Ind.	Lafayette, Ind.	Do.
Do.	do.	Terre Haute, Ind.	Wet; pump.

ILLINOIS.

Etna Sand & Gravel Co.	Chicago, Ill.	Algonquin, Ill.	Dry; steam shovel.
Anderson-Theobald Co.	Vincennes, Ind.	Lawrence County, Ill.	Wet and dry; dragline excavator.
American Sand & Gravel Co.	Chicago, Ill.	Carpentersville, Ill.	Dry; steam shovel.
Do.	do.	Antioch, Ill.	Do.
Atwood-Davis Sand Co.	do.	Winnebago County, Ill.	Do.
The Barry Sand & Gravel Co.	Lincoln, Ill.	Near Barry, Ill.	Wet; cableway dragline.
Beder Woods Sons Co.	Moline, Ill.	Moline, Ill.	Wet; pump.
Chicago Gravel Co.	Chicago, Ill.	Plainfield, Ill.	Dry; steam shovel.
Do.	do.	Rockdale, Ill.	Do.
Do.	do.	Spaulding, Ill.	Do.
H. D. Conkey.	Mendota, Ill.	Yorkville, Ill.	Do.
Do.	do.	Oregon, Ill.	Wet; pump.
Do.	do.	Moronts, Ill.	Dry; dragline scraper.
Do.	do.	Sheridan, Ill.	Dry; locomotive crane clamshell.
Construction Material Co.	Chicago, Ill.	Chicago, Ill.	Wet; pump.
Decatur Sand & Gravel Co.	Decatur, Ill.	Decatur, Ill.	Do.
R. H. Eastwood Sand & Gravel Co.	Grayville, Ill.	Grayville, Ill.	Do.
Egyptian Gravel Co.	St. Louis, Mo.	Oliver Branch, Ill.	Dry; steam shovel.
Galesburg Sand & Gravel Co.	Galesburg, Ill.	Buda, Ill.	Do.
H. H. Halliday Sand Co.	Cairo, Ill.	River near Cairo, Ill.	Wet; pump.
Illinois Sand & Gravel Co.	Marion, Ill.	Metropolis, Ill.	Do.
Interstate Sand & Gravel Co.	Chicago, Ill.	Libertyville, Ill.	Wet; dragline excavator.
Joliet Gravel Co.	Joliet, Ill.	Joliet, Ill.	Dry; steam shovel.
Keokuk Sand Co.	Quincy, Ill.	River near Quincy	Wet; pump.
Lake Shore Sand Co.	Chicago, Ill.	Algonquin, Ill.	Dry; steam shovel.
Lincoln Sand & Gravel Co.	Lincoln, Ill.	Lincoln, Ill.	Wet; pump.
Mississippi Lime & Material Co.	Alton, Ill.	River near Alton, Ill.	Do.
Mississippi Sand & Gravel Co.	Burlington, Iowa.	Keithsburg, Ill.	Do.
Missouri Portland Cement Co.	St. Louis, Mo.	East St. Louis, Ill.	Do.
McGrath Sand & Gravel Co.	Lincoln, Ill.	Forreston, Ill.	Dry; cableway dragline.
Do.	do.	Chillicothe, Ill.	Do.
Do.	do.	Mackinaw, Ill.	Do.
Do.	do.	Pekin, Ill.	Do.
Mount Carmel Sand & Gravel Co.	Mount Carmel, Ill.	River near Mount Carmel, Ill.	Wet; pump.
Mount Carmel Elevator Co.	do.	do.	Do.
Moline Consumers Co.	Moline, Ill.	Moline, Ill.	Do.
Do.	do.	Ottawa, Ill.	Wet; derrick clamshell.
Neal Gravel Co.	Mattoon, Ill.	Palestine, Ill.	Wet; pump.
Peoria Washed Sand & Gravel Co.	Peoria, Ill.	Peoria, Ill.	Wet; derrick clamshell.
Pyott Gravel & Sand Co.	Chicago, Ill.	Algonquin, Ill.	Dry; dragline excavator.
Quincy Sand Co.	Quincy, Ill.	Quincy, Ill.	Wet; pump.
Reinert Gravel Co.	Chicago, Ill.	Algonquin, Ill.	Dry; steam shovel.
A. Y. Reed Gravel Co.	do.	Elgin, Ill.	Do.
Richardson Sand Co.	do.	Carpentersville, Ill.	Do.
Do.	do.	Coleman, Ill.	Do.
Rockford Sand & Gravel Co.	Rockford, Ill.	Rockford, Ill.	Dry; mechanical digger.
Do.	do.	do.	Wet; pump.
Rock Island Sand & Gravel Co.	Rock Island, Ill.	Rock Island, Ill.	Do.
Shawneetown Sand & Gravel Co.	Shawneetown, Ill.	Shawneetown, Ill.	Do.
South Elgin Sand & Gravel Co.	South Elgin, Ill.	South Elgin, Ill.	Dry; dragline excavator.
Stoker Gravel & Construction Co.	Highland, Ill.	Highland, Ill.	Dry; mechanical excavator.
Terry & Lewis.	Galesburg, Ill.	Gladstone, Ill.	Wet; pump.
Virginia Timber Co.	Springfield, Ill.	Springfield, Ill.	Do.
Western Sand & Gravel Co.	Spring Valley, Ill.	Spring Valley, Ill.	Dry; dragline scraper.
Yourtee Roberts Sand Co.	Chester, Ill.	River near Chester, Ill.	Wet; pump.

MICHIGAN.

