U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 2, NOS. 16–17 WASHINGTON, D. C. AUGUST–SEPTEMBER, 1919

TYPICAL COUNTRY THROUGH WHICH PENNSYLVANIA No. 12 RELOCATION WAS MADE

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1919

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U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

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GRANITE BLOCK CONSTRUCTION.

By JULES L. GOLDBERG, Chief Editorial Division, Bureau of Public Roads.

PORTION OF THE APPIAN WAY, DECAYED AND NEVER REPAIRED, THOUGH MAJOR PART OF HIGHWAY, NOW 2,000 YEARS OLD, IS IN GOOD CONDITION.

THE history of stone block pavements begins back in the days of King Menes, who built a road 10 inches thick to the Pyramids. Later, in the early days of the Roman Empire, stone pavements were constructed of large flags, with the smooth face turned up. The spaces between these large stones were chinked with smaller stones, bedded in mortar. The historic and famous Appian Way is probably the greatest example of this type of pavement ever constructed. This road, in general, is in reasonably good condition to-day, considering the fact that it has been in use for more than 2,000 years.

The earliest stone pavements in this country were composed of cobble stones taken from benches or gravel beds, laid in sand and the joints filled with gravel or sand. The old city of Panama in the time of the buccaneers, when Morgan, the pirate, destroyed the city in 1680, had streets paved in this manner, good examples of which may be seen among the ruins to-day. In many of the cities in the United States there are remains of these cobble-paved streets that were laid more than 100 years ago. In many cases these old cobble-stone pavements have formed the base for sheet pavements of various types and materials, making in this manner a durable smooth pavement, many years after the original construction of the street, without relaying.

APPROACHING THE MODERN TYPE.

Finally, it became desirable to obtain a flatter, smoother surface for the top of the paving, and the quarry split blocks began to come into use in the vicinity of all centers where granite quarries were in operation, and gradually spreading to the larger cities. In earlier times in this country, owing to the fact that vessels were loaded with rum, molasses, and cotton from the South for shipment to New England points, a considerable industry was created through the necessity of ballast for return loads, and the holds of the vessels were loaded with the old-style granite blocks as ballast for return trips to the South. These old flagging pavements are in existence to-day in many Southern Atlantic and Gulf cities. The blocks used in that period generally were from 12 to 18 inches in length, 12 inches in width, and 6 to 8 inches in depth. These were laid on the graded natural subsoil on a sand bed with sand joints.

That this was a very durable pavement is evidenced by the pavements still existing, particularly in the city of New Orleans, where many streets in the old section have this old type of pavement. These pavements show so little signs of wear that the material would lend itself very readily to the production of a reasonably well-cut paving block, which could be used in making a first-class modern grouted pavement. The old-style pavement was naturally quite rough to travel over and the blocks would sometimes rock on their beds and tilt up.

UTILIZATION OF CONCRETE.

A theory was advanced later that if the block were smaller the surface would be smoother, and 6-inch cubes began to be used. But these were found not to be very satisfactory on account of not being able to break joints in a proper manner, and were followed with the old-style block, 4 to 7 inches in width, 9 to 16 inches in length, and about 8 inches in depth.

About 1880 came the realization that the blocks should be cut with less depth in order to save transportation charges, and in order to provide a smooth riding surface they should be made shorter in length. The reason for this was that it was felt that shorter blocks would more readily fit the contour of the crown of the roadway and it was thought that for the proper toe-hold for horses blocks 6 to 7 inches in width were too wide, so in order to cut down the expense of transportation concrete foundations were introduced and the use of a shallower block was begun.

Following the use of the concrete base at about 1888 the first examples of cement grouted granite block began to make their appearance in Massachusetts. This pavement was constructed on a 5-inch concrete foundation, 1-inch sand cushion. The joints were partially filled with peastone spread upon the blocks and broomed in previous to the rolling of the blocks, it being thought necessary at that time that the peastone should be incorporated in the joints in order to properly key up the blocks to hold them in place after ramming was accomplished. This method of laying later proved to be extremely disastrous owing to the fact that the grout in most cases stopped on coming in contact with the peastone and did not fill the joints from top to bottom as is done in present methods of construction. The old style block previously referred to was used in this construction.

SEEK INFORMATION ABROAD.

In 1905 New England quarry owners inspected paving laid in the city of Liverpool where the general custom was to use a 4-inch cube on a concrete base. This type of paving is what is now known in paving practice as Durax pavement, which is made in these times of small cubes varying from 2¾ to 4 inches in diameter, laid in concentric circles at right angles to the direction of travel. Many pieces of this style of pavement were laid in Germany, where they are known as Kleinpflaster. Many pieces have now been laid in this country, some examples existing in Washington where many short pieces are laid straight instead of in the oyster shell or concentric circle pattern. It has been the custom in many places, in connection with this style of pavement, where the granite blocks were of the old style, poorly-cut type, to use these old blocks remade into Durax cubes as a relaying proposition where such blocks were not of sufficient quality to admit recutting or napping into large size paving blocks such as is done in many cases. The 4-inch blocks in the city of Liverpool were giving good service and brought home more fully to them the realization that it was not necessary to cut and transport the deep 8-inch block, provided the concrete base was used underneath it. Consideration of this matter led to the production of the 4-inch block and the 5-inch standard block, in most common use to-day.

ENGINEERS DIFFER.

It was found in laying the 4-inch block in the manner customary at that time, which was with the addition of pea stone in the joints to steady the blocks in ramming, that if extreme care were not exercised in the use of the peastone, owing to the fact that the block was not very deep, the grouting (which had come into use at a little earlier period) did not get a proper hold and disastrous effects followed. This tended to develop the 5-inch standard block, giving a little more depth and a little more stability. This block is more generally used to-day than any other type.

The opinion of engineers varied materially in respect to the various sizes of blocks and many hesitated to change so radically from the original deep block to this later shallow block. Many of the engineers even preferred to use the old style blocks on a sand cushion with a grouted joint, rather than switch to the new shallow depth blocks with the concrete base. From the deep block, grouted, has developed the present trunk-line highway construction which is being advocated for use on many truck traffic lines using the block paved as above mentioned, but with the additional stability of being laid on a cushion base course consisting of one part cement to three parts sand, instead of employing the usual sand cushion on a well-compacted subgrade.

VARYING SIZES CAUSED DELAY.

The quarries were called upon to cut so many different varieties of blocks that they were unable to cut any size in advance for storage, with the result that many times jobs were held up owing to the fact that the blocks had to be custom made on order. In 1912 a meeting was held by a committee of the officials of various cities in order to standardize paving specifications and to endeavor to fix upon a special size of paving block, to be called the Standard Block. Even after this meeting the block was not universally adopted as was expected, and to-day the

OLD STYLE FLAGSTONE PAVING IN NEW ORLEANS.

manufacturers are turning out many different styles and sizes and grades of granite blocks known to the trade by various designations.

With many different sizes of blocks, it can readily be seen that great difficulty arose in production in advance of any amount of stock, as the producers hesitated to cut any quantity before knowing what particular sizes they would be called upon to deliver. No advantage whatever is obtained through variations in size, as with the "Standard" specifications for laying to-day, very little difference in durability or smoothness can be attained by deviating from the standard 5-inch or the 4-inch block in general use.

IMPROVEMENT IN CONSTRUCTION.

The improvement in the matter of construction has been very marked. The old flag-stone was replaced by the truer cut block, laid on sand or gravel, covered with a light coating of pebbles or sand, rammed and then covered a second time with a coating of sand which was broomed into the joints, forming the old style sand joint, which pavement, in its turn, disagreeably cobbled and made a rough riding surface. This was succeeded by a modification of the pebble and pitch joint, pebbles being broomed into the joints of the paving blocks, followed by a pouring of hot bitumen, filling the joints from top to bottom, which pavement also cobbled similar to the sand-joint block. This, in turn, was followed by the closely cut block laid in cement grout, making a true, smooth pavement; with a later modification of the bituminous mastic filler, composed of bitumen and sand, which made the pavement easier to open in case repairs to subsurface construction were necessary.

PREPARING THE BLOCK.

Classified under the trade name of granite are such allied rocks as monsonite, syenite, gneiss, and certain other igneous and metamorphic rocks. The granite occurs in nature in various shapes and forms. In some quarries it occurs in sheets with vertical joints. Naturally it would be expected that the grain of the stone would follow the bed and joint, but sometimes this is not true, the grain of the stone running diagonally across. In other quarries the stone was thrown up in its original shape, in an entirely different manner, being one great solid mass, without beds or seams.

In the manufacture of granite block no pressure or tendency to fracture is imposed on the stone at any time. Granite has a grain similar to wood, and splits readily on the natural lines of cleavage, differing from the case of crushed stone, where an enormous pressure is exerted internally in the production of the material in passing through the crusher. The paving block has been subjected to no internal strain, consequently to keep and preserve it in its original condition it should not be thrown from any great height in loading or unloading, which might

FIVE-INCH GRANITE BLOCKS RAMMED AND READY FOR GROUTING.

be apt to cause the conditions which have been avoided all through the manufacture, and which might also fracture the edges and corners of the stone, spoiling its proper shape. To further the interest of transportation and economy, the blocks, if possible, should be inspected at the quarry and all rejected material left there, rather than have it transported to the work itself.

TESTS.

The usual tests applied to determine the value of the paving block are, first, hardness; second, toughness; third, resistance to wear or abrasion.

(1) Test for hardness—that is, the resistance of the surface particles to displacement by abrasion—is usually determined with a Dorry machine. This machine consists of a circular steel disk, revolving horizontally, against which is held a cylindrical core of granite, cut from the sample to be tested by a diamond core drill, the cylinder being 25 millimeters in diameter, and is held perpendicularly against a disk under a constant pressure of 1,250 grams, while standard quartz sand, between 30 and 40 mesh, is fed onto the disk to act as the abrasive agent. At the end of 1,000 revolutions of the disk the loss in weight is determined and the test repeated with the specimen reversed. The average loss in weight computed from the two runs is used in determining the hardness of the rock. The following method of expressing the hardness has been adopted: Hardness, $H = 20 - \frac{W}{3}$. in which W = loss in grams per 1,000 revolutions.

(2) The toughness test as applied to paving blocks means the ability of the material to resist fracture due to impact. A cylindrical sample 25 millimeters in diameter and 25 millimeters in height is cored from the test piece by a diamond drill. The sample is then placed in the impact machine. The test consists of a 1 centimeter fall of a hammer weighing 2 kilograms for the first blow and an increased drop of 1 centimeter for each succeeding blow until failure of the test piece occurs. The number of blows required to cause failure is used to represent the toughness.

(3) The abrasion test: The Deval abrasion machine is used in testing the hardness as well as the toughness of the rock. The rock is broken into pieces as nearly uniform in size as possible. Fifty of the pieces, weighing in all 5 kilograms, are thoroughly dried before weighing, are then placed in a revolving cylinder and are given 10,000 revolutions at the rate of 30 to 33 to the minute. The per-

POURING ASPHALT MASTIC FILLER COMPOSED OF ONE PART ASPHALT AND ONE PART SAND.

centage of material worn off, or abraded, which will pass through a $\frac{1}{16}$-inch mesh seive is considered as determining the amount of wear. The amount of wear is expressed either in the percentage of the 5,000 grams used in the test, or else the French coefficient, which is in more general use, is given, viz, the coefficient of wear $= \frac{400}{W} = \frac{40}{\text{per cent of wear.}}$ in which W is the weight in grams of the detritus under $\frac{1}{16}$ inch in size per kilogram of rock used. In this test the sample is thrown the length of the cylinder twice at each revolution, so that the individual stones grind against each other as well as against the sides of the cylinders. The rocks are likewise somewhat broken by the impact, so that the abrasion test can be considered as one not only for hardness but also for toughness.

CONSTRUCTION.

The original construction of the old cobble paving first used as a pavement was to excavate to the proper depth, which was fixed by the cobble itself. On this subgrade was placed a bed of gravel or sand; in this the cobbles were bedded with their longest dimensions vertically. Sand or gravel was then thrown over the top, a broom was used to remove the excess sand, leaving the head of the cobble bare, and the cobble was then rammed with a wooden paving rammer sometimes studded with steel plugs. As has been previously mentioned, examples of this work were found in the old city of Panama, and many examples are in existence to-day in cities in the United States, particularly Baltimore and Washington.

The next step in construction was the old flag blocks. These were bedded on a cushion of sand, rammed, and the joints filled with sand. Following these came the sand-joint block pavement, from which developed the granite block of to-day. This block was laid on a sand or gravel cushion, partially filled with sand in the joints, and then rammed; finally covered with a layer of sand, which, as it dried, was broomed into the joints. The pebble and pitch style of pavement was made by the use of screened pebbles of about $\frac{1}{2}$ inch in diameter, which were deposited in the joints, the paving then being rammed, and the final process was the filling of the joints with hot paving pitch by means of pouring pots.

A modification of this style of joint filling has been in use in recent years, asphalt usually being used as a joint filler, the pebbles and asphalt being placed in the joints in several layers with several pourings with the final finish a mat of asphalt and trap rock peastone.

TYPE FOR TRUNK LINES.

The method used in a number of instances, and which seems to be giving very good results, was to place on a well-compacted subgrade a cushion course of sand in which the blocks were paved, then rammed and grouted with a 1 to 1 cement and sand grout. If the 5-inch block of to-day is to be used in this style of paving, it should be paved on a cushion course of 1 to 3 dry cement mortar, instead of the sand cushion.

This last type of construction is being introduced for trunk line truck highway construction on through traffic lines and State highway construction.

On traffic highways it usually is customary to use a concrete base course varying in depth from 4 to 8 inches, constructed on a well-compacted subgrade. On this is placed either a cushion course of sand or of 1 to 3 or 1 to 4 dry cement mortar. On this the blocks are paved and rammed in courses of uniform width at right angles to the lines of traffic, using either the 4 or 5 inch block, and grouted with a grouting mixture of 1 part cement and 1 part sand.

Another type of filler used in connection with this style of pavement is that known as a bituminous mastic. This joint filler is composed of nearly equal parts of hot sand and hot bitumen, the proportion of sand usually running from 35 to 50 per cent of the combination. Whereas it is necessary in the use of the cement-grout filler to close the street to traffic for not less than six days after the grouting has been completed, where the bituminous mastic is used the street may be opened immediately upon the cooling of the bitumen, which takes place within an hour after the installation of the joint filler. Therefore where extremely heavy traffic congestion occurs it sometimes is advantageous to use the bituminous mastic filler. Also, in case of frequent openings in the pavement, it can be opened more easily than is the case with the cement grout filler. Naturally this type of pavement requires a very substantial concrete base to bridge over the soft spots and depressions and to sustain the mastic filled pavement.

PREPARING THE SUBGRADE.

In preparing the subgrade all soft and loamy spots must be excavated and filled with cinders or gravel, or other material proper for such purpose, and the entire subgrade then rolled and compacted by ramming and shaping to a true and uniform contour, care being taken that so far as possible no plowing or picking shall be carried below the final finished subgrade line. Proper drainage facilities should be provided either by ditching, tiling, or trenching.

The concrete base should be constructed of 1–3–6 cement concrete or better, the sand used to be clean, reasonably coarse and free from clay or loam, the stone used either clean graded crushed stone or clean screened cobbles, free from any rotten or disintegrated stone. The cement to be standard brand of approved quality, which will meet any of the standard tests called for in general construction work. The concrete should be mixed reasonably wet, but not so wet that the mortar will flow away after being deposited in the roadway.

SAND CUSHION.

Bedding sand should contain no particles which would be retained on a ⅜-inch mesh screen and should not contain over 10 per cent of loam or clay. If the concrete base has been allowed to set for not less than six days the sand and paving blocks may be carted in and dumped in windrows on the base.

This sand cushion may be substituted by a dry cement sand cushion mixed in the proportions of 1 part cement to 3 or 4 parts sand. This cushion should not in any event be mixed more than a half hour ahead of the time of using, and none of this material should be left over at the close of work and used again upon the resumption of work.

The blocks should be laid on this cushion course in courses of uniform width, as nearly as possible at right angles to the direction of travel. They should be rammed individually to a true and firm bearing, and under no condition should they be rolled with either a hand or steam roller, as rolling will force the bedding material up between the joints, and rock a block on its cushion. As the blocks are not of uniform depth the roller would only strike on the high, deep blocks, without ramming the shallow blocks at all. All low blocks after ramming should be raised with paving tongs, no pinch bars being used, as pinch bars usually dislocate surrounding blocks as well as the one which it is desired to lift.

READY FOR GROUTING MATERIAL.

The ramming should be done with a rammer weighing from 25 to 50 pounds, with a steel base. After the blocks are properly rammed they are ready for the grouting material, which usually is a cement grout mixed in the proportions of 1 part cement to 1 part sand, the sand being of such fineness that no particles should be retained on a 20-mesh screen and not over 10 per cent of it pass a 100-mesh screen. The cement should be any well known brand Portland cement that will meet standard specifications for such material. The grout should be mixed thin enough to run freely to the bottom of all joints, but thick enough so that it will not run away in the flow line of the street.

Before the initial set takes place a second finish coating of grouting should be applied, filling the joints flush with the blocks. The whole should be broomed, first with a street broom to remove the surplus grout from the top of the blocks, and finally

POURING JOINTS WITH ASPHALT FILLER BY POURING-POT METHOD.

finished by the application of an ordinary bristle house broom, leaving the whole surface smooth and uniform. The finished surface should be protected from the weather by frequent sprinklings and by the addition of a thin layer of sand or dirt, which should be dampened, applied to the top of the pavement after the first set has taken place.

A barrier should be erected to prevent traffic from entering upon the work, as any trespass at this time means a sacrifice of the paving. Once the grout has broken it never can mend. Watchmen should be provided for 24 hours per day, if necessary.

The application of the bituminous mastic grout follows along practically the same lines as the cement grout, the bitumen being heated in kettles and the sand-heating plants or over pipe heaters. After the bitumen has been drawn into wheel-barrows, the hot sand is added, the two ingredients mixed with a steel squeegee and the mass then dumped upon the pavement, running down into the joints, as much as possible of the mastic being squeegeed from the top of the blocks while it is hot.

MAINTENANCE COST LOW.

While the initial cost of granite block construction is high the maintenance of the pavement, if properly laid and grouted, is less than that of almost any other type of pavement. In the city of Worcester, Mass., over a period of ten years the average cost per yard was $0.00415. This also is true in other cities regardless of the fact that in general the streets covered with granite block paving are those carrying the most severe traffic of any. And in considering maintenance cost it should be in connection with the amount of traffic.

City of Worcester, Mass., statistics on granite block paving (new blocks on concrete foundation with joints and surface grouted with cement).

MAINTENANCE COST FOR 10 YEARS ENDING NOV. 30, 1918.

Year.	Maintenance cost.	Yardage existing in city at date indicated.	Cost per yard.
1918	$738.72	261,048.6	$0.0028
1917	2,563.03	255,934.8	.01001
1916	910.62	252,270.2	.0036
1915	806.33	265,246.6	.00303
1914	857.30	237,292.0	.0036
1913	1,091.66	229,313.3	.0047
1912	406.87	219,868.3	.0018
1911	1,167.66	185,402.5	.0062
1910	806.90	160,025.6	.0050
1909	29.63	33,805.9	.0008
	[1] 9,378.72	....	[2] .0415

[1] Divided by 10=$937.87 average maintenance.
[2] Divided by 10=$0.00415 average cost per yard for maintenance per year.

GROUT MIXED BY MACHINE TO PROPER CONSISTENCY TO FLOW READILY TO BOTTOM OF JOINTS.

Usually in connection with different types of permanent pavements, if the workmanship and materials be right, very little trouble occurs so far as defects are concerned, but defects sometimes occur and their causes are enumerated.

CAUSES OF DEFECTS.

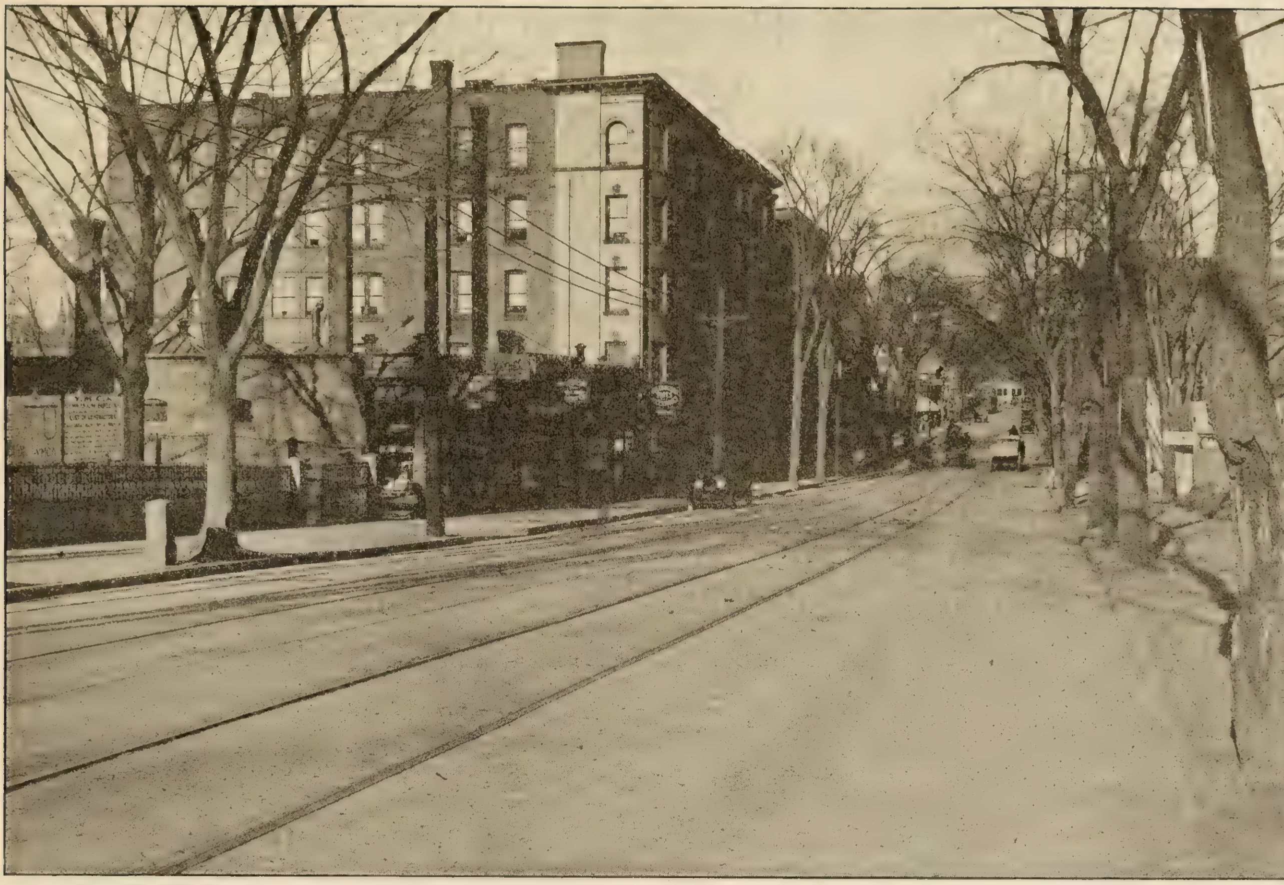
One of the defects most common is that occurring through the fact that the contractor has filled the joints nearly to the top with either sand or pea stone. Consequently, when the grout filler is applied it does not work down more than a short distance below the top of the block. The result is that the block is held in suspension by a narrow collar of grout around the top and around the bottom by pea stone or sand. The impact of travel on the top of the block drives the center of the block down, breaking the entire surface of the block away from the main block itself.

Difficulty usually is experienced where an excess amount of sand is used in the cushion course. In this case the excess depth of sand cushion in the bed seems to shift under the impact of travel and to compress more than the ramming of the blocks compressed it, in this way causing a slight settlement which is followed by the breaking down in the joints; although the blocks themselves do not break up in the same manner as when the narrow collar of grout is around the top. This difficulty, naturally, is more or less eliminated by the use of the 1 to 3 or 1 to 4 mortar cushion in place of the straight sand cushion.

Improper ramming is another cause of defects. When the blocks are not rammed home to a true bedding spaces are left underneath, affording the sand cushion a chance to shift its position after the pavement has been constructed and causing the joints to break down.

METHOD OF MIXING GROUT.

It has been proven by observation and by actual services that the 1 to 1 cement grout makes the most ideal joint filler so far as durability is concerned and a great many of the difficulties with granite block paving occur through the fact that a weaker grout than a 1 to 1 has been used in the construction. There are two methods in common use for mixing the cement grout joint filler. One is the hand-mixing method, using a box either tilted to one end or tilted to one corner, having a gate in the lower end which can be raised when the grout is mixed thoroughly. It is absolutely necessary, if proper work is to be accomplished, that the cement and sand shall be thoroughly mixed together first, and after the water has been incorporated that the entire mass be agitated constantly so that the sand will be



GRANITE BLOCK, GROUTED WITH 1 TO 1 CEMENT GROUT, WORN SMOOTH BY TRAFFIC.

afforded no opportunity for settling at the bottom, as the cement is lighter in suspension, and so that there should be in the mixture no lumps which would clog the joints.

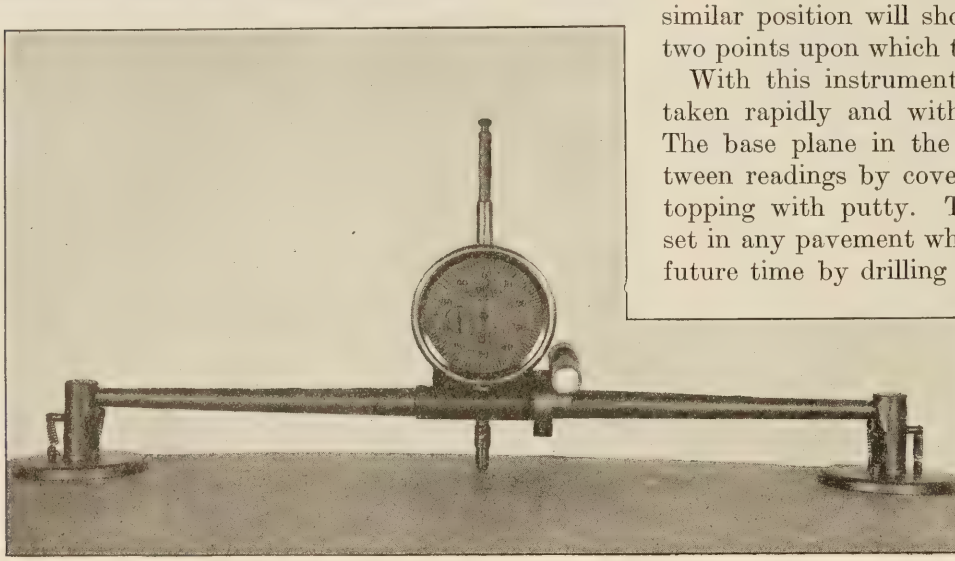
The other method of mixing is by machine. There are a number of different types of machines for this purpose, but all machine mixing in general is an improvement over the hand mixing method, owing to the fact that it keeps the grout much better agitated. There is more chance to obtain poor work through improper mixtures of the cement grout than through improper mixtures in the bituminous mastic grout for the reason that whereas it is extremely easy to mix any proportion of cement and sand together up to about 1 part cement and 5 parts of sand and agitate sufficiently so that it can be poured into the joints, filling them easily; it is much more difficult to incorporate sand in the bitumen in excess and get it to run into the paving joints, for the reason that any proportion more than that of equal parts of sand and bitumen becomes so stiff that it is incorporated with difficulty in the joints and easily shows to the eye that the proper proportions have not been used in the mix.

Hardly any paving material outside of old worn-out macadam roadways lends itself to salvage to such an extent as granite block. Old blocks transported to Southern ports many years ago if recut into granite blocks now would more than cover the street areas where they are. The same is true of most of the old-style large blocks which were used in the earlier days of block production. In this case the method pursued would be to trace a line across the center of the block, the block then being struck a sharp blow on the opposite side it breaks in two, forming two blocks nearly of the standard size, which could be used with the new face turned up, forming a new, fresh granite surface built of old blocks napped in the manner described. If the blocks are cobbled on top through excessive wear they can be recut or trimmed on the sides, eliminating the cobbled effect, and still making use of practically the entire block. If the blocks are not suitable for napping or recutting, there is still another salvage value, for they may be cut into small Durax cubes so that regardless of the length of time they have been in service there is a salvage value until they are completely worn out or broken up.

INSTRUMENT FOR MEASURING WEAR OF CONCRETE AND OTHER SURFACES.

By W. E. Rosengarten, Highway Engineer, Bureau of Public Roads.

THE design of our highways is becoming more and more an exact science and detailed data on various phases is urgently needed. A factor which should be known to intelligently decide on a particular material or method of construction is the life of the resulting pavement. One of the important elements in determing this is the rate of wear of the road surface.

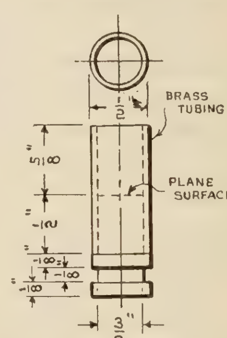


An attempt has been made to measure the wear caused by traffic. The instrument shown in the accompanying illustration was designed and made in the Research Division of the Bureau of Public Roads under the direction of A. T. Goldbeck. It consists essentially of two bearing plates each 2 inches in diameter, pivoted on universal joints to a spanner $11\frac{1}{2}$ inches long. At the midpoint is mounted a micrometer, whose plunger has a travel of 1 inch, and whose dial is graduated to read to 1/1000 of an inch. A level bubble indicates when the plunger is vertical.

In order to form a base to which measurements can be referred from year to year, brass plugs, as shown in the accompanying sketch, are set in the pavement where readings are desired. Readings are taken by resting the bearing plates on the road surface and allowing the spindle or plunger to rest on the base plane of the plug. The instrument is plumbed with the aid of the level bubble, the spanner bar being held parallel to the center line of the road. Another set may be taken with the bar at right angles to the center line of the road. Additional sets may also be taken if desired by placing the bar at other angles with the center line of the road. The difference in readings taken in later years in a similar position will show the average wear at the two points upon which the bearing plates rest.

With this instrument accurate readings may be taken rapidly and without interruption to traffic. The base plane in the pavement is protected between readings by covering with cotton waste and topping with putty. The brass plugs are readily set in any pavement while it is being laid or at any future time by drilling as small hole with star drills and setting the plug in cement grout. The purpose of the groove near the base of the plug is to give a good bond with the pavement. These plugs do not affect the pavement, are not injured by traffic and may be set in a concrete pavement at the rate of 30 or 40 per man per day.

Readings on the wear of concrete road surfaces are being taken on the Chevy Chase Lake Road, Montgomery County, Md., and the Camp Humphreys Road, Alexandria County, Va. Five plugs are set across the road at a section. It is hoped to determine from these and other readings the relation between wear caused by traffic and the per cent of grade, the compressive strength of the concrete, the kind of aggregate, the method and type of construction, etc. It is proposed to start readings on other projects so that considerable data may be collected not only on concrete but on brick, macadam and other classes of road surfaces. Detailed blue prints of the instrument will be gladly furnished to anyone applying to the Bureau of Public Roads, Washington, D. C.



BASE PLUG
Brass

CONSTRUCTING PENNSYLVANIA FEDERAL AID PROJECT NO. 12.

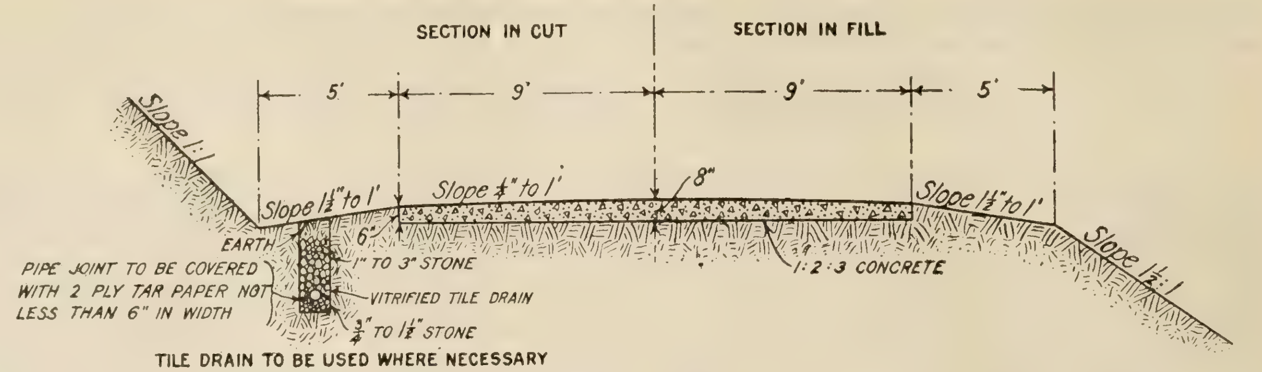
ROAD RELOCATION TO ELIMINATE GRADE CROSSING.