Battjes Fuel & Building Material Co.	Grand Rapids, Mich.	Grand Rapids, Mich.	Dry; derrick clamshell.
Boice Bros.	Pontiac, Mich.	Pontiac, Mich.	Dry; cableway dragline.
Brownlee Park Gravel & Material Co.	Battle Creek, Mich.	Brownlee Park, Mich.	Dry; steam shovel.
G. W. Bunker Co.	Grand Rapids, Mich.	Wyoming Township, Mich.	Dry; dragline excavator.
Burwell Gravel Co.	Lansing, Mich.	Lansing, Mich.	Dry; steam shovel.
Cadillac Builders Supply Co.	Detroit, Mich.	River near Detroit	Wet; clamshell dredge.
Cadillac Sand & Gravel Co.	Ann Arbor, Mich.	Geddes, Mich.	Dry; steam shovel.
Hugh Campbell & Son.	Bay City, Mich.	Mason, Mich.	Do.
J. Calverts Sons Washing Plant.	Detroit, Mich.	Clarkson, Mich.	Dry; cableway dragline.
Cass City Sand & Gravel Co.	Cass City, Mich.	Cass City, Mich.	Do.
Champion Sand & Gravel Co.	Marquette, Mich.	Dishneau, Mich.	Dry; steam shovel.
Consumers Gravel Co.	Detroit, Mich.	Detroit, Mich.	Wet; pump.
Crescent Gravel Co.	Hershey, Mich.	Hershey, Mich.	Dry; steam shovel.
Detroit-Greenville Gravel Co.	Greenville, Ohio.	Brighton, Mich.	Do.
Detroit-Oxford Gravel & Stone Co.	Oxford, Mich.	Oxford, Mich.	Dry; locomotive crane clamshell.
Detroit Sand & Gravel Co.	Detroit, Mich.	Utica, Mich.	Do.
Federal Sand & Gravel Co.	Saginaw, Mich.	Evart, Mich.	Dry; dragline excavator.
Do.	do.	Greenbush, Mich.	Do.
Do.	do.	Emerson, Mich.	Dry; locomotive crane clamshell.
Do.	do.	Stinson, Mich.	Do.
Genesee Gravel Co.	Detroit, Mich.	Earlstead, Mich.	Wet; cableway dragline.
F. D. Gleason Coal Co.	do.	Rivers near Detroit.	Wet; clamshell dredges (3).
Grand Rapids Gravel Co.	Grand Rapids, Mich.	Granville Road, Grand Rapids.	Dry; steam shovel.
Do.	do.	Wyoming, Mich.	Do.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

MICHIGAN—Continued.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Grand River Washed Sand & Gravel Co.	Ann Arbor, Mich.	Brighton, Mich.	Dry; dragline excavator.
Gohr Bros.	Lansing, Mich.	Miller's Road, Lansing.	Dry; locomotive crane clamshell.
Handy Bros. Mining Co.	Bay City, Mich.	Douglas Pit, Mich.	Do.
Harrison Land Co. (Ltd.)	Grand Rapids, Mich.	Grand Rapids, Mich.	Dry; steam shovel.
Heller Bros.	Lansing, Mich.	Lansing, Mich.	Do.
Hershey Gravel Co.	Hershey, Mich.	River near Hershey.	Do.
Ireland & Lester.	Benton Harbor, Mich.	Benton Harbor, Mich.	Wet; pump.
Johnson & Johnson.	Pontiac, Mich.	Pontiac, Mich.	Wet; cableway dragline.
Kalamazoo-Greenville Gravel Co.	Greenville, Ohio.	Kalamazoo, Mich.	Dry; steam shovel.
W. R. Kemp.	Pontiac, Mich.	Pontiac, Mich.	Wet; cableway dragline.
Midland Gravel Co.	Millbrook, Mich.	Millbrook, Mich.	Dry; steam shovel.
Michigan Materials Co.	Muskegon, Mich.	Grand Haven, Mich.	Dry; locomotive crane clamshell.
Michigan Sand & Gravel Co.	Dexter, Mich.	Dexter, Mich.	Dry; derrick clamshell.
Otisville Gravel Co.	Saginaw, Mich.	Otisville, Mich.	Wet; cableway dragline.
Ohio Michigan Sand & Gravel Co.	Toledo, Ohio.	Chilson, Mich.	Dry; steam shovel.
Pfent & O'Brien.	Utica, Mich.	Utica, Mich.	Dry; dragline scraper.
Julius Porath.	Detroit, Mich.	Oxford, Mich.	Dry; cableway dragline.
Puritan Sand & Gravel Co.	do.	Tecumseh, Mich.	Dry; steam shovel and cableway dragline.
Rochester Sand & Brick Co.	do.	Rochester, Mich.	Dry; derrick clamshell.
Standard Gravel Co.	Pontiac, Mich.	New Hudson, Mich.	Dry; cableway dragline.
A. E. Sheltraw.	Saginaw, Mich.	Mason, Mich.	Dry; steam shovels (2).
Superior Sand & Gravel Co.	Detroit, Mich.	River near Detroit.	Wet; pump.
Tecumseh Gravel Co.	Tecumseh, Mich.	Tecumseh, Mich.	Wet and dry; cableway dragline and steam shovel.
Tuscola Sand & Gravel Co.	Cass City, Mich.	Cass City, Mich.	Dry; cableway dragline.
United Fuel & Supply Co.	Detroit, Mich.	Oxford, Mich.	Dry and wet; cableway dragline.
Do.	do.	Detroit, Mich.	Wet; pump.
Do.	do.	New Hudson, Mich.	Wet; cableway dragline.
Valley City Sand & Gravel Co.	Grand Rapids, Mich.	Kelly Siding, Mich.	Dry; dragline excavator.
Isaac Van Weelden.	Grand Haven, Mich.	River near Grand Haven.	Wet; dragline excavator.
Ward Sand & Gravel Co.	Detroit, Mich.	Oxford, Mich.	Wet; cableway dragline.
Do.	do.	do.	Wet; pump.
Hoyt Woodman.	Lansing, Mich.	Lansing, Mich.	Dry; horse scraper.
Ypsilanti Sand & Gravel Co.	Ypsilanti, Mich.	Ypsilanti, Mich.	Dry; steam shovel.