In order to secure the high standard of excellence which is the desire of all who are dealing with Federal Aid Highways, the highest standards should prevail at all stages in the development of every project. This implies high standards in location, and in design as well as in methods of construction and it is possible that from this description of the work done by the Pennsylvania State highway department, on project No. 12, highway engineers may devise some material benefit.

LOCATION.

This project is located between Marten's Creek and the Bangor Boro line, Northampton County, Pa., and is 5.45 miles in length. In general the location follows an old right of way between these two points but the original alignment has been greatly improved, sharp curves eliminated, reasonably long tangents introduced and, wherever the alignment required, entirely new locations selected. Two of these new locations are significant of the advanced ideas now prevailing in highway design. The first shows the new location in the foreground and the old road in the distance, the railroad lying between. This relocation was made for the purpose of eliminating two grade crossings, a most important matter in modern highway location. The new location takes advantage of a high railroad crossing over a small creek, at which point it passes under the company's rails. This appears to be an excellent solution of the problem of grade crossing elimination and one which could be adopted more frequently.

The second significant relocation is one made to save distance as well as to improve alignment. Hard surface pavements are expensive. On this highway, the surfacing alone costs $6 per lineal foot of highway. Where such costly pavements are used, savings in distance may be rather expensive as to excavation and as to right of way costs and still show material net savings in total cost owing to the high value of the paving which is eliminated. A slate hill had to be cut away in order to make one of the relocations and the cover illustration shows the general nature of the country traversed but even under such adverse conditions as these,



TYPICAL SECTION
PENNSYLVANIA FEDERAL AID PROJECT NO. 12

extensive changes in alignment are justified if the saving in pavement cost which results is greater than the cost of the increased earthwork. The new location used on this project is clearly shown by the loose rock which has been drilled and blasted and now lies ready for the shovel.

Other important features in the location of this road might be mentioned but aside from a statement that great care has been exercised to secure the proper adaptation of the line to local drainage features, they need no special mention in this connection.

DESIGN.

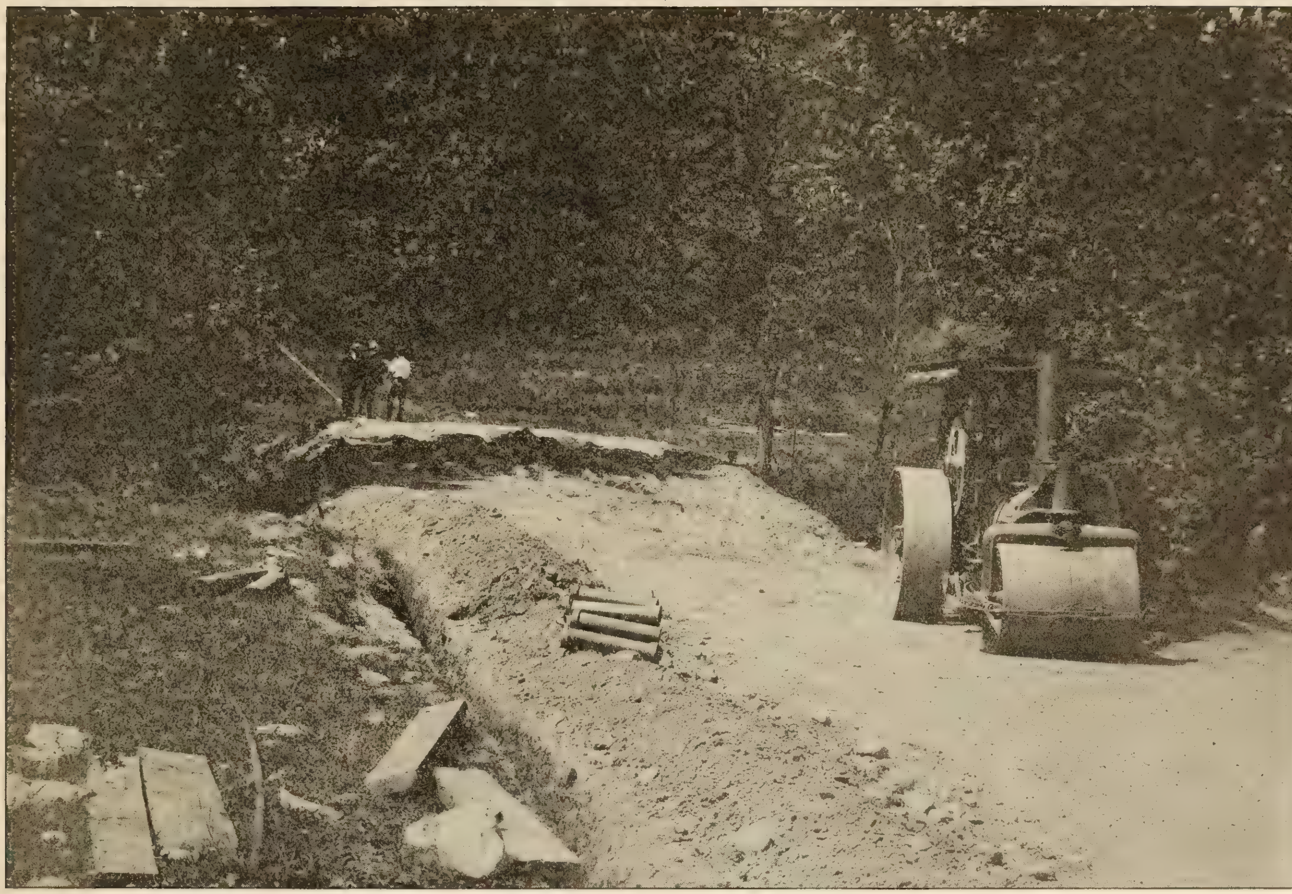
It is no idle remark to state that the design of a road begins with its location, and this was the case with the design of this highway. However, to treat the subject in more ordinary fashion, the salient features, particularly those not common to highway design generally, will be considered as matters of design rather than as a combination of location and design.

The first of these features is the use of short uniform gradients, frequent breaks in grade, and long vertical curves. In laying the grade line, highway engineers quite generally use long uniform gradients and short, vertical curves, an evident adaptation from railroad engineering which, almost always, results in producing heavy excavations and heavy embankments. In refreshing contrast with this custom as to laying in the grade line one finds, on this project, every evidence of a distinct effort to reduce both the cuts and the fills to a minimum by a careful and well thought out policy as to maximum grades coupled with the use of short uniform gradients, frequent breaks in grade, and vertical curves fitted to the original ground surface. In so proceeding there is evident not only the idea of effecting a valuable saving in earth work, but also of adhering to a cross-section which has in it a minimum of the element of danger to rapidly moving traffic.

The adjustment of the grade line on this project has also been influenced by the fact that, speaking generally, hard surface pavements have given more trouble on deep fills and deep cuts than where the original ground surface has been only slightly disturbed. This subject would by itself admit of extended discussion, but it is sufficient to mention it in this connection, and to note that the evidence so far produced justifies the impression that, aside from such work as is necessary to keep within whatever maximum grade has been established, on this project 6 per cent, the less cutting there is done the better both from the standpoint of the safety of the pavement and of the traffic passing over it.

The cross section adopted may also be worthy of careful study. It is the ditchless cross section and is advocated by those who have a keen appreciation of the element of danger to fast moving traffic which is found in the more common cross sections a major feature of most of which is a heavy ditch. Extensive tile drainage and careful maintenance are the two factors that control the effectiveness of this section, and both are adequately provided for in this State.

The dimensions of the concrete surfacing deserves a word of comment. It now is generally recognized that an 18-foot width of surfacing is the standard for two-way traffic. The fact, however, that this highway is located in a country district where the present traffic is light and the prospective traffic not by any means heavy, when coupled with the fact that this width has been adopted indicates the farsighted policy which is at the basis of highway design in this State. The same may be said as to the thickness of the surfacing and as to the mix, an 8-inch (center) concrete pavement of a 1–2–3 mix being indicative of a keen appreciation of the traffic which all pavements must ultimately carry.



ROLLING THE SUBGRADE.

CONSTRUCTION.

The construction of this highway was let for approximately $320,000. Work was begun immediately upon letting and is progressing favorably.

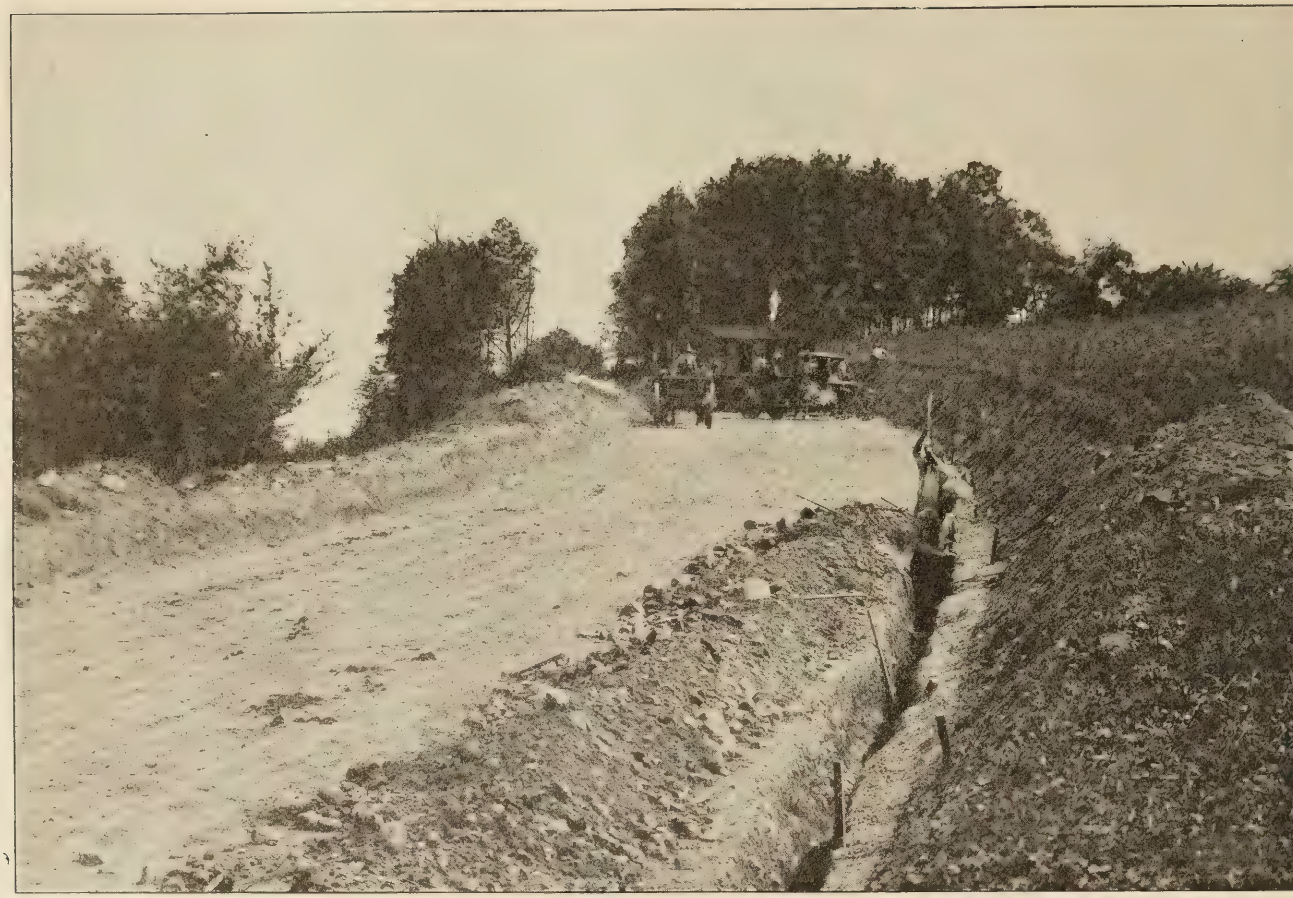
The first impression that one obtains on viewing this project is of the effective use which is being made of modern machinery throughout the job. Light jack-hammer drills are in use wherever rock is encountered. A steam shovel handles all earthwork, the earth being taken out with unusual accuracy. Not a dollar is lost by inaccurate cutting which must, later on, be shaped up and realigned. This is of no little importance, for carelessness in taking out earthwork with consequent alterations and readjustments of slopes, all of which must be done by hand, are a common cause of serious loss to road contractors.

The specifications for this project require that the fill shall be rolled in layers. All of the features illustrated the use of modern machinery in modern highway construction with the consequent elimination of human labor. Still though there are good machines at work on all phases of this work there is no surplus equipment. Every piece of equipment is in the right place, and is being used in the right way. No money has been squandered on needless machinery.

HANDLING OF MATERIALS.

But in spite of the efficiency with which other parts of the work are being conducted the most radical and the most interesting departure from customary procedure is in the handling of the materials for the concrete itself. These materials are delivered by rail on the siding. They are unloaded by a locomotive crane which operates a clamshell bucket, and dumped onto the material piles which lie over the hoppers. A light industrial track, laid on a gravity grade, runs under these hoppers, which are so built that six buckets can be loaded at once, the operation being carried on as follows:

The engine delivers a train at the top of the gravity track. Six cars are then cut loose and moved by hand so that the first bucket of each is under its stone hopper. The hopper is then opened and stone compartment of the first bucket on the car is filled. The 6 cars are then moved forward till the second bucket comes under the chutes and the stone compartments in these buckets are filled. The 6 cars are then shoved forward and placed under the 6 sand chutes. In two operations the 12 sand compartments are filled and the cars are then pushed on to the 3 cement chutes where the cement compartments are filled. The whole



MAKING LOW COSTS WITH PROPER MACHINERY AND CAREFUL WORK. NOTE ACCURACY OF SIDE SLOPES, AND EXCAVATION FOR TILE DRAINS.

operation uses 9 men and filling 6 cars (12 full charges for the mixer) takes about five minutes.