WISCONSIN.

Beloit Sand & Gravel Co.	Janesville, Wis.	Riton, Wis.	Dry; mechanical digger.
Big Bend Sand & Gravel Co.	Big Bend, Wis.	Big Bend, Wis.	Dry; cableway dragline.
Casco Gravel Co.	Green Bay, Wis.	Casco Junction, Wis.	Dry; dragline scraper.
Cast Stone Construction Co.	Eau Claire, Wis.	Shawtown, Wis.	Dry; dragline excavator.
Cook & Brown Lime Co.	Oshkosh, Wis.	Lake Beaumont, Wis.	Dry; steam shovel.
J. Donahue & Sons.	Milwaukee, Wis.	Waukesha, Wis.	Do.
Elkhart Lake Sand & Gravel Co.	Elkhart Lake, Wis.	Elkhart Lake (3 plants).	Dry; dragline scraper.
Eau Claire Sand & Gravel Co.	Eau Claire, Wis.	Shawtown, Wis.	Dry; derrick clamshell.
Federal Sand & Gravel Co.	Chicago, Ill.	Beloit, Wis.	Dry; steam shovel.
Do.	do.	Janesville, Wis.	Do.
Grand Rapids Sand & Gravel Co.	Grand Rapids, Wis.	Bosserton, Wis.	Dry; horse scraper.
Hayworth Sand & Gravel Co.	Milwaukee, Wis.	Lapham, Wis.	Dry; mechanical digger.
J. G. James Sand & Gravel Co.	do.	Milwaukee, Wis.	Do.
Janesville Sand & Gravel Co.	Janesville, Wis.	Janesville, Wis. (3 plants).	Do.
Lincoln Gravel Co.	Tomahawk, Wis.	Tomahawk, Wis.	Dry; steam shovel.
Moraine Gravel Co.	Plymouth, Wis.	Glenbeulah, Wis.	Do.
Northern Gravel Co.	Chicago, Ill.	Barton, Wis.	Do.
Racine County Sand & Gravel Works.	Racine, Wis.	Burlington, Wis.	Dry; dragline scraper.
Rasmussen-Ebbe Sand & Gravel Co.	Waupaca, Wis.	Waupaca, Wis.	Wet; cableway dragline.
Reed Sand & Gravel Co.	Burlington, Wis.	Burlington, Wis.	Dry; cableway dragline.
Stevens Point Sand & Gravel Co.	Stevens Point, Wis.	Rocky Run, Wis.	Wet; cableway dragline.
Waukesha Lime & Stone Co.	Waukesha, Wis.	Waukesha, Wis.	Dry; steam shovel.
Waukesha Washed Sand & Gravel Co.	do.	do.	Wet and dry; cableway dragline and steam shovel.
Do.	do.	Okauchee, Wis.	Dry; cableway dragline.
Waupaca Sand & Gravel Co.	Waupaca, Wis.	Amherst Junction, Wis.	Do.
Wausau Sand & Gravel Co.	Wausau, Wis.	Wausau, Wis.	Do.
Whitney Bros.	Superior, Wis.	Superior, Wis.	Wet; pump.
Wilcox Sand & Gravel Co.	Chicago, Ill.	Janesville, Wis.	Do.
Do.	do.	Fontana, Wis.	Dry; steam shovel.
Wisconsin Sand & Gravel Co.	Milwaukee, Wis.	North Lake, Wis.	Do.
Wisota Sand & Gravel Co.	Eau Claire, Wis.	Anson, Wis.	Dry; dragline excavator.

MINNESOTA.