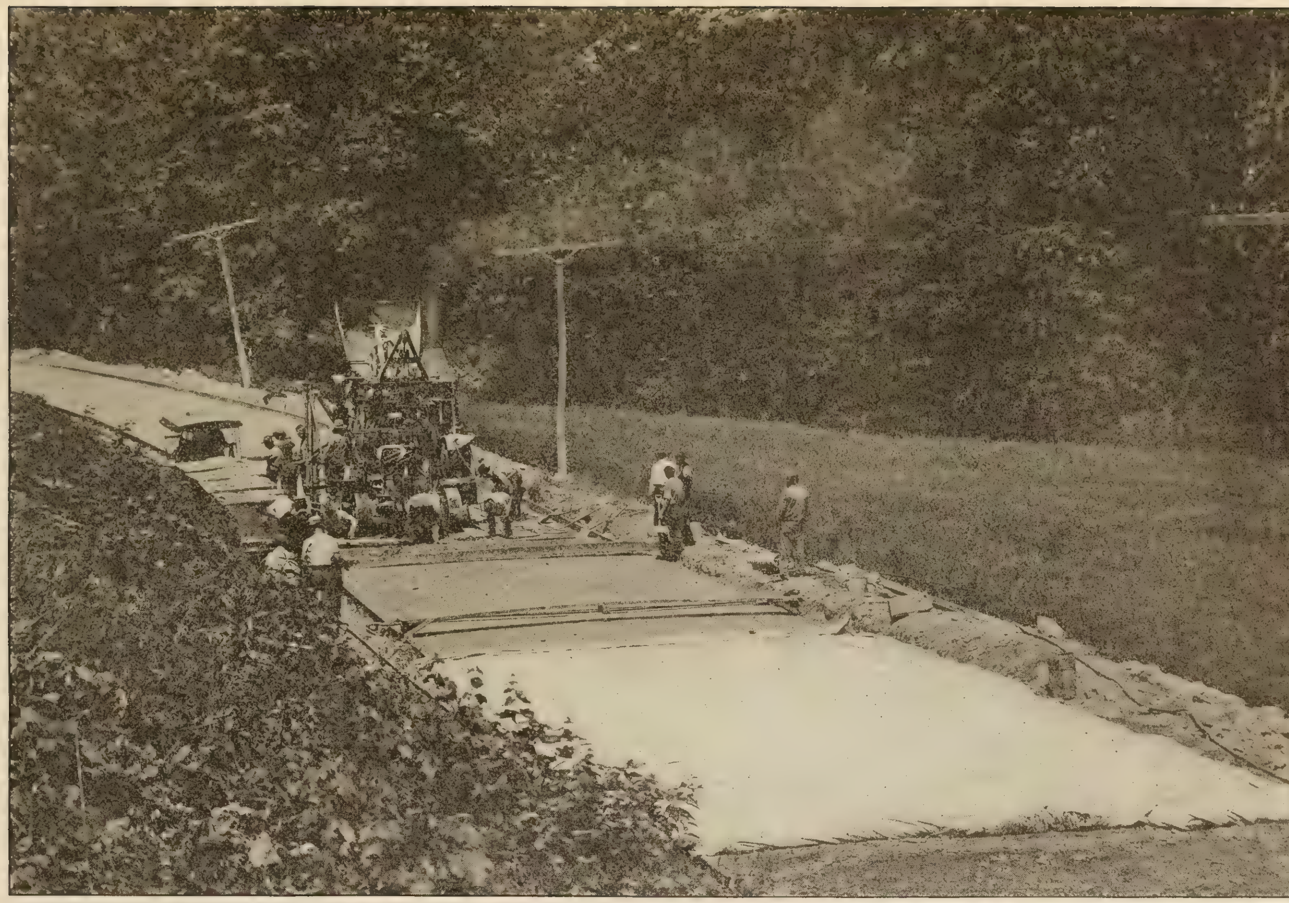
In the meantime the engine has picked up another string of the cars, this string having been loaded while the engine was at the mixer, and starts for the mixer. Near the mixer there is a switch where this train lies till the mixer has handled the material delivered to it by the alternate train. When this alternate train pulls out, the first train pulls in with its load and lies at the mixer until its load is used up. In this way two engines handling three strings of cars can keep a large mixer operating at full capacity up to a distance of about 6 miles between mixer and loading bins and on a good track can be operated over grades of 6 to 8 per cent.

A general view of the plant in operation and the small number of men engaged around the mixer can not but impress everyone familiar with concrete pavement construction. This cut also gives a splendid view of the proper protection of recently placed concrete, the earth-covered pavement appearing in the immediate foreground with the canvas-covered slab, just laid, immediately beyond.

By handling materials in this way something over 400 feet of pavement is being laid per day, and while the economies which this plant develops must be the great argument for its more general adoption, the fact remains that, from the standpoint of the technical expert, the entire absence of any disturbance of the prepared subgrade, and the entire absence of those rehandling processes which are so apt to more or less contaminate the aggregate by the inclusion of earthy material, will present themselves as very potent reasons for the more general adoption of such systems as this for delivering the materials used in concrete road construction.

INDEPENDENT OF WEATHER CONDITIONS.

Another important consideration which should influence the more frequent selection of this system of handling materials is the fact that it is almost entirely independent of weather conditions. Road improvements, even those involving the use of a high type of surfacing on a general route formerly covered by a gravel or a macadam surface, involve enough widening, reshaping, and realigning of the subgrade so that the movement of materials has to be stopped not only during rain storms, but for a considerable period thereafter. A moist subgrade is not, however, any hindrance to the actual laying of the pavement itself. Therefore, except during the time when rain is actually falling, this outfit can be operated to the capacity of the mixer, and the average rate of progress made is therefore high.



GENERAL VIEW OF PLANT IN OPERATION. NOTE METHOD OF COVERING CONCRETE.

The extent to which labor has been saved on this project has nowhere been better illustrated than in obtaining a feed water supply for the locomotive crane which unloads the aggregate. To provide the necessary water an old tank wagon was mounted on a platform, a hydraulic ram set in a nearby creek, and the two connected by a pipe line. Since that day, and without further attention, this makeshift tank has never been short of water. It is by such savings as this that construction jobs are made to show a profit.

The proof of the advantage of any method of construction lies in the results secured. On this job the layout in plant is not excessive; indeed it is rather below the average for jobs of this size. However, since concreting began the mixing plant has worked 30 days out of 31 working days (data to Aug. 15), has averaged 240 feet of 1–2–3 concrete pavement 18 feet wide and an average of 7.33 inches thick per day with a force of 8 men on the mixer, 6 men on the material piles, and 4 men on the trains. This compares very favorably with the personnel usually required to accomplish this amount of work. Those who wish to use these figures for making comparisons with the personnel on other oing jobs will, of course, remember that the men on the trains and at the storage piles are not a part of the mixer crew, but correspond to the personnel engaged in delivering material on other jobs.

CITY CONTRIBUTES FOR ROADS.

The New York Commission of Highways let a contract in August for constructing a highway 4.03 miles connecting the village of Carrollton, Cattaraugus County, with the city of Bradford, Pa. Thi road will cost $153,344.

In order to insure the building of the road connecting the New York town with Pennsylvania the Bradford Chamber of Commerce raised $90,000 as the city's share of the cost, establishing a unique precedent in financing highways connecting two States. The road will be of concrete and will cost about $33,300 a mile.

Commissioner Greene of New York obtained the consent of Secretary of Agriculture Houston for the road to cross the Allegany Indian Reservation. The Secretary also approved changes in the original plans which eliminated three grade crossings, saving to the State of New York $70,000. When the road is completed the citizens of Bradford will hold a celebration.

WHAT FROST DOES TO CONCRETE.

As cold weather approaches the problem of so laying concrete pavement that it will not freeze becomes a serious one. The above illustration shows the result of laying a concrete base in such cold weather that the methods adopted for its protection failed and the concrete froze. It became necessary to build a new base and integral curb over the old one.

It sometimes happens that concrete roads must be laid during cold weather, but the practice is always attended with risk and should be avoided unless most urgent necessity requires immediate construction in spite of weather conditions. It is better to stop laying concrete a little early than to stop a little late.

ROAD BONDS IN MISSOURI.

Missouri counties which have voted road bonds, which are to hold bond elections or in which bond issues are being agitated include the following: Greene, $2,000,000; Laclede, $250,000; Texas, $225,000; Howell, $500,000; Jasper, $250,000; St. Francis, $1,000,000; Franklin, $1,000,000; St. Louis, $3,000,000; Phelps, $400,000; Warren, $400,000; Dunkin, $23,000; Butler, $500,000; Buchanan, $2,000,000; Scott, $1,000,000; Oregon, $300,000; Stoddard, $200,000; Ripley, $120,000; Wayne, $30,000; Gentry, $100,000; Clay, $100,000; Harrison, $113,000; Cole, $300,000; Livingston, $1, 250, 000; Atchison, $1,000,000; Andrew, $1,250,000; DeKalb, $1,250,000; Clinton, $1,250,000; Ray, $1,250,000; Nodaway, $2,000,000; Daviess, $1,000,000; Carroll, $1,100,000; Sullivan, $1,000,000; Putnam, $750,000; Marion, $1,500,000; Adair, $750,000.

Special road districts throughout the State have also voted large amounts of bonds.

OREGON ROAD BUILDING.

During the first seven months of this year the state highway commission of Oregon spent $1,714,343. Contracts have been awarded for more than 1,000 miles of road, at an estimated total cost of $16,903,361. These roads, including work on 20 different highways, will be made up of 370.1 miles of paving, 193.8 miles of macadam, and 528.6 miles of graded roads.

BIG ROAD PROJECTS INCLUDED IN JULY AND AUGUST APPROVALS.

FEATURES of the Federal-aid record in both July and August were three road projects to cost over $1,000,000, one of them over $2,600,000, and the large total amount of improvements covered by the projects submitted in several States.

In both July and August the number of Federal-aid projects approved showed a decline from the high record set in June, and there was a decrease in both the estimated cost of the roads and the Federal aid allowed.

The falling off does not indicate any decrease in the road-building activities throughout the country. The June business was probably greatly increased by efforts made by various State highway departments to rush in many projects for approval before the close of the last fiscal year, ending June 30.

There was a decrease in the projects signed by the Secretary in July from the previous month. In August agreements executed showed a large increase over the July figures and were much above those for June. In agreements signed the August figures make a new high record.

Up to and including August 31 the total number of projects approved was 1,583 and the project agreements executed by the Secretary of Agriculture 826. The approvals covered 15,124.82 miles of road, whose estimated cost is $172,248,883.66 and the Federal-aid allowance is $70,800,791.39. The agreements covered 6,908.34 miles, for which Federal aid was allowed to the amount of $32,069,204.81 on an estimated cost of $75,314,016.37.

FEDERAL AID IN JULY.

In July 144 Federal-aid projects were approved, there were 5 revisions, and 6 statements previously approved were withdrawn. Approvals, covered 1,268.07 miles of road, estimated to cost $20,682,523.37, for which the Federal-aid allowances amounts to $7,193,942.85. The withdrawals covered 44.81 miles, with an estimated cost of $129,629.77 and an allowance of $50,700.

During the month 58 agreements for Federal aid were signed by the Secretary of Agriculture, while 15 agreements previously signed were modified, with increases in the amount of Federal aid allowed. These 73 agreements covered 413.045 miles of road, the estimated cost of which is $6,296,370.91 and the Federal aid allowed $2,671,356.46.

In the July projects approved hard-surface roads represented slightly less than one-third of the total mileage. Earth, sand-clay, gravel and macadam roads aggregated over 800 miles.

PENNSYLVANIA'S PROJECTS.

Pennsylvania occupied first place in the record of statements approved during July in number and in the amount of Federal-aid allowance and in the estimated cost of the roads to be constructed, while Nebraska turned in the greatest mileage. Seventeen projects in Pennsylvania approved will cost $4,607,028.41, for which the Federal aid is $1,968,997.40.

Ohio with 12 projects came next to Pennsylvania in the number approved and in the estimated cost of the roads to be improved and third in the amount of Federal aid. The figures are, respectively, $1,959,691.12 and $615,800. Oklahoma's two projects occupy third place in the estimated cost of the roads and second in the amount of Federal-aid allowance. The cost is estimated at $1,771,555.64 and the amount of Federal aid, $850,000. Washington with 10 projects is the only other State whose estimated cost exceeds $1,000,000 for the month. On a mileage of 57.498 the aggregate cost is estimated at $1,215,433.36 and the Federal aid $607,761.65. Indiana with 2 approvals and 2 revised projects, with an aggregate mileage of 25.92, fell just below the million-dollar mark in the estimated cost of roads, $940,876.81, for which the Federal-aid allowance is $464,612.19.

In Indiana the ratio of Federal aid requested and allowed was a little over 25 per cent of the cost of the roads, in Ohio less than 35 per cent, in Pennsylvania slightly more than 40 per cent, in Oklahoma almost 50 per cent, while in Washington it was exactly 50 per cent.

Nebraska, which was third in the number of projects approved, 11, has the greatest aggregate mileage, 233.20. Minnesota's 7 approvals aggregated 121.66 miles. Seven new projects approved and one revision in Texas aggregated 100.5 miles. One of the Nebraska projects is 56.9 miles long and another one 30.6 miles. A single project in Oklahoma was for 46.158 miles, a Minnesota project 38.5, and a Texas project 30. The average length of all projects approved during the month was 8.806 miles.

OKLAHOMA'S BIG PROJECT.

Oklahoma leads the country in the size of a single project handled in July. It is estimated to cost $1,271,555.60, for which $600,000 Federal aid is allowed. It is for 46.158 miles of concrete or bituminous road in Tulsa County. The third largest project is also an Oklahoma road—20 miles of concrete in Washington County, to cost $500,000, with Federal aid of $250,000. The second largest project is 13.24 miles of bituminous or concrete in Lackawanna and Wyoming counties, Pennsylvania, for which $304,616 Federal aid is allowed on an estimated cost of $609,232.80. Other projects costing large sums approved during the month include one for 7.14 miles of brick or concrete in Somerset County, Pa., to cost $457,065.50 and Federal aid to the amount of $147,071; and 6 miles of bituminous, brick, or concrete in Hamilton County, Ohio, with an estimated cost of $423,066.60 and Federal aid, $120,000.

SOME HIGH GRADE ROADS.

On a Massachusetts project, a short concrete road, the estimated cost is at the rate of $127,864 a mile. This is the highest average cost per mile so far shown in a Federal-aid road. A bituminous, brick or concrete road in Ohio will average $67,716 a mile and the 7.14 miles of concrete or brick in Pennsylvania mentioned will average $64,015. Another project in Pennsylvania will average $56,443 a mile.

In States in which the projects are all for brick, concrete, asphalt, or bituminous roads the average estimated cost is: Pennsylvania, $47,885; Maryland, $45,288.75; Ohio, $35,992; and Oklahoma, $26,779.

In the agreements executed Kansas leads in the estimated cost of roads and also in the amount of Federal-aid allowed. Two agreements in that State signed in July were for 29.578 miles of road, estimated to cost $1,302,451.12, with an allowance of $443,700 Federal aid. For a single project in Pennsylvania for which an agreement was signed and a modification of an agreement previously signed the estimated cost is $491,998.72 and the Federal aid $208,121.35. No other State received as much as $200,000 of Federal aid, though both New Jersey and Virginia approached that amount. The former received $192,175.92 for 3 projects estimated to cost $458,148.28, and the latter $190,847.22 for 4 projects to cost $334,102.64.

AUGUST APPROVALS AND AGREEMENTS.

In August 112 Federal-aid projects approved were for 1,246.92 miles of road, estimated to cost $18,238,303.19, for which the Federal-aid allowance is $7,171,784.84.

There were 81 agreements executed during the month and modifications of 20 previously executed. The mileage amounted to 697.59, the estimated cost was $12,159,034.77 and the amount of Federal aid allowed $5,190,791.15.

In the record of approvals for the month, Arkansas occupies first place in the estimated cost and mileage of projects and in the largest project. Minnesota is first in the total number of projects approved (11), and second in the amount of Federal-aid allowance. Pennsylvania received the largest amount of Federal aid and her six approved projects come second in the estimated cost of the roads.

BIG ARKANSAS PROJECT.

Arkansas had four projects approved, whose estimated cost is $3,166,338.93, and Federal aid requested of $475,000. Project No. 24, that State, is for 152.99 miles of asphalt and macadam road running from Grady to the Louisiana State line through Ashley, Desha, Drew, Chicot, and Lincoln Counties. It is estimated to cost $2,684,177.10, and a Federal-aid allowance of $332,000 is made for it. It is a part of the Arkansas-Louisiana highway.

Two other approvals in August were for projects whose estimated cost is in excess of $1,000,000. Project No. 9, Indiana is, for 40 miles of concrete, brick, or asphalt road in Johnson and Bartholomew Counties, estimated to cost $1,353,330, or $33,830 a mile. The Federal-aid allowance is $676,000, the largest made to a single project during the month. Project No. 30, Kansas, is estimated to cost $1,131,539.20, and calls for $306,750 Federal aid. It is for 20.45 miles of brick or concrete road in Lyon County, Kans. The cost per mile is $55,330.

In addition to Arkansas, project approvals for four States amounted to over $1,000,000. The estimated cost of the 33.41 miles of Pennsylvania projects approved is $1,786,103, an average cost of $53,430 a mile. The Federal-aid allowance is $702,782. Indiana's cost is next, for the single project already mentioned. The 11 projects in Minnesota aggregate 77.86 miles, are estimated to cost $1,188,080.86, and will receive a Federal-aid allowance of $604,536.76. Kansas follows with the estimated cost of $1,131,539.30 for her one approved project.

In the estimated cost of roads and the amount of Federal aid allotted for the projects executed by the Secretary of Agriculture during August Pennsylvania leads. Ten projects with an aggregate length of 53.98 miles are estimated to cost $2,477,483.78 and will receive $1,101,339.84 in Federal aid.

Fourteen Ohio projects aggregate 55.227 miles, have an estimated cost of $2,051,799.80 and a Federal-aid allowance of $704,650.

The estimated cost of the 85.06 miles of agreements for California projects is $1,372,644.56 and the Federal-aid allowance is $686,322.27.