Barnett & Record.	Duluth, Minn.	Lake Superior.	Wet; pump.
Best Construction Co.	Rochester, Minn.	Near Rochester, Minn.	Dry; derrick clamshell.
Biesanz Stone Co.	Winona, Minn.	Near Winona, Minn.	Wet; dragline excavators (2).
Biwabik Sand & Gravel Co.	Biwabik, Minn.	Biwabik, Minn.	Dry; steam shovel.
Blue Limestone Co.	Minneapolis, Minn.	Minneapolis, Minn.	Do.
Casey & Co.	do.	do.	Dry; dragline excavator.
Foley Bros.	St. Paul, Minn.	New London, Minn.	Dry; cableway dragline.
D. W. Harding & Co.	Minneapolis, Minn.	Golden Valley, Minn.	Dry; dragline scraper.
Kasota Sand & Gravel Co.	Kasota, Minn.	Kasota, Minn.	Dry; cableway dragline.
Landers-Morrison-Christenson Co.	Minneapolis, Minn.	Near Minneapolis, Minn.	Do.
W. H. Malone Co.	St. Paul, Minn.	St. Paul, Minn.	Dry; horse scrapers.
Marshall Concrete Tile Co.	Marshall, Minn.	Russell, Minn.	Dry; steam shovel.
C. E. Mason & Co.	Minneapolis, Minn.	Minneapolis, Minn.	Dry; dragline scraper.
Medford Washed Sand & Gravel Co.	Medford, Minn.	Medford, Minn.	Dry; cableway dragline.
Minnesota Gravel Co.	Springfield, Minn.	Courtland, Minn.	Dry; plant planned.
Minnesota Pipe & Tile Co.	Mankato, Minn.	Appleton, Minn.	Wet; pump.
Do.	do.	Mankato, Minn.	Do.
National Concrete Materials Co.	Luverne, Minn.	Luverne, Minn.	Do.
S. J. Peterson Sand & Gravel Co.	Minneapolis, Minn.	Minneapolis, Minn.	Dry; mechanical digger.
Randolph Sand & Gravel Co.	St. Paul, Minn.	Randolph, Minn.	Wet and dry; pump, cableway dragline, and steam shovel.
River Sand & Gravel Co.	Winona, Minn.	Winona, Minn.	Wet; pump.
J. L. Shiely Co.	St. Paul, Minn.	St. Paul, Minn.	Dry; steam shovel.
The A. M. Smith Sand & Gravel Co.	Minneapolis, Minn.	Golden Valley, Minn.	Do.
Stiefel Material Co.	St. Paul, Minn.	St. Paul, Minn.	Dry; mechanical digger.
United Materials Co.	do.	do.	Dry; steam shovel.
Winona Sand & Gravel Co.	Winona, Minn.	Winona, Minn.	Wet; cableway dragline.
Zenith Concrete Gravel Co.	Carlton, Minn.	Carlton, Minn.	Dry; steam shovel.

TABLE 1.—Permanent-type commercial sand and gravel plants—Continued.

IOWA.

Name of producer.	Office address.	Location of plant.	Method of excavation.
Automatic Gravel Products Co.	Muscatine, Iowa	Muscatine, Iowa	Wet; cableway dragline.
Bartlett & McFarland	Waterloo, Iowa	River near Waterloo	Do.
Frank Beutin Sand & Gravel Co.	Dubuque, Iowa	Dubuque, Iowa	Wet; pump.
Big Sioux Sand & Gravel Co.	Akron, Iowa	Akron, Iowa	Dry; cableway dragline.
John Brooks Sand & Gravel Co.	Waverly, Iowa	Shellrock, Iowa	Dry; horse scraper.
Builders Sand & Gravel Co.	Davenport, Iowa	River near Davenport	Wet; pump.
Burlington Sand & Gravel Co.	Muscatine, Iowa	River near Muscatine	Do.
Capital City Sand Co.	Des Moines, Iowa	River near Des Moines	Do.
Cedar River Sand & Material Co.	Waterloo, Iowa	7 miles east of Waterloo, Iowa	Do.
City Sand & Gravel Co.	Iowa City, Iowa	River near Iowa City	Do.
Clermont Brick & Sand Co.	Clermont, Iowa	Clermont, Iowa	Dry; steam shovel.
Clinton Sand & Gravel Co.	Clinton, Iowa	Clinton, Iowa	Wet; pump.
Coon River Sand Co.	Des Moines, Iowa	River near Des Moines	Do.
Frank Cramm & Sons	do	do	Do.
Des Moines Building Material Co.	do	do	Do.
Des Moines Sand & Fuel Co.	do	do	Do.
Eddyville Sand & Gravel Co.	Eddyville, Iowa	Near Eddyville, Iowa	Dry; drag-line excavator.
Flint Crushed Gravel Co.	Des Moines, Iowa	Porter, Iowa	Do.
M. J. Gilles Co.	Cherokee, Iowa	3 miles north of Cherokee, Iowa	Dry; locomotive crane clamshell.
Graettinger Tile Co.	Graettinger, Iowa	Graettinger, Iowa	Dry; cableway drag line.
Hahn-Muscatine Co.	Muscatine, Iowa	Muscatine, Iowa	Wet; pump.
Harvey Sand & Gravel Co.	Harvey, Iowa	River near Harvey, Iowa	Wet; cableway drag line.
Hayden Sand & Gravel Co.	Rock Valley, Iowa	Rock Valley, Iowa	Dry; steam shovel.
Hills Sand & Gravel Co.	Hills, Iowa	Hills, Iowa	Wet; cableway drag line and pump.
W. Horrabin	Iowa City, Iowa	5 miles south of Iowa City, Iowa	Wet; pump.
Humboldt Gravel & Tile Co.	Humboldt, Iowa	3 miles south of Humboldt, Iowa	Dry; locomotive crane clamshell.
Ideal Sand & Gravel Co.	Mason City, Iowa	Near Mason City, Iowa	Dry; drag-line excavators (2).
Independent Sand & Gravel Co.	Des Moines, Iowa	River near Des Moines	Wet; pump.
Interstate Material Co.	Davenport, Iowa	Davenport, Iowa	Do.
Iowa Sand & Gravel Co.	Oskaloosa, Iowa	River near Oskaloosa	Do.
Johnston Bros. Clay Works	Fort Dodge, Iowa	Clay Works, Iowa	Dry; steam shovel.
Kelly Sand & Fuel Co.	Burlington, Iowa	River near Burlington	Wet; pump.
J. J. Kemp Sand & Gravel Co.	Oyens, Iowa	Oyens, Iowa	Do.
Keokuk Sand Co.	Keokuk, Iowa	River near Keokuk, Iowa	Do.
Kings Crown Plaster Co.	Cedar Rapids, Iowa	River near Cedar Rapids	Do.
Lake View Sand & Gravel Co.	Lake View, Iowa	Lake View, Iowa	Do.
Do.	do	do	Wet; pump and cableway dragline.
Langworthy Silica Co.	Dubuque, Iowa	Clayton, Iowa	Dry; steam shovel.
Larimer & Shaffer Sand Co.	Cedar Rapids, Iowa	Cedar Rapids, Iowa	Wet; pump.
Le Mars Gravel Co.	Le Mars, Iowa	Le Mars, Iowa	Do.
Do.	do	Cherokee, Iowa	Dry; cableway drag line.
Do.	do	Hawarden, Iowa	Wet; pump.
Do.	do	Doon, Iowa	Do.
McHose Sand & Tile Co.	Boone, Iowa	Fraser, Iowa	Wet; pumps (2).
Miller Sand Co.	Doon, Iowa	Doon, Iowa	Dry; horse scrapers.
Mole Sand & Gravel Co.	Dubuque, Iowa	Dubuque, Iowa	Wet; pump.
Muscatine Sand & Gravel Co.	Muscatine, Iowa	River near Muscatine	Do.
National Concrete Materials Co.	Sioux City, Iowa	Akron, Iowa	Wet; cableway dragline.
Niles Sand & Gravel Co.	Charles City, Iowa	Nilesville, Iowa	Wet; pump.
Northern Gravel Co.	Muscatine, Iowa	Muscatine, Iowa	Do.
C. A. Oehlerking	Hawarden, Iowa	Hawarden, Iowa	Wet; drag-line excavator.
Oak Park Sand Co.	Des Moines, Iowa	Valley Junction, Iowa	Wet; pump.
Ottumwa Sand Co.	Ottumwa, Iowa	1 mile west of Ottumwa, Iowa	Do.
Pearl City Gravel Co.	Muscatine, Iowa	3 miles south of Muscatine	Do.
Portland Sand & Gravel Co.	Des Moines, Iowa	Valley Junction, Iowa	Do.
Do.	do	Booneville, Iowa	Do.
Reliance Sand & Gravel Co.	do	3½ miles Des Moines, Iowa	Dry; derrick clamshell.
Remsen Sand & Gravel Co.	Remsen, Iowa	Remsen, Iowa	Wet; pump.
Do.	do	Correctionville, Iowa	Dry; locomotive crane clamshell.
Sabula Sand & Gravel Co.	Lincoln, Ill.	Sabula, Iowa	Wet; pump.
Saction Sand & Gravel Co.	Lake View, Iowa	Saction, Iowa	Dry; cableway drag line.
Schneider Sand & Gravel Co.	Clinton, Iowa	Clinton, Iowa	Wet; pump.
J. M. Smith Sand Co.	Cedar Falls, Iowa	Cedar Falls, Iowa	Wet; cableway dragline.
Spencer Washed Sand & Gravel Co.	Spencer, Iowa	Spencer, Iowa	Wet; pump.
Standard Sand & Gravel Co.	Oskaloosa, Iowa	Harvey, Iowa	Do.
Wapelle Sand & Building Material Co.	Ottumwa, Iowa	River near Ottumwa	Do.
Waterloo Dredging Co.	Waterloo, Iowa	River near Waterloo	Wet; cableway dragline.
Woodbury County Gravel Works	Correctionville, Iowa	Correctionville, Iowa	Plant not completed.