FEDERAL AID PROJECT APPROVALS AND AGREEMENTS FOR JULY, 1919.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement executed.	Estimated cost.	Federal aid.
Alabama	12	Lowndes	[1] 2.51		July 22		[1] $15,737.12	[1] $7,868.56
	44	Dale	.625	Concrete		July 23	67,845.25	32,982.12
	45	do	7.90	Sand-clay		July 19	45,750.54	22,875.27
	58	Jefferson	3.15	Earth	July 7		19,882.50	9,941.25
	59	do	5.00	Concrete	do		173,415.00	86,707.50
	60	Monroe	9.26	Gravel	July 22		21,127.49	10,563.74
	61	Crenshaw	11.113	Sand-clay	do		31,977.27	15,988.63
Arizona	9	Pima	3.79	Concrete or bituminous	do		122,445.48	61,222.74
	10	Maricopa		Bridge	July 29		40,000.00	20,000.00
	14	Cochise	23.32	Earth	July 28		173,958.40	86,979.20
Arkansas	1	Carroll		Gravel		July 14	[2] 16,991.38	[2] 8,495.86
	17	Craighead	5.81	Macadam		July 2	69,509.55	10,000.00
	18	Benton		Gravel		July 14	[2] 17,736.28	[2] 8,868.14
	23	Jackson	8.85	do	July 10		86,416.88	40,000.00
	25	Jefferson	9.47	Bituminous	July 31		40,331.50	20,000.00
Colorado	12	Weld	.89	Concrete or bituminous		July 22	20,973.96	10,486.98
	13	Boulder	.417	Concrete	July 29		10,468.81	5,234.40
	14	do	.504	do	July 25		20,780.73	10,390.36
	16	Morgan	.45	Concrete or bituminous		July 29	10,996.97	5,498.48
Florida	16	De Soto	.67	Concrete		July 26	11,798.80	5,899.40
Georgia	1	Clayton, Henry, Pike, Spaulding, Monroe.		Sand-clay or top soil		July 11	[2] 158,078.80	[2] 79,456.92
	8	Montgomery, Wheeler		Bridge		July 19	[2] 44,915.57	[2] 22,457.79
	18	Dooley		Sand-clay		July 11	[2] 3,329.75	[2] 3,734.45
	76	Wheeler	10.30	do	July 18		78,908.50	39,454.25
Idaho	10	Elmore	12.50	Gravel	July 29		95,502.85	47,901.42
	13	Canyon and Owyhee		Bridge	July 7		89,980.00	44,990.00
	14	Bonneville	6.00	Gravel	July 11		51,533.68	25,776.84
	15	Bannock	8.92	Macadam	July 15		75,000.00	37,500.00
	17	do	9.00	Gravel and macadam	July 21		69,999.25	33,999.62
Illinois	3	Will	[1] 19.00	Brick	July 2		[1] 592,592.50	[1] 325,538.10
Indiana	3	Marion, Johnson	[1] 6.26	Brick, concrete, or bituminous	July 18		[1] 221,970.00	[1] 14,500.00
	7	Marion	6.10	do	do		230,843.00	50,000.00
	8	Hamilton, Marion	[1] 4.76	do	do		[1] 171,150.00	[1] 15,750.00
	12	Jackson	8.80	do	July 22		343,380.00	171,690.00
Iowa	46	Pottawatomie	2.65	Earth	July 21		24,310.00	12,155.00
Kansas	15	Reno	17.57			July 1	729,496.74	263,580.00
	24	Sedgwick	12.008	Brick		July 14	592,954.37	180,120.00
Kentucky	2A	Fayette	6.383			June 30	[3] 200,000.00	[3] 100,000.00
Louisiana	15	Avoyelles		Gravel		July 2	[2] 1,660.97	[2] 5,348.82
	35	Jefferson Davis	7.50	Sand-clay or gravel		July 11	64,589.66	32,294.83
	39	Concordia	18.10	Gravel	July 29		200,226.40	100,113.20
	40	Tensas	3.03	do	July 21		23,777.05	11,888.52
	42	Jefferson	13.58	do	July 25		135,493.09	62,746.54
Maryland	6B	Prince Georges, Howard, Baltimore.		Concrete		July 28	[2] 2,475.00	[2] 1,327.49
	28	Anne Arundel	10.50	do	July 29		506,000.00	210,000.00
	33	Carroll	5.77	do	do		230,848.75	115,400.00
Massachusetts	9	Essex	3.122	Bituminous macadam		July 11	130,944.55	65,472.27
	14	Barnstable	3.345	Bituminous	July 29		52,037.15	26,018.57
	15	Plymouth	4.38	Concrete	do		121,328.90	60,664.45
	23	Berkshire	2.123	do	July 26		62,185.75	31,092.87
	24	Bristol	2.756	Bituminous	July 28		39,055.50	19,527.75
	25	Middlesex	.578	Concrete	do		73,906.79	36,359.08
Minnesota	17	Carlton	8.59	Gravel		July 1	34,666.64	17,333.32
	26	Todd	4.80	do		July 19	30,537.69	10,000.00
	35	Hennepin	5.86	Concrete, brick, or asphalt		July 9	247,900.00	60,000.00
	38	Mower	24.50	Earth	July 22		145,244.00	72,622.00
	41	Isanti	5.66	Gravel	do		48,481.12	24,240.56
	42	Washington	7.50	do	July 18		65,438.01	25,000.00
	43	Cottonwood	4.07	do	July 7		23,159.63	11,579.81
	44	Sherburne	4.43	Asphalt, brick, or concrete		July 11	136,180.36	67,430.55
	49	Chippewa	15.00	Gravel		July 31	83,066.37	41,533.18
	51	Crow Wing	19.93	do	July 25		108,909.62	54,454.81
	54	Lac qui Parle	38.50	do	July 7		72,111.29	36,055.64
	59	Becker	3.97	do		July 2	21,928.69	10,964.34
	60	Sherburne	6.50	Asphalt, brick, or concrete	July 31		229,141.00	114,570.50
Mississippi	3	Hinds	[4] 3.00		July 1		[4] 13,578.90	[4] 5,000.00
	4	Scott	[4] 5.50		do		[4] 11,165.00	[4] 5,000.00
	8	Perry	[4] 21.00		do		[4] 32,972.00	[4] 10,000.00
	16	Simpson	7.842	Clay-gravel		July 11	44,509.78	22,259.89
	29	Union	17.80	Slag or gravel	July 7		172,245.04	60,000.00
	32	Lee	16.20	Concrete	July 31		312,620.00	125,000.00
	43	George	7.30	Earth	July 10		15,400.00	7,500.00
Missouri	5	Scott	7.19	Gravel		July 1	59,287.55	14,821.89
	10	do	27.44	do		do	211,463.57	52,865.89
	17	Jasper	6.00	Concrete		do	135,684.89	67,842.44
Montana	1	Wibaux	4.74	Gravel		July 2	21,978.33	10,989.16
	20	Missoula	6.87	do		do	21,993.54	10,996.77
	30	Broadwater		Bridge		do	70,836.15	35,418.07
	45	Missoula	[4] 2.50	Macadam	[4] July 10		[4] 11,000.00	[4] 5,500.00
Nebraska	26	Chase and Hayes	15.97	Earth		July 1	51,623.09	25,811.54
	29	Butler		do		do	[2] 4,472.10	[2] 2,236.05
	37	Sherman	11.90	do	July 11		37,455.00	18,727.50
	38	Frontier	12.08	do		July 11	34,481.92	17,240.96
	41	Dundy	12.72	do		July 1	56,036.64	28,018.32
	42	Custer and Loup	18.20	Earth and sand-clay	July 11		52,140.00	26,070.00
	43	Johnson	17.00	Earth	July 6		25,850.00	12,925.00
	51	Franklin and Kearney	30.00	do	July 21		60,995.00	30,497.50
	52	Phelps	16.00	Sand-clay	July 10		45,315.60	22,657.80
	54	Deuel	12.00	Earth	July 15		25,421.00	12,710.50
	59	Wheeler	8.00	Sand-clay	July 11		42,398.40	21,199.20
	62	Thomas	4.80	Earth and sand-clay	July 7		22,330.00	11,165.00
	73	Buffalo	20.40	Earth		July 21	79,431.60	39,715.80
	76	Box Butte and Dawes	56.90	do	July 29		122,100.00	61,050.00
	94	Arthur and Keith	27.80	Sand-clay	July 15		134,349.60	67,174.80
	97	Pawnee	30.60	Earth	July 10		84,150.00	42,075.00
New Hampshire	20	Merrimack and Grafton	1.38	Gravel		July 11	20,487.89	10,243.94
	23	Hillsborough	2.06	do		July 1	29,958.06	14,979.03
	25	Merrimack	1.10	do		July 11	7,864.12	3,932.06
	37	Rockingham	9.666	Bituminous		July 1	195,109.13	97,554.56

[1] Revised statement. Figures given are increases over those in the original statement approved.
[2] Modified agreement. Figures given are increases over those in the original agreement signed.
[3] Should have been included in the June record.
[4] Withdrawn.

FEDERAL AID PROJECT APPROVALS AND AGREEMENTS FOR JULY, 1919—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement executed.	Estimated cost.	Federal aid.
New Hampshire	47	Merrimack and Sullivan	1.33	Gravel	July 27		$17,223.25	$8,611.62
	48	Cheshire	.87	do	July 15		19,152.21	9,576.10
	52	Sullivan and Merrimack	1.27	do	July 26		15,044.15	7,522.07
	56	Cheshire	.945	do	July 21		11,478.83	5,739.41
	58	Grafton	1.51	do	July 15		29,920.00	14,960.00
	64	Rockingham	.77	do	July 18		10,998.08	5,499.04
	65	Hillsborough	1.23	do	July 26		13,111.56	6,555.78
	68	do	1.27	do	July 21		15,128.19	7,564.09
	69	Cheshire and Sullivan	.62	do	July 26		9,775.76	4,887.88
New Jersey	3	Somerset and Middlesex	3.84	Concrete		July 1	207,053.90	76,800.00
	4	Monmouth	1.59	do		do	87,254.64	33,456.05
	11	Atlantic	4.418	do		July 19	163,839.74	81,919.87
	12	do	9.87	do	July 15		385,378.31	192,689.15
	13	Gloucester and Salem	7.238	do	do		317,635.21	144,760.00
New Mexico	15	Dona Ana	11.68	do		July 11	229,246.84	114,623.42
	21	Taos	8.00	Gravel	July 1		96,000.00	48,000.00
North Carolina	16	Haywood		Gravel and sand-clay		July 1		[1] 15,000.00
	25	Person	8.175	Sand-clay	July 31		76,440.43	38,220.21
	28	Lee	[2] 12.05	Gravel	[2] July 17		[2] 27,933.95	[2] 10,000.00
	40	Union	4.287	Sand-clay or gravel		July 9	10,679.51	4,000.00
	41	Watauga	11.60	Gravel	July 7		61,652.41	25,000.00
	46	Beaufort	.73	Concrete	do		24,178.70	12,089.35
	47	Guilford	4.626	Concrete or asphalt	July 31		144,036.86	72,018.43
	48	Northampton	8.60	Sand-clay	July 21		45,815.00	22,907.50
	49	Lenoir	6.017	Asphalt or concrete	July 15		190,833.50	95,416.75
	51	Guilford	2.26	do	July 26		59,118.40	29,559.20
	52	Cabarrus	8.986	Sand-clay or gravel	July 21		96,857.75	48,428.87
	55	Mecklenburg	10.71	Bituminous	July 29		241,943.76	120,991.88
North Dakota	44	Bottineau	4.50	Earth	July 15		20,000.00	10,000.00
	45	Foster	11.10	do	July 21		19,800.00	9,900.00
	51	Grand Forks	1.087	Concrete	July 26		39,605.50	19,802.75
Ohio	40	Medina	4.73	Bituminous or concrete		July 1	153,000.00	75,000.00
	53	Mercer	5.74	Concrete	July 28		166,000.00	61,500.00
	54	do	1.68	do	July 22		51,000.00	16,000.00
	63	Hamilton	2.75	Bituminous, brick, or concrete	July 29		186,221.20	55,000.00
	64	do	6.00	do	July 28		423,066.60	120,000.00
	71	Darke	4.60	Concrete	July 11		162,000.00	45,000.00
	72	do	4.50	do	July 10		141,000.00	45,000.00
	73	do	4.31	do	do		137,000.00	45,000.00
	82	Cuyahoga	2.73	Brick or bituminous	July 11		144,949.00	54,600.00
	83	do	9.76	Bituminous	July 31		163,370.72	81,000.00
	91	Wood	6.74	do	July 11		165,083.60	37,700.00
	92	Crawford	2.36	Brick or bituminous	do		106,000.00	25,000.00
	95	Paulding	3.00	Brick or concrete	July 31		114,000.00	30,000.00
Oklahoma	7	Muskogee	2.50	Bituminous		July 21	84,189.60	42,094.80
	12	Tulsa	46.158	Concrete or bituminous	July 11		1,271,555.64	600,000.00
	15	Washington	20.00	Concrete	July 7		500,000.00	250,000.00
Oregon	9	Baker	4.65	Gravel		July 11	51,224.54	22,612.27
	20	Wasco	11.50	Asphalt or concrete	July 11		285,000.00	117,500.00
Pennsylvania	7	Lawrence		Reinforced concrete		July 2	[1] 54,048.77	[1] 49,800.00
	34	Berks and Schuylkill	7.59	Concrete		July 19	437,949.95	158,321.35
	45	Center	5.29	Concrete or bituminous	July 7		251,425.74	105,800.00
	46	Lancaster	7.137	do	do		292,931.10	142,740.00
	47	Lycoming	7.44	Concrete	July 10		361,452.30	148,800.00
	48	Potter	5.00	Concrete or bituminous	July 7		245,789.15	100,000.00
	49	Dauphin	4.69	Concrete	July 16		197,110.10	93,800.00
	50	Lancaster	4.07	Concrete or bituminous	July 15		193,237.00	81,400.00
	51	McKean	5.96	Concrete or brick	July 16		296,181.60	119,200.00
	52	Northumberland	4.81	Brick, concrete, or bituminous	do		193,247.22	96,200.00
	54	Bucks	2.82	Bituminous or concrete	July 29		110,207.90	55,103.95
	57	Clearfield	2.46	Concrete or brick	do		111,782.00	49,200.00
	59	Lehigh	5.70	do	do		265,482.80	114,000.00
	60	Somerset	7.14	do	do		457,066.50	147,071.00
	61	do	6.06	do	July 31		295,755.90	124,466.45
	62	Sullivan	3.29	Asphalt, brick, or concrete	do		185,697.60	65,800.00
	63	Susquehanna	5.73	Concrete	do		265,433.30	114,600.00
	64	Tioga	5.31	Asphalt, brick, or concrete	do		276,995.40	106,200.00
	66	Lackawanna and Wyoming	13.24	Bituminous or concrete	July 29		609,232.80	304,616.00
South Carolina	7	Horry	20.37	Sand-clay		July 19	63,827.58	31,913.79
	24	Spartanburg	1.83	Asphalt		do	53,146.42	26,573.21
	25	Lexington	23.97	Sand-clay	July 29		67,693.58	20,422.10
	33	Beaufort		Bridge piers	do		13,192.30	6,596.15
South Dakota	10	Clark	16.45	Gravel		July 29	95,136.52	47,586.26
Texas	18	Franklin	12.47	Gravel		July 2	58,920.00	25,000.00
	52	Callahan	22.75	do	July 28		[3] 180,065.72	[3] 49,773.15
	84	Van Zandt	9.889	do	July 11		88,240.22	40,000.00
	85	Freestone	10.30	Gravel or macadam	July 21		154,213.41	37,500.00
	86	Montague	18.00	Gravel	July 29		202,276.93	100,998.87
	91	Taylor	2.998	do	do		13,618.48	4,950.00
	92	Hood	30.00	Gravel and macadam	July 11		208,397.86	70,000.00
	94	Baylor	4.313	Sand-clay	July 29		21,400.15	10,692.22
	95	Red River	2.25	Concrete and gravel	July 21		30,000.00	15,000.00
Utah	27	Cache	10.45	Concrete	July 15		291,280.25	145,640.00
Vermont	11	Chittenden	1.40	Concrete or bituminous	July 7		53,460.00	26,730.00
Virginia	7	Albemarle		Macadam		July 2	[1] 8,262.69	[1] 4,131.34
	9	Chesterfield		Concrete		July 11		[1] 3,908.69
	10	James City and York		do		do		[1] 9,887.22
	29	Princess Anne	2.775	do		July 14	84,360.60	42,180.30
	31	Northampton	1.59	do	July 11		45,991.00	22,995.50
	34	Norfolk	4.59	do		July 1	132,950.40	66,475.20
	36	Halifax	3.42	do		July 11	92,502.85	46,251.42
	39	Buckingham	6.18	Sand-clay	July 29		49,417.50	24,708.75
	41	Alleghany	9.50	Macadam and bituminous	July 15		164,609.50	82,304.75
	42	King George	5.70	Sand-clay		July 12	36,026.10	18,013.05
	46	Rappahannock	7.40	Macadam	July 29		133,210.00	66,605.00
	58	Prince George	11.00	Gravel	July 7		72,820.00	36,410.00
Washington	33	Clarke	4.25	Concrete	July 18		120,899.35	60,494.67
	35	Whitman	21.95	Macadam	do		253,922.51	126,961.25
	36	Clarke	3.32	Concrete	July 18		79,085.05	39,542.52
	37	Douglas	2.79	Macadam	do		25,399.00	12,699.50

[1] Modified agreement. Figures given are increases over those of original agreement.
[2] Withdrawn.
[3] Revised statement. Figures given are increases over the amounts in the original statement.

FEDERAL AID PROJECT APPROVALS AND AGREEMENTS FOR JULY, 1919—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement executed.	Estimated cost.	Federal aid.
Washington	38	Yakima	2.95	Concrete	July 29		$115,123.25	$57,561.62
	39	do	5.31	do	do		170,045.70	85,022.85
	40	Walla Walla	3.788	do	do		139,901.25	69,950.62
	41	Thurston	6.27	Gravel	July 22		108,591.52	54,295.76
	42	Grays Harbor	4.20	Concrete	July 29		119,907.43	59,953.71
	43	do	2.87	do	July 22		82,558.30	41,279.15
West Virginia	31	Lewis	1.25	Brick		July 11	56,500.00	25,000.00
	37	Marion	[1] .76	Concrete	[1] July 11		[1] 32,979.92	[1] 15,200.00
	48	Boone	5.00	Earth		July 18	66,000.00	33,000.00
	49	Marion	1.40	Brick	July 18		50,796.00	25,165.00
	50	Clay	4.50	Earth	July 25		47,170.00	23,575.00
	51	Wayne	3.20	do	do		66,000.00	30,000.00
	52	Hancock	2.00	Brick	July 7		53,250.00	18,300.00
	53	Harrison	2.50	do	July 15		88,265.50	38,000.00
	54	Greenbrier	2.00	Bituminous	do		30,973.80	15,486.90
Wisconsin	22	Polk	13.127	Graded and drained earth		July 21	53,983.04	17,994.34
	28	La Crosse	3.31	Bituminous macadam		July 11	41,771.67	13,923.89
	31	Taylor	10.56	Earth		July 31	34,077.96	11,359.32
	38	Marathon		Gravel		July 2	[2] 8,649.78	[2] 2,883.26
	40	Sheboygan		Bituminous macadam		July 19	[2] 4,045.42	[2] 1,348.47
	55	Door and Kewanie	8.69	Gravel		[3] June 30	[3] 50,950.27	[3] 16,850.09
	67	Monroe	2.82	Earth	July 31		30,446.68	10,148.89
	80	Green	5.407	do		July 15	38,996.94	12,998.98
	87	Buffalo	[2] .70	do	July 22		[4] 20,601.46	[4] 6,903.82
	90	Washburn	4.492	do		July 21	25,998.73	8,666.24
	91	Rusk	6.02	do		July 16	24,018.98	8,006.33
	93	Marquette	4.06	Sand-clay	July 21		25,386.35	8,462.11
	94	Marathon	4.35	Concrete	July 7		103,170.90	34,390.30
	97	Sauk	2.34	Gravel	July 28		50,292.00	16,764.66
	98	Washburn	.57	Earth	July 18		5,995.00	1,998.33
Wyoming	33	Albany	2.10	Macadam	July 8		25,575.00	12,787.50
Total	226		1,636.305				26,849,264.51	9,814,599.31

[1] Statements heretofore approved withdrawn.
[2] Modified agreement. Figures given are increases over those in the original agreement.
[3] Should have been included in the June record.
[4] Revised statement. Figures given are increases over those in the original statement.

FEDERAL AID PROJECT APPROVALS AND AGREEMENTS IN AUGUST, 1919.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	26	Cleburne		Gravel		Aug. 29	[1] $15,933.65	[1] $7,766.82
	42	Talladega	5.7	Sand-clay	Aug. 8		42,056.74	21,028.37
	53	Calhoun	3.2	do	Aug. 19		16,412.00	8,206.00
	63	Dale	6.5	do	Aug. 7		36,795.00	18,397.50
	64	Pike	13.96	Gravel	Aug. 22		103,625.50	51,812.75
	65	do	8.83	Sand-clay and gravel	Aug. 16		50,336.00	25,168.00
Arizona	11	Cochise	8.463	Concrete	Aug. 5		232,799.83	116,399.91
	12	Yavapai	1.961	Macadam	Aug. 7		121,969.17	39,220.00
	13	Greenlee	5.276	Gravel	Aug. 16		171,900.85	85,950.47
	17	Yavapai	5.0	Macadam	Aug. 7		166,761.98	83,380.99
Arkansas	24	Ashley, Desha, Drew, Chicot, Lincoln.	152.99	Asphalt and macadam	Aug. 1		2,684,177.10	332,000.00
	26	Jackson	14.26	Bituminous	Aug. 14		134,184.31	60,000.00
	28	St. Francis	18.19	Gravel	Aug. 12		268,262.72	50,000.00
	29	Craighead	5.62	Macadam	Aug. 14		79,714.80	33,000.00
California	11	Fresno	8.17	Concrete		Aug. 29	246,668.29	123,334.14
	12	Merced	14.89	do		Aug. 1	266,667.85	133,333.92
	13	Los Angeles	17.62	do		Aug. 29	310,338.10	155,194.05
	14A	Mendocino	24.12	Earth		Aug. 1	152,946.92	76,473.46
	16	Humboldt	2.80	do		Aug. 1	39,471.56	19,735.78
	17	Del Norte	7.73	do		Aug. 11	239,133.84	119,566.92
	19	Mendocino	9.73	do		Aug. 29	117,368.81	58,684.00
	21	Ventura	5.19	Concrete	Aug. 7		167,255.00	83,627.50
	22	Los Angeles	1.29	do	do		42,240.00	21,120.00
	23	do	5.23	Bituminous	Aug. 12		94,624.75	47,312.37
	24	Orange	9.37	do	Aug. 9		145,225.85	72,612.92
	25	Santa Barbara	3.56	Concrete	Aug. 16		85,382.00	42,691.00
	26	Kern	10.7	do	Aug. 11		324,170.00	162,085.00
Colorado	10	Adams	1.786	Concrete or bituminous		Aug. 27	42,793.96	21,396.98
	21	Otero	.4	Concrete	Aug. 5		10,654.87	5,327.43
	22	do	.407	do	Aug. 7		10,572.92	5,286.46
	24	Castilla	6.6	Earth and gravel	Aug. 9		20,363.85	10,181.92
	57	Prowers	1.408	Concrete	Aug. 8		39,508.70	19,754.35
	60	Otero	.413	do	Aug. 7		10,618.85	5,309.47
	61	do	.4	do	do		10,602.07	5,301.03
	62	do	.909	do	Aug. 16		23,097.80	11,548.90
	63	do	.918	do	do		23,431.65	11,715.82
Connecticut	5	Fairfield	11.18	Bituminous		Aug. 1	314,060.89	157,030.44
Delaware	1B	New Castle	.492	Brick		Aug. 26	50,734.64	4,500.00
	3	Kent, Sussex	4.006	Concrete		do	175,395.55	36,000.00
Florida	15	De Soto	3.26	do		Aug. 11	54,570.67	20,000.00
Georgia	77	Charlton	19.2	Bituminous	Aug. 11		285,441.86	142,720.93
	78	Pulaski		Bridge and approaches	Aug. 16		180,932.40	90,466.20
Idaho	12	Elmore	7.4	Macadam	Aug. 14		74,955.54	37,477.77
Illinois	[2] 1	Du Page, Kane, DeKalb, Ogle, Lee, Whiteside.	11.446	Concrete and bituminous macadam resurfacing.		Aug. 4	306,789.63	153,394.81
	[2] 1	do	4.854	do		do	152,968.94	76,484.47
	[2] 1	do		do		do	[2] 23,632.72	[2] 20,990.67
	[2] 1	do	6.502	do		do	205,336.71	102,668.35
	2	Kankakee, Iroquois		Bituminous macadam and concrete		do	[1] 2,554.17	[1] 1,277.09

[1] Modified agreements. Amounts given are increases over those in the original.
[2] Separate agreements for portions of project No. 1. The first is for sections 1, 5, 8, and 18, the second for section 4; the third for section 7; and the fourth for section 15. That for section 7 is a modification of the original, and the amounts given are increases over those in the original agreement.

FEDERAL AID PROJECT APPROVALS AND AGREEMENTS IN AUGUST, 1919—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement signed.	Estimated cost.	Federal aid.
Indiana	9	Bartholomew, Johnson	40.00	Concrete, brick, or asphalt	Aug. 27		$1,353,330.00	$676,665.00
Iowa	12	Dallas	16.8	Gravel		Aug. 4	37,288.07	18,000.00
	27	Appanoose	10.58	Graded earth		Aug. 26	50,649.01	25,000.00
	28	Sioux	24.4	Earth		...do...	77,782.10	29,381.20
	34	Keokuk	12.21	.....do		Aug. 1	58,266.79	29,000.00
Kansas	10	Geary	7.471	Concrete		Aug. 27	270,809.81	112,065.00
	25B	Wyandotte	1.274	Brick or concrete		Aug. 26	52,512.07	19,110.00
	30	Lyon	20.45	.....do	Aug. 16		1,131,539.20	306,750.00
Louisiana	19	St. Landry	11.3	Gravel	Aug. 5		130,537.33	50,000.00
	21	West Baton Rouge		.....do		Aug. 11	[1] 17,263.54	[1] 13,128.94
	32	Grant	20.23	.....do		Aug. 12	214,629.58	107,314.79
	36	Tangipahoa	12.56	.....do	Aug. 27		110,777.75	55,388.87
	38	Natchitoches	17.89	.....do	Aug. 16		213,756.51	101,878.25
	43	Calcasieu	11.71	Shell and gravel	Aug. 27		245,092.59	122,546.29
	45	Caddo	8.35	Gravel	...do...		65,945.27	32,972.63
Maryland	6A	Prince Georges, Howard, Baltimore		Concrete		Aug. 22		[1] 18,524.98
	14	Frederick, Washington	3.5	.....do		Aug. 7	99,849.97	49,924.98
	16	Howard	2.51	.....do		Aug. 29	97,838.95	48,919.47
	17A	Harford	2.6	.....do		Aug. 1	70,781.28	35,490.64
	18	Cecil	2.088	.....do		Aug. 29	69,966.88	34,983.44
	20	Dorchester	2.15	.....do		...do...	65,976.60	32,988.30
Massachusetts	10	Norfolk	2.42	Bituminous		Aug. 11	81,374.75	40,687.37
	12	Essex	2.173	.....do		Aug. 16	43,703.00	21,851.50
	18	Worcester	2.797	Concrete	Aug. 11		124,533.75	55,940.00
	19	Bristol	2.116	.....do		Aug. 7	86,898.90	42,320.00
	20	Middlesex	2.173	Bituminous		Aug. 11	43,703.00	21,851.50
Michigan	20	Van Buren, Kalamazoo		Concrete		Aug. 29	[1] 54,275.43	[1] 36,863.75
	24	Berrien		Macadam surface treated		Aug. 21	[1] 38,975.27	[1] 15,058.22
Minnesota	1	Pine		Gravel		Aug. 4	[1] 37,568.55	[1] 24,859.34
	20	Goodhue		.....do		...do...	[1] 12,519.38	[1] 38,002.86
	23	Dakota	6.0	Concrete, brick, or asphalt		Aug. 12	205,031.21	100,000.00
	24	Morrison	[2] 40.85	Gravel	Aug. 11		[2] 75,196.00	[2] 23,798.00
	36	Faribault	26.1	.....do	Aug. 27		162,699.68	81,349.84
	39	Fillmore	8.48	.....do	...do...		66,607.30	30,000.00
	40	Meeker	16.35	.....do	Aug. 7		115,867.40	57,933.70
	47	Pope	16.20	.....do		Aug. 21	73,076.32	36,538.16
	52	Itasca	9.5	.....do	Aug. 7		60,106.91	30,053.45
	53	Lyon	9.0	.....do	Aug. 9		103,938.84	51,991.92
	55	Lac qui Parle	6.5	.....do	Aug. 7		9,605.48	4,802.74
	56	.....do	16.8	.....do	Aug. 9		33,289.73	16,644.86
	58	Nobles	5.5	Concrete, brick, or asphalt		Aug. 1	145,617.34	60,000.00
	63	Stevens	9.48	.....do	Aug. 21		267,346.86	133,673.43
	64	Rice	12.8	.....do	Aug. 16		420,444.49	210,222.24
	67	Pennington	3.7	Gravel	Aug. 27		23,325.17	11,662.58
Mississippi	18	Rankin	3.775	.....do		Aug. 4	20,774.59	10,387.29
	30	Lauderdale	6.727	.....do		...do...	40,259.18	20,000.00
	40	Monroe	14.00	.....do	Aug. 12		49,995.00	20,000.00
	65	Yazoo	6.9	.....do	...do...		51,425.00	25,712.50
Montana	46	Jefferson	3.5	Earth	Aug. 27		22,000.00	11,000.00
	49	Meagher	23.00	.....do	...do...		45,980.00	22,990.00
	51	Gallatin	.75	Concrete	Aug. 15		49,500.00	15,000.00
Nebraska	40	Thayer	7.25	Gravel	Aug. 16		23,496.00	11,748.00
	49	Burt, Dakota, Thurston	48.5	Earth	Aug. 22		107,800.00	53,900.00
	56	Seward, York, Hamilton	48.987	.....do		Aug. 6	167,871.24	83,935.62
	57	Dixon	11.00	Sand-clay	Aug. 14		34,056.00	17,028.00
	64	Pierce	12.65	Earth	Aug. 22		28,820.00	14,410.00
	71	Franklin, Harlan	27.05	.....do	Aug. 18		71,500.00	35,750.00
	74	Dundy	17.5	.....do	Aug. 11		41,250.00	20,625.00
	79	Morrill	34.2	Earth and sand-clay	Aug. 14		76,560.00	38,280.00
	87	Madison, Stanton	9.9	Earth	Aug. 15		38,500.00	19,250.00
	95	Chase	24.3	Sand-clay	Aug. 16		47,410.00	23,705.00
	100	Douglas	9.9	Earth	Aug. 11		38,500.00	19,250.00
New Hampshire	45	Strafford	1.25	Gravel	Aug. 20		9,900.00	4,950.00
	46	Rockingham	1.00	Macadam	Aug. 12		13,165.02	6,582.51
	54	Strafford	2.045	Gravel	Aug. 11		20,784.17	10,392.08
	61	Cheshire	2.49	.....do	Aug. 27		21,903.20	10,951.60
	63	Rockingham	.81	.....do	Aug. 12		7,474.66	3,737.33
	66	Carroll	1.21	.....do	Aug. 11		10,185.91	5,092.95
	67	Strafford	.80	.....do	Aug. 12		6,507.49	3,253.74
	70	Coos	.568	Macadam	Aug. 15		11,863.17	5,931.58
	73	Carroll	.84	Gravel	Aug. 12		14,816.37	7,408.18
	75	Belknap	1.59	.....do	Aug. 11		13,233.13	6,616.56
New Jersey	2	Mercer	5.99	Concrete		Aug. 1	377,270.73	119,800.00
	10	Hunterdon	2.03	.....do	Aug. 14		165,625.99	50,142.50
	14	Somerset, Middlesex	3.665	.....do	Aug. 5		266,055.91	73,300.00
	16	Hunterdon	2.13	.....do	Aug. 14		256,319.51	42,600.00
New Mexico	22	Guadalupe	18.00	Gravel	...do...		117,447.00	58,723.50
	23	De Baca	10.00	.....do	...do...		87,972.50	43,986.25
	29	Eddy	21.00	Earth	Aug. 12		89,487.20	44,743.60
North Carolina	13	Wayne	12.6	Sand-clay or gravel	Aug. 11		51,535.00	25,767.50
	18	Alexander	9.8	Topsoil		Aug. 4	66,446.49	25.000.00
	27	Orange	17.17	Topsoil or sand-clay		Aug. 19	34,132.07	12,000.00
	42	Stanley	11.67	Sand-clay or gravel		Aug. 12	80,922.15	16,700.00
	50	Guilford	2.003	Bituminous	Aug. 11		56,622.28	28,311.14
	54	Wake	6.9	.....do	Aug. 12		246,336.64	123,168.32
North Dakota	7	Stutsman		Earth		Aug. 20	[1] 4,949.94	[1] 2,474.97
	11	Cavalier		Graded earth		Aug. 29	[1] 1,090.86	[1] 545.43
	18	Ramsey	4.51	Earth		...do...	12,384.50	6,192.25
	40	Bottineau	8.01	Earth and gravel		...do...	24,769.11	12,384.55
	43	....do	10.13	Gravel		...do...	42,960.76	21,480.38
	46	Traill	4.02	Earth	Aug. 27		6 400.00	3,200.00
Ohio	11	Ashtabula		Brick or concrete		Aug. 12	63,000.00	31,500.00
	24A	Madison	2.47	Concrete, asphalt, or brick		...do...	52,200.00	24,700.00
	24B	.....do	5.92	.....do		...do...	165,000.00	59,200.00
	30	Delaware	6.18	Concrete or macadam		Aug. 19	201,000.00	62,000.00
	36	Columbiana	2.961	Concrete		Aug. 26	88,000.00	35,600.00
	43	Ottawa	7.15	.....do		Aug. 16	244,500.00	71,500.00
	47	Wood	6.13	Concrete or asphalt		Aug. 26	200,000.00	90,000.00
	50	Columbiana, Mahoning	4.12	Brick		Aug. 20	150,000.00	54,000.00

[1] Modified agreements. Amounts given are increases over those in the originals.
[2] Revised statement. Figures given are decreases in estimated cost and Federal aid in original statement.