TABLE 2.—Permanent-type commercial sand and gravel plants in twenty-two north central and north eastern States.

State.	Number of plants.				Daily capacity, tons.	1919, tonnage.	1920, estimated tonnage.	Increased, tons.	Decreased, tons.	1920, tons used on roads.	Claims of car shortage effect on production at various plants.			
	Total.	Wet. ¹	Dry. ¹	Both.							1919		1920	
											Number affected.	Per cent reduced.	Number affected.	Per cent reduced.
Maine.....	3		3		900	57,000	77,000	20,000		9,200	0		1	50
New Hampshire.....	1		1		210	30,000	35,000	5,000		5,250	0		1	15
Vermont ²	0													
Massachusetts.....	12	1	11		9,885	674,000	968,000	294,000		147,600	0		3	20 to 70
Rhode Island ²	0													
Connecticut.....	10	2	8		2,750	326,000	360,500	34,500		69,850	0		1	90
New York.....	26	6	20		28,615	2,867,600	3,469,700	602,100		846,850	5	25 to 60	9	15 to 75
New Jersey.....	25	5	18	2	26,425	1,967,000	2,352,000	395,000		956,850	15	5 to 75	15	5 to 75
Pennsylvania.....	50	18	32		50,200	4,936,000	5,633,200	697,200		1,229,650	19	10 to 50	26	10 to 75
Delaware.....	2		2		700	60,000	44,000		16,000	26,000	2	25 to 50	2	50
Maryland and District of Columbia.....	10	3	7		12,250	1,907,000	1,802,170		104,830	470,100	7	10 to 33	7	10 to 40
Virginia.....	14	3	11		17,650	1,101,000	1,046,900		54,100	356,000	7	15 to 80	11	25 to 60
West Virginia.....	18	13	5		10,000	465,400	526,400		61,000	216,500	13	10 to 90	16	10 to 90
Ohio.....	78	33	43	2	71,120	4,287,150	5,369,500	1,082,350		1,818,125	36	5 to 80	40	10 to 90
Kentucky.....	12	10	2		14,040	877,750	1,089,750		212,000	180,800	6	25 to 50	5	20 to 60
Indiana.....	63	33	30		59,825	4,380,400	4,225,500		154,900	1,687,800	29	10 to 95	33	15 to 95
Illinois.....	51	22	27	2	79,225	5,467,800	5,425,000		42,800	2,944,000	35	6 to 85	38	20 to 90
Michigan.....	51	20	31		59,415	4,320,085	4,847,000	526,915		1,403,565	32	10 to 75	39	10 to 90
Wisconsin.....	35	3	32		33,750	1,979,942	3,211,000	1,231,058		883,700	17	10 to 60	18	25 to 90
Minnesota.....	32	6	26		20,835	838,964	1,676,000	837,036		497,700	8	30 to 70	11	40 to 90
South Dakota.....	3		3		2,400	(a)	78,000			25,000	0		0	
Iowa.....	71	42	29		57,540	2,055,873	2,661,000	605,127		642,000	38	10 to 80	49	20 to 85
Total.....	567	220	341	6	557,735	38,598,964	44,897,620	6,593,286	372,630	14,416,540	269	5 to 95	325	5 to 95