FEDERAL AID PROJECT APPROVALS AND AGREEMENTS IN AUGUST, 1919—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement signed.	Estimated cost.	Federal aid.
Ohio	51	Sandusky	5.76	Brick or bituminous		Aug. 4	$345,000.00	$86,400.00
	52	Huron	1.28	Brick		Aug. 12	51,000.00	17,000.00
	65	Hancock	6.04	Brick, asphalt, or concrete		Aug. 16	241,600.00	90,000.00
	66	Defiance	2.04	Concrete		Aug. 26	55,500.00	22,750.00
	78	Mahoning, Columbiana	2.15	Brick		do	94,999.80	15,000.00
	80	Washington	3.026	Concrete		Aug. 4	100,000.00	50,000.00
	86	Paulding	2.02	do	Aug. 11		61,500.00	20,200.00
	93	Gallia	6.00	Bituminous	Aug. 27		130,000.00	65,000.00
	94	Lawrence	4.39	do	do		120,000.00	60,000.00
	96	Paulding	2.02	Concrete	Aug. 11		61,800.00	20,200.00
	99	Jefferson	2.27	do	Aug. 27		106,843.00	45,000.00
	100	Harrison	3.76	do	do		138,600.00	50,000.00
Oklahoma	13	Pushmataha		Bridge	Aug. 14		150,000.00	75,000.00
	16	Hughes		do	Aug. 15		12,156.92	6,078.46
Oregon	18	Polk	13.07	Hard surface		Aug. 26	447,667.22	223,833.61
	21	Clatsop	14.8	Bituminous	Aug. 12		318,835.00	159,417.50
	22	do		Bridge	Aug. 14		255,860.00	85,286.66
Pennsylvania	8	Erie	5.19	Cement concrete or bituminous concrete on concrete base.		Aug. 26	261,452.87	122,757.73
	35	Tioga	4.98	Concrete		Aug. 12	239,319.09	99,600.00
	36	Blair	2.58	do		do	112,771.78	51,600.00
	37	Butler	6.10	Concrete or bituminous		Aug. 16	254,067.00	122,000.00
	40	McKean	10.11	Concrete		Aug. 26	488,304.34	207,489.78
	41	Mercer	3.39	Concrete or bituminous		Aug. 12	130,424.67	65,212.33
	43	Wayne	5.244	do		Aug. 28	231,331.65	104,880.00
	44	Cambria	6.1	Concrete		Aug. 26	285,948.85	122,000.00
	45	Center	5.29	Concrete or bituminous		Aug. 27	237,270.55	105,800.00
	48	Potter	5.00	do		Aug. 29	236,552.98	100,000.00
	53	Bradford	5.94	Bituminous, brick, or concrete	Aug. 11		329,322.40	118,800.00
	55	Butler	7.89	Brick or concrete	do		390,920.20	157,800.00
	56	Center	2.33	Bituminous or concrete	Aug. 9		108,351.10	46,600.00
	58	Fayette	4.98	Brick or concrete	Aug. 27		302,128.20	99,600.00
	65	Westmoreland	6.07	do	Aug. 11		326,691.20	134,659.00
	67	York	6.2	do	Aug. 7		328,689.90	145,323.00
Rhode Island	5	Providence, Kent	.945	Bituminous	Aug. 11		27,178.14	13,589.07
South Carolina	11	Chester	9.46	Sand-clay		Aug. 12	76,923.11	38,461.55
South Dakota	6	Moody	13.56	Earth, graveled in part		Aug. 4	62,574.57	31,287.28
	7	Deuel		Gravel		do	[1] 4,238.23	[1] 2,119.12
	8	Butte		Earth		do	[1] 5,888.45	[1] 2,944.22
	9	Brown	12.84	Gravel		Aug. 9	94,954.00	47,477.00
	12	Minnehaha	21.82	do		Aug. 21	167,213.23	83,606.61
Tennessee	11	Johnson, Sullivan	21.92	Earth and macadam	Aug. 5		168,387.45	70,000.00
	12	Claiborne, Union	13.714	Macadam	do		221,057.69	110,528.84
Texas	28	Morris		Sand-clay		Aug. 4	13,626.00	6,813.39
	33	Harris	[2] —.497	Gravel, shell base, bituminous surface		Aug. 29	[2] —2,753.80	[2] —120.03
	36	Caldwell	[2] —2.31	Gravel		Aug. 4	[2] —2,267.33	
	39	Dallas	9.125	Concrete		do	380,916.00	78,000.00
	40	Bell	36.65	Bituminous gravel		Aug. 9	145,200.89	50,000.00
	70	Colorado	17.12	do		Aug. 4	161,986.79	44,000.00
	76	Galveston		Shell		do	[1] 5,108.32	[1] 3,500.00
	79	Caldwell	6.67	Gravel	Aug. 14		11,785.72	5,892.86
	81	Freestone	2.79	Gravel or macadam		Aug. 4	44,273.58	20,000.00
	87	Travis	10.00	Bituminous	Aug. 14		32,853.20	16,426.50
	96	Fisher	9.00	Gravel	Aug. 8		64,068.40	32,034.00
	98	Collins	25.00	Shale	Aug. 27		328,786.24	172,926.86
Utah	19	Garfield, Piute	51.10	Macadam	Aug. 7		328,581.00	164,290.50
	25	Juab, Utah	23.6	Concrete	Aug. 27		606,260.53	303,130.26
Virginia	21	Frederick	5.37	Macadam		Aug. 29	88,333.10	44,166.55
	35	Rockbridge	4.27	do		do	64,535.90	32,267.95
	47	Hanover, Louisa	21.50	Sand-clay	Aug. 14		101,653.75	50,826.87
	48A	Amherst, Bedford	5.473	Macadam		Aug. 29	109,714.44	54,857.22
	50	Campbell	2.11	do		do	46,056.12	23,028.06
	51	Loudoun	4.5	do	Aug. 5		73,755.00	36,877.50
	52	Lee	5.25	do	Aug. 9		83,050.00	41,525.00
	53	Fauquier	3.1	do	do		42,680.00	21,340.00
	62	Roanoke	.718	Concrete	Aug. 12		22,550.00	11,275.00
	63	Warren	1.65	Bituminous	Aug. 11		26,455.00	13,227.50
West Virginia	3A	Pendleton	10.0	Graded and drained earth		Aug. 27	25,709.31	12,500.00
	16	Barbour		Bituminous macadam		Aug. 1	[1] 16,082.00	[1] 8,000.00
	27	do		Macadam		Aug. 21	[1] 2,740.50	[1] 1,890.00
	39	Doddridge	2.82	Concrete		Aug. 1	64,780.00	29,780.00
	40	Wood	2.00	do		Aug. 4	36,000.00	18,000.00
	46	Ohio	1.06	do		Aug. 21	37,965.00	18,000.00
	55	Tyler	1.00	Bituminous	Aug. 9		29,667.40	14,833.70
	56	Jackson	.35	Concrete	Aug. 12		13,000.00	6,500.00
	57	Cabell	1.00	Brick	Aug. 9		34,144.00	12,800.00
	58	Pleasants	5.4	Earth	Aug. 7		30,800.00	15,400.00
	59	Jackson	1.06	Concrete	Aug. 12		34,700.00	17,350.00
	62	Hardy	7.00	Gravel	Aug. 27		43,775.00	21,887.00
	63	Morgan	2.00	Concrete or bituminous	do		42,000.00	21,000.00
Wisconsin	26	Wood		Gravel		Aug. 12	[1] 45,027.08	[1] 15,009.03
	35	Dodge		Gravel or macadam		Aug. 4	[1] 4,459.59	[1] 1,486.52
	47	Vernon		Earth		do	[1] 11,205.38	[1] 3,735.12
	58	Outagamie	3.78	Concrete		Aug. 12	89,408.43	29,802.81
	60	Greenlake		Grading and concrete		Aug. 4	[1] 7,167.50	[1] 3,024.18
	77	Waushara	4.02	Topsoil		do	22,139.10	7,379.70
	96	Rock	6.15	Concrete	Aug. 11		164,890.00	54,963.33
Wyoming	38	Hot Springs	3.381	Gravel	Aug. 27		33,550.00	16,775.00
	39	Big Horn	8.161	do	Aug. 25		74,767.00	37,383.50
Total	234		1,944.41				30,397,337.96	12,362,585.99

[1] Modified agreements. Amounts given are increases over original agreement.
[2] Modified agreements. Figures are a decrease from those in original agreements.

BRIDGE APPROACHES.

FOR various reasons it frequently is advisable to raise the floor of a bridge above the elevation which is the most elevation for the roadway leading to the bridge. The reasons for this do not need further discussion in this connection than to say that the most potent reason for such a difference in elevation when it occurs is the necessity of securing ample clearance between the maximum high-water level and the bridge structure in order to pass floating débris. However, the fact that these differences of elevation do exist, leads to the necessity of connecting the two elevations, that is, the bridge floor and the road surface, by a suitable ramp, concerning which a number of points deserve more attention than generally is given to them.

The first of these points is that economy in road design dictates that the elevation of the roadway should be selected without any reference whatever to the elevation of the bridge floor. The elevation of the roadway at any point is dependent on such factors as foundation conditions, drainage, gradient, etc., and when these conditions are satisfied, whatever addition is made in the height of an embankment must be recognized as involving additional risk to high speed traffic, additional construction cost and additional maintenance cost and, therefore, demanding full justification.

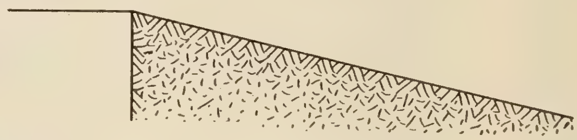
SHORT RAMPS MAKE FOR ECONOMY.

On the other hand, the logical result of all this is short ramps which, though somewhat to be condemned on the ground that they mar the beauty of the roadway are, nevertheless, in the interest of economy. This is particularly true where a bridge crosses a stream laying in a low, flat valley, the stream carrying enough drift to require rather a high clearance. In such cases the difference in elevation between the economical level of the road surface and the proper elevation of the floor of the bridge may be considerable and it is seldom economical or advisable to raise the road grade to the elevation of the floor of the bridge, as such a procedure would involve a considerable amount of expensive embankment. The obvious solution, then, is the construction of a comparatively short bridge approach and the real problem lies in the choice of a gradient for such approaches.

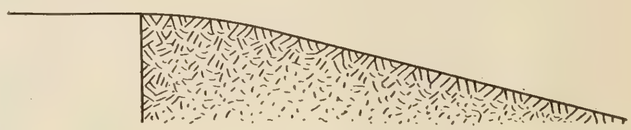
SHOULD BE BUILT FULL WIDTH.

The present tendency is to build bridge approaches on long easy grades, but this involves a heavy expense and tends to nullify the gain accruing from the independent selection of the proper elevation for the bridge floor and for the roadway. A better practice is to base the gradient of the approach on the ruling grade in force on other parts of the road. In other words, if there is a 10-feet difference in elevation between the normal position of the road surface and the proper elevation of the floor of the bridge and if 5 per cent grades are common throughout the length of the road, there is no particular reason for constructing the ramp connecting these two elevations on less than a 5 per cent grade, particularly as the shorter ramp will usually be less expensive and should be more easily maintained than a longer structure built on a light grade.

Ramps used for bridge approaches should be built full width. It frequently happens that where the shoulder width of the road proper is, say 24 feet, and the clear width of the bridge floor is 16 or 18 feet,



IMPROPER BRIDGE APPROACH.



PROPER BRIDGE APPROACH

the ramp is allowed to pinch down in width as the bridge is approached until there is a distinct constriction at and near the bridge. It is much better practice to provide abutments which will enable the use of full width ramps, or if this is, for any reason, inadvisable to fence approaches which are of any considerable height.

PROPERLY EASED APPROACHES.

Finally, breaks in grade between bridge approaches and the elevations which they connect should be eased by the use of vertical curves under the same rules which apply to breaks in grade at other points along the highway. The use of easement curves will somewhat increase the length of bridge approaches because of the necessity of building the whole of the easement in the approach. However, this is not a matter of great importance and the added cost is more than justified by the fact that approaches which have been properly eased are a distinct assistance in driving onto and off of a bridge structure. Moreover, they make the maintenance of a road at the bridge very much simpler.

NEW METHOD FOR ADJUSTING EARTH EXCAVATION AND DETERMINING HAUL.

By J. W. Ball, Highway Engineer, and C. R. Shore, Highway Draftsman, Bureau of Public Roads.

EVERY highway engineer who is striving for economy in highway design finds that his greatest problem lies in the adjustment of his grade line so that he can avoid unnecessary earth work. The amount of surfacing which he must use is rather arbitrarily determined by the length of the route selected and is all but independent of the gradients finally adopted. Similarly, the number and the size of the drainage structures is determined, almost entirely, by the location and is quite independent of the gradients used. These, with the earth work, make up the three major portions of the cost of any highway but, differing essentially from the other two in this respect, the quantity of earth work can be modified, to a very marked extent, by modifications in the grade line, no matter what location is chosen. Economy of design, therefore, dictates that the gradients which are finally selected not only meet general engineering requirements, but that, as far as possible, all economies which do not involve a conflict with general engineering principles be adopted.

METHODS ARE USEFUL.

With this thought in mind, the following discussion of a graphic method of adjusting excavation and of determining overhaul is presented. The methods described are believed to be original, but whether original or not, it is felt that their usefulness justifies their presentation at this time and that their careful study and more general adoption by highway engineers will result in noticeable savings in the cost of excavation. On the other hand, it is recognized that these methods are not competent to correct improper location nor do they suffice to determine the most economical general adjustment of the grade line. They do, however, suffice to indicate local changes in grade alignment which are in the interest of economy. The changes worked out may or may not be in keeping with general engineering principles, and where this method is adopted it is, therefore, necessary to caution those who use it that the changes which this method develops as in the interest of economy may have to be rejected as in violation of major engineering principles. An illustration of this fact would be the development, by the use of this method, of the fact that a shorter curve should be adopted at a point where the minmum has already been selected, or that a short adverse grade in a long ascending grade would save excavation. In either case an engineer would hesitate to follow the dictates of economy and should, in fact, reject the information developed as of no value, more important considerations preventing its use.