¹ Wet and Dry, as used here, apply only to excavation and not to screening method.

² Local pits only.

³ Started 1920.

In the statistics above, small, locally used sand and gravel pits are not included. These, however, are abundant, especially in the northern States.

TABLE 3.—Showing number of plants using various sand and gravel excavation methods.

State.	Dry excavation.				Dry or wet excavation.			Wet excavation.			No report.	Total plants.	Total of all methods at all plants.			
	Steam shovel.	Mechanical digger.	Horse scraper.	Hand.	Clamshell.		Drag line.			Pump.				Dredges.		
					Der-rick.	Loco-motive crane.	Cable-way.	Excavator.	Scraper.					Ladder.	Dipper.	Clam-shell.
Maine.....	2													2	2	
New Hampshire.....	1													1	1	
Vermont ¹																
Massachusetts.....	5				1	4		1		1				12	12	
Rhode Island ¹					1			3						7	7	
Connecticut.....	1				3	2	1			4	1			20	21	
New York.....	11	1			3	1	1			5	2			24	24	
New Jersey.....	11			4		1	5			10	10	1		41	42	
Pennsylvania.....					1									1	1	
Delaware.....					1											
Maryland and District of Columbia.....	3				1						3			7	7	
Virginia.....	2						2	5		4				13	13	
West Virginia.....	1		1		3		1			7	7	1		20	21	
Ohio.....	27		2	1	2	4	8	1		18	3	2	1	69	71	
Kentucky.....	3							1		7			1	13	13	
Indiana.....	17				2	6	23	4		13			1	65	67	
Illinois.....	16	2			2	1	5	4	2	23				55	55	
Michigan.....	19		1		3	7	15	6	1	5		2		57	59	
Wisconsin.....	11	4	1		1		8	2	3	1			1	31	32	
Minnesota.....	7	2	1		1		6	2	2	5			1	27	28	
South Dakota.....	1						1		1					3	3	
Iowa.....	4		2		1	3	12	4		43			1	68	70	
Total.....	150	10	8	5	25	30	88	33	9	146	26	4	9	6	536	549

¹ Locally used pits only.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN MARCH, 1921.

State.	Project No.	County.	Length, in miles.	Type of construction.	Project statement approved.	Total estimate.	Federal aid.
Arizona.....	44	Mohave.....	0.500	Gravel.....	Mar. 17	\$12,295.25	\$6,147.62
Arkansas.....	62	Washington.....	¹ 1.150	do.....	Mar. 25	¹ 4,115.54	
	121	Phillips.....	9.080	Concrete.....	Mar. 11	233,789.49	60,000.00
	126	Saline.....	5.400	Gravel.....	Mar. 25	16,114.15	7,500.00
	128	Cleveland.....	6.570	do.....	do.	30,380.02	10,000.00
	131	White.....	4.080	do.....	do.	50,490.35	24,000.00
	132	Pope.....	4.250	Macadam.....	Mar. 26	80,176.99	30,000.00
California.....	66	Amador.....	5.860	Earth.....	do.	49,995.00	24,997.50
	67	Sacramento.....	8.440	do.....	do.	112,530.00	56,265.00
Colorado.....	103	San Miguel.....	5.000	do.....	Mar. 19	29,365.60	14,682.80
	104	Montrose.....		Bridge.....	Mar. 25	33,044.00	16,522.00
	180	Costilla.....	2.135	Earth.....	Mar. 2	20,403.24	10,201.62
	183	Mesa.....	.997	Concrete.....	Mar. 25	46,093.98	19,940.00
	184	do.....	.806	do.....	Mar. 11	39,995.89	16,120.00
	190	Summit.....	1.017	Earth.....	Mar. 23	30,988.38	15,494.19
Georgia.....	212	Ware.....	11.360	do.....	Mar. 25	100,000.01	50,000.00
	219	Washington.....		Bridge.....	Mar. 2	60,698.00	30,000.00
	223	Appling.....	4.503	Sand-clay.....	Mar. 25	39,667.47	19,833.73
	224	Gordon.....	2.500	do.....	Mar. 23	28,694.60	14,347.30
Kansas.....	56	Grady.....	² 6.000	Gravel.....	Mar. 26	³ 69,991.90	³ 28,750.00
Kentucky.....	40	Muhlenburg.....	27.700	do.....	Mar. 3	550,206.25	275,103.12
	47	Hopkins.....	20.800	Gravel and macadam.....	Mar. 23	489,225.00	244,612.50
	50	Jefferson.....	8.650	Concrete.....	do.	406,456.32	173,000.00
	57	Bell.....	1.511	Earth.....	Mar. 25	22,332.20	11,166.10
Louisiana.....	32	Grant.....	¹ 15.510	Gravel.....	Mar. 17	¹ 182,546.53	¹ 91,273.26
Maine.....	17	Piscataquis.....	³ 2.060	do.....	Feb. 28	³ 30,580.55	³ 15,290.27
Minnesota.....	168	Itasca.....	³ 8.430	Concrete brick or asphaltic.....	Feb. 14	³ 346,568.64	³ 168,600.00
	190	St. Louis.....	1.510	Gravel.....	Feb. 25	33,803.00	16,000.00
	200	Big Stone.....	2.250	do.....	Feb. 23	23,067.00	7,000.00
	202	St. Louis.....	2.080	Brick, concrete, or asphalt.....	Feb. 25	120,204.48	38,000.00
	204	Itasca.....	6.460	Gravel.....	Feb. 29	100,199.22	10,000.00
Mississippi.....	91	Simpson.....	12.760	Gravel.....	Feb. 11	121,952.82	60,976.41
	109	Pike.....	.980	do.....	Feb. 17	15,178.24	7,589.12
	114	Grenada.....	14.800	do.....	Feb. 11	192,612.64	75,000.00
	115	Hinds.....	5.830	Concrete, brick, or asphalt.....	Feb. 25	221,633.50	100,000.00
Missouri.....	182	Newton.....	9.940	Gravel and chat.....	Feb. 19	52,833.04	26,416.52
Montana.....	152	Phillips.....	8.000	Gravel.....	Feb. 23	60,225.00	30,112.50
	155	Valley.....	5.000	do.....	Feb. 17	39,600.00	19,800.00
Nebraska.....	143	Polk, York, and Fillmore.....	2.400	Earth.....	Feb. 19		
North Dakota.....	124	Barnes.....	² 2.500	do.....	Feb. 14	² 17,930.00	² 8,965.00
Ohio.....	128	Montgomery.....	1.633	Concrete or bituminous macadam.....	Feb. 25	70,000.00	20,000.00
Oklahoma.....	6	Oklmulgee.....	³ 15.000	Bituminous macadam.....	Feb. 7	³ 183,717.60	³ 91,858.80
Oregon.....	20	Wasco.....	³ 11.5	Concrete or asphalt on concrete base.....	do.	³ 285,000.00	³ 117,500.00
South Carolina.....	85	Williams and Berkeley.....		Bridge.....	Feb. 11	848,309.00	424,154.50
	101	Florence and Marion.....		do.....	Mar. 3	349,670.20	150,000.00
	106	Richland and Sumter.....		do.....	Mar. 25	149,881.05	74,940.52
South Dakota.....	114	Greenville.....	.865	Topsoil.....	Mar. 2	9,457.80	4,728.90
	62	McCook.....	14.000	Gravel.....	Mar. 23	97,834.00	48,917.00
	73	Campbell.....	12.196	Earth.....	Mar. 19	59,200.68	29,600.34
	75	Perkins.....	8.640	do.....	Mar. 2	41,197.75	20,598.87
Texas.....	16	McColloch.....	³ 37.400	Gravel and sand-clay.....	Mar. 6	³ 75,774.60	³ 35,000.00
	212	Val Verde.....	7.290	Gravel.....	Mar. 3	50,759.94	25,000.00
	224	Shelby.....	35.500	do.....	Mar. 2	428,409.76	100,000.00
	235	Howard, Midland, Martin, and Ector.....	95.00	do.....	Mar. 11	877,264.41	302,279.00
	236	Washington.....	33.000	do.....	Mar. 23	963,228.20	200,000.00
Utah.....	27	Cache.....	³ 10.450	Concrete.....	Mar. 12	³ 291,280.25	³ 145,640.12
Vermont.....	23	Bennington.....	.890	do.....	Mar. 22	39,297.50	19,648.75
Virginia.....	99	Halifax and Pittsylvania.....	6.220	Topsoil.....	Mar. 7	40,418.40	20,209.20
Wisconsin.....	119	Barron.....	.727	Earth.....	Mar. 21	16,329.17	8,000.00
	130	Price.....	¹ 2.430	do.....	Mar. 14	¹ 20,509.94	¹ 9,922.02
	181	Dane.....	3.000	do.....	Mar. 23	38,822.68	13,000.00
	191	Clark.....	.470	Gravel.....	Mar. 29	19,125.70	7,500.00
	195	Columbia.....	3.310	do.....	Mar. 8	30,000.00	12,000.00
	197	Dane.....	3.310	Earth.....	do.	39,259.17	17,000.00
	199	do.....	5.360	Gravel.....	Mar. 11	49,500.00	16,500.00
	207	Forest.....	4.850	do.....	Mar. 8	64,650.22	24,000.00
	212	Iron.....	5.540	do.....	Mar. 23	58,874.82	20,000.00
	222	Langlade.....	5.640	do.....	Mar. 8	71,315.41	25,000.00
	227	Marquette.....	1.636	do.....	do.	31,468.88	11,500.00
	232	Outagamie.....	2.350	Concrete.....	do.	102,551.79	42,000.00
	233	Pepin.....	2.150	Shale and gravel.....	do.	14,997.40	6,000.00
	255	Manitowoc.....	3.670	Concrete.....	do.	146,159.74	50,109.12

¹ Revised statement. Amounts given are increases over those in the original statement.

² Revised statement. Amounts given are decreases over those in the original statement.

³ Withdrawn.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

- Report of the Director of the Bureau of Public Roads for 1918.
- Report of the Chief of the Bureau of Public Roads for 1919.
- Report of the Chief of the Bureau of Public Roads for 1920.

DEPARTMENT BULLETINS.

- Dept. Bul. *105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
- *136. Highway Bonds.
220. Road Models.
- *230. Oil Mixed Portland Cement Concrete.
- *249. Portland Cement Concrete Pavements for Country Roads. 15c.
- 257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
- 314. Methods for the Examination of Bituminous Road Materials.
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- *393. Economic Surveys of County Highway Improvement. 35c.
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- 583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
- 586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
- 660. Highway Cost Keeping
- 670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
- *691. Typical Specifications for Bituminous Road Materials. 15c.
- 704. Typical Specifications for Nonbituminous Road Materials.
- *724. Drainage Methods and Foundations for County Roads. 20c.
- *Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918. 15c.
- *Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

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- F. B. 338. Macadam Roads.
- *505. Benefits of Improved Roads. 5c.
- 597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

- Y. B. Sep. 727. Design of Public Roads.
- 739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

- Bul. *45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

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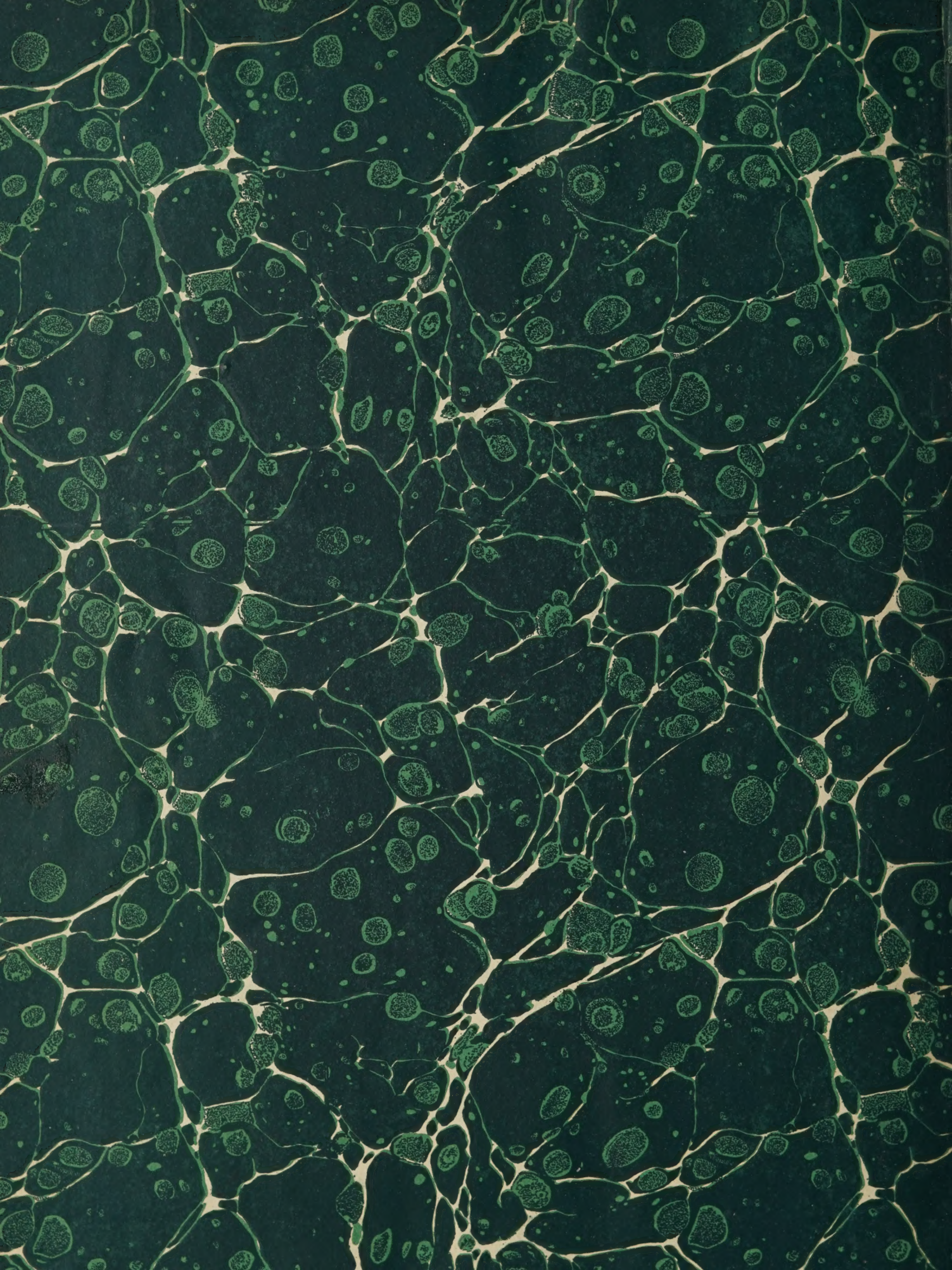
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- *90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
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- *94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
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- Vol. II, No. 15. State Highway Mileage and Expenditures in the United States in 1918. 15c.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

- Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
- Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
- Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
- Vol. 5, No. 24, D- 6. A New Penetration needle for Use in Testing Bituminous Materials.
- Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
- Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
- Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
- Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.



PUBLIC ROADS

R.C. / V. 4, 1921

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