These and other cases will occur where the information developed can not be used but they serve simply as an illustration of the general statement that this system is an assistance in the proper adjustment of highway grade lines, not a panacea to be applied for the elimination of excessive costs rightly chargeable to poor location or to improper general assumptions as to the laying in of the grade line. The discussion follows:

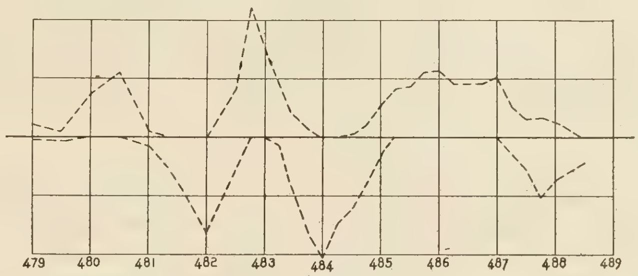


FIG. I.
QUANTITIES DIAGRAM

THE QUANTITIES DIAGRAM.

The "quantities" diagram, as applied to highway design, consists of two curves obtained by connecting the two series of points which result if the stations are platted as abscissas and the corresponding end areas of excavation and embankment, respectively, as ordinates. Excavation is platted positive, and embankment negative. The excavation curve would then always appear above the horizontal axis (or coincident with it wherever there is no excavation), and the embankment curve would appear below the horizontal axis (or coincident with it, where there is no embankment). With end areas platted in square feet and the stations and fractions thereof in linear feet (see Fig. 1), the area included between the horizontal axis and the curve which lies above it represents the volume of excavation, while the area included between the horizontal axis and the curve which lies below it represents embankment, both in cubic feet.

These areas are readily found by a planimeter and by using a horizontal scale of 1 inch to 100 linear feet and a vertical scale of 1 inch to 100 square feet, 1 square inch on the "quantities" diagram represents 10,000 cubic feet of excavation or of embankment, as the case may be.

This "quantities" diagram furnishes a quick and accurate means of determining the quantities for preliminary estimates, but, more important still, it presents a useful yardage curve to be studied in connection with general grade revisions, since it shows the location and amount of earth work at all points along the line. These curves are particularly useful in locating sections of a highway which are grossly out of balance, for the predominance of cut or of fill over any section of a highway is very noticeable. These curves do not, however, give any indication as to whether the failure to secure a balance is due to a general policy of doing too much cutting or of calling for too much filling or is caused by a failure to make proper use of the maximum grade. These curves simply indicate where a lack of balance exists. The question as to whether this lack of balance is to be corrected at all and, if so, what methods are to be adopted, is one of engineering judgment which can not be assisted by any set formula.

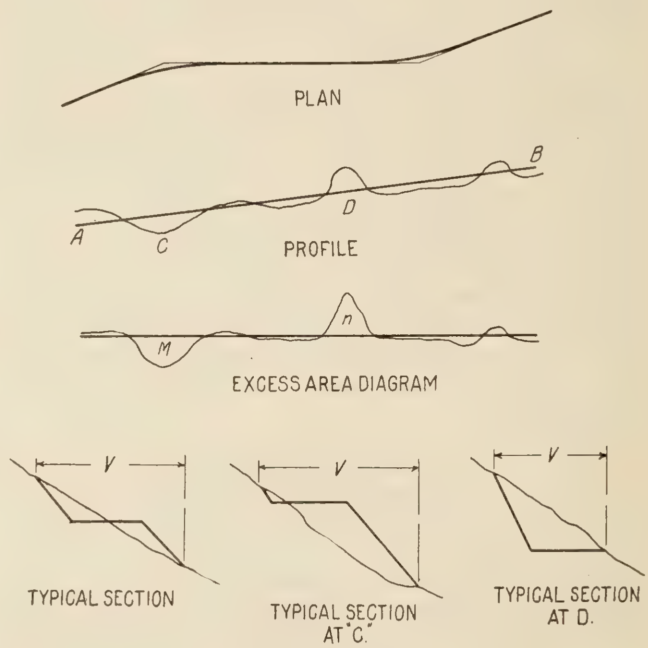
THE EXCESS AREA DIAGRAM.

The "excess area" diagram is the algebraic sum of the excavation curve and the embankment curve of the "quantities" diagram. Excavation excess is platted as positive and embankment excess is platted as negative and the line stations are platted along the horizontal axis as before. In this graph the ordinate for each station is in square feet and is the difference in square feet between the excavation included in the end area and the embankment included in the end area for that station. This is platted as positive if the excavation exceeds the embankment and as negative if the embankment exceeds the excavation. Where the road is all in cut or all in fill the "excess area" curve will coincide with the quantities curve but where, as in side hill work, cross sections include both cut and fill, the "excess area" curve will fall between the two curves of the quantities diagram. Moreover, wherever the cut and the fill are equal, the "excess area" curve will intersect the horizontal axis, from which it naturally follows that, on a hillside location, where an ideal location would cause the cut along any section to exactly make the fill along that section, the excess area curve will be a straight line coinciding with the horizontal axis. Any deviation from such a location causes the excess area curve to separate from this horizontal axis.

The excess area diagram therefore shows to what extent the location of the grade line varies from this ideal line. Moreover, the area below the excess area curve and above the horizontal axis represents the volume of excavation in excess of that required to make the corresponding fill along this portion of the line and the area below the horizontal axis but above the excess area curve represents the volume of embankment which is in excess of that produced by the excavation over that section. The excavation and the embankment on any given length of a project are, then, theoretically balanced when the plus and minus areas on the excess area diagram are equal over this length of the project. The quantity to be hauled is also accurately and clearly shown and the distance of the haul can be closely approximated.

Whenever an allowance is to be made for shrinkage it is advisable to increase the embankment areas by the customary per cent (which usually varies from 15 to 25 per cent of the volume of embankment in common excavation) before calculating the difference between excavation and embankment. The amount of increase to be used is generally fixed by established rules but may, in the absence of fixed rules, be adjusted according to the judgment of the engineer.

FIG. 2.



USE OF THE EXCESS AREA DIAGRAM.

The road location having been made in the usual way, and the end areas from cross sections having been obtained from a tentative grade line, to apply the excess area diagram in the design of the road, first plat the quantities diagram, using for this purpose the information secured from the cross sections for the tentative grade line. Any gross errors in the balance will be shown by the quantities diagram and the first step should be to secure a decision as to their adjustment. If they are to be eliminated, the grade line should be relaid and the quantities diagram redrawn until there is some approach to a balance between controlling points. The excess area diagram should then be drawn and the work of refining the grade line may proceed. This refinement of the grade line will involve minor changes in the position of the line; that is, pushing it into or pulling it out of the hill on sidehill work, or minor changes in the established gradient. These will be discussed independently.

ALIGNMENT REVISIONS FOR BALANCING QUANTITIES.

Assuming now a section of sidehill road of profile AB (see fig. 2) with a typical cross section as S and with the elevations of A and B as fixed or controling points, then naturally the desirable grade line would be unbroken, that is, would show no reverse grades from A to B.

If a location made from A to B on the plan and profile as shown in figure 1 results in an excess area diagram as shown in this figure, and if the excavation on the section as a whole is practically in balance it is at once apparent that points C and D vary from the economical location by the excess embankment m at C, and the excess excavation n at D, and that if the balance is preserved the excess excavation at D must be hauled to C. The problem then is to revise the alignment at C and D so that the excess area curve will approach as closely as possible to its most economical position, that is, the horizontal axis, and to do this without disturbing the balance on the section, AB, as a whole, and without introducing any improper gradients.

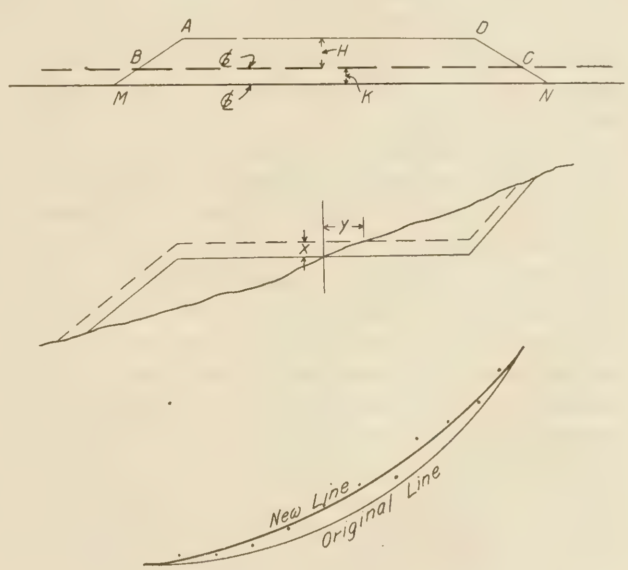
On a sidehill location, pulling the alignment out of the hill has the same effect on the quantity of earthwork as raising the grade. Similarly shoving the line into the hill has the same effect as lowering the grade. If now the effective width of a cross section is defined as the horizontal distance V (see typical cross section fig. 2) between the intersections of the original ground slope and the ditch slopes, then the result of a change in the elevation of the grade depends upon the effective widths of the cross sections involved.

Thus (see fig. 3) assume a fill on level ground. The area of the cross section is $\frac{AD+BC}{2}\times H$. If this fill is increased down by a height Y the area becomes $\left(\frac{AD+BC}{2}\times H\right)+\left(\frac{MN+AD}{2}\times Y\right)$. The reverse of this holds true if the height of the fill is decreased. This same also holds true if part of the section is in cut and part in fill, the fill being increased by raising the grade line and decreased by lowering the grade line by the average width of the bases times the amount of the change in grade. But AB is the same as V in the type figures, MN is the same as V′ and Y the same as g. There results the general deduction that for any change in grade, the change in excess area of the cross section equals $g\,\frac{(V+V')}{2}$, which is positive when the grade is raised and negative when the grade is lowered. For small changes in grade elevation V′ may be assumed as equal to V and the equation there becomes gV. For changes of grade elevations exceeding half of a foot the average effective widths should be determined by scaling the cross sections.

CHANGES IN CENTER LINE POSITION.

At points such as C and D in figure 2 the change required in grade elevations at each cross section, if an economical balance is to be secured is easily computed in feet as will be more clearly brought out later on. However, it is often inadvisable to make adjustments by means of local changes in grade and, on hillside locations, a similar result can be

FIG. 3.



PLAN

secured by moving the center line a corresponding distance from or into the hill so that the required lowering or raising of the ground surface results. The amount of this lateral movement (see fig. 3) is easily determined. Raising the grade line reduces the excavation and increases the fill. By an inspection of figure 3 it will be clear the primary effect of raising the grade line a distance x is to throw the center line out of the hillside a distance y. If on the other hand embankment is to be decreased, the line must be pushed into the hill. This distance y may be determined for any cross section by platting on this cross section the change of elevation which has been calculated as necessary to accomplish the desired change in excavation or in embankment and scaling y. To determine the desirable change in the position of the center line over any section of the highway, the y distances are platted as shown in the plan figure 3 and a new curve laid which will as nearly as possible average these points.

It is seldom possible to achieve what would theoretically be the most economical location, for in rounding points maximum grades must be considered and excess excavation must be provided to make the embankments in the gullies. Moreover, the closeness of the approximation of the alignment to its most economical location is governed by general conditions as to maximum grade, maximum radius, length of line of sight, etc., but the excess area diagram is of much help in adjusting the grade within the limits imposed by such requirements.

GRADE REVISIONS FOR BALANCING QUANTITIES.

Consider a profile as shown in figure 4 and for convenience assume a level ground line, and excavation and embankment section 10 feet wide with vertical slopes. Then the area of the cross section is directly proportional to the depth of the cut or fill, and in this special case the cross-section area is always either (1) all excavation, (2) all embankment, or (3) zero.

With the original grade line as shown at EF in figure 4 the excess area diagram is platted as in figure 5 and shows that the excess excavation for a 10-foot width of cross section is 60,000 cubic feet and the excess embankment 20,000 cubic feet. The balance is, therefore, 40,000 cubic feet, deficient in embankment, no account being taken of shrinkage. Assume that it is desirable to raise the grade line parallel to itself, but that, on account of local conditions, it must be broken at G and H to connect with the former grade at E and F. Let M be the vertical ordinate representing this change as it will appear on the excess area diagram, that is the average required change in the area of cross section in square feet. Then, since $\frac{AB+CD}{2}$ is the average length of the trapezoid ABDC in figure 3, to determine the vertical ordinate or its equivalent the required change in cross section, there results the equation

$$M=\frac{40{,}000}{\frac{AB+DC}{2}}=\frac{40{,}000}{\frac{1{,}000+600}{2}}=50$$

which is the average change in cross section required to produce the desired result.

On a cross section 10 feet wide, as assumed, a change of 50 square feet in end area is secured by a change of 5 feet in grade elevation. Hence the grade line from G to H, figure 4, should be raised 5 feet, the grade EGHF resulting.

After this change in grade line is made, the resulting excess area diagram may be plotted, as in figure 6, which is a rectification of figure 5 about ACDB, which line thus becomes the new horizontal axis and the quantities are found to be balanced within ordinary working limits of accuracy.

With similar conditions as to vertical slopes and width of cross section figure 7 is a profile with a tentative grade line placed at EF, which yields the excess area diagram shown in figure 8. The excavation is considerably out of balance. It is desired to balance the quantities by raising the grade line at one point as G. In figure 8, ACB illustrates the effect of this change on the corresponding excess area diagram. But

$$M=\frac{\text{Deficiency of balance}}{\frac{AB}{2}}$$

and

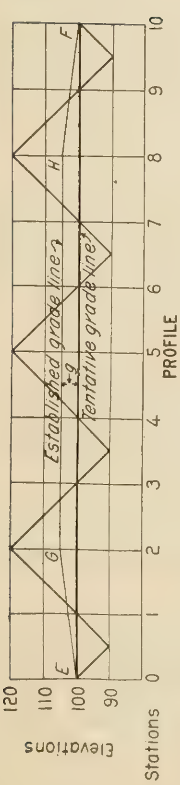
$$g=\frac{M}{\text{Average area of cross section}}$$

Proceeding as before, figure 9 is the excess area diagram with the new grade line EGF as the axis. However, this adjustment involves a long haul between station 2 and station 9+50 and to further adjust the grade line to eliminate this haul the line of balance of the excess area diagram should be revised. By proceeding as before the excess area diagram (fig. 9) is modified to show a new balance along AONB and the grade line is revised to EG′H′F in figure 7, g' and g'' being computed as indicated above. The excess area diagram may then be plotted again as in figure 10, which is a rectification of the excess area diagram about the grade line EG′H′F, which shows that the quantities are in balance with a minimum haul. When familiar with the method of procedure one makes the first revision from the quantities diagram and the final revision generally without a preliminary trial.

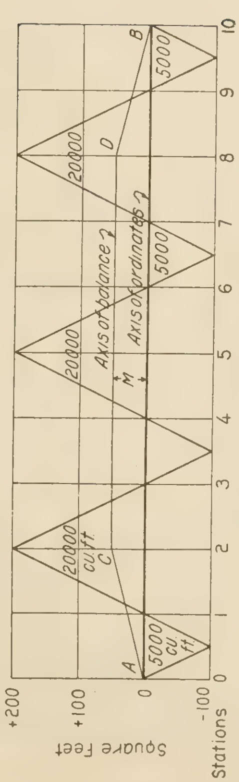
In actual construction, because of the approximation in determining the effective widths of cuts and fills, it is sometimes found that after revision the quantities are still somewhat out of balance. In this case by using two trial excess area diagrams, one can interpolate for the real balance very accurately.

OVERHAUL OF EXCAVATION.

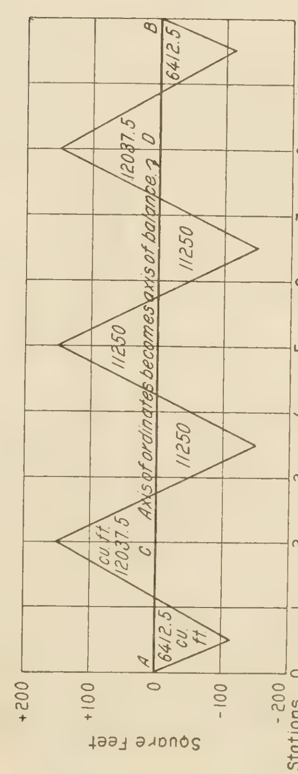
"When the distance between the center of mass of any cut and the center of mass of the corresponding embankment exceeds 1,000 feet, all of the material obtained from the cut and used in the embankment shall be known as 'overhaul excavation', and the length of overhaul shall be measured as the distance between center of mass of cut and center of mass of fill, minus 1,000 feet." [From U. S. Bureau of Public Roads, Typical Specifications.] This defines the method by which overhaul shall be calculated in making final payment for overhaul, and where this definition is used it must be adhered to strictly in making final payments to contractors. However, for other purposes, the center of volume of excavation to be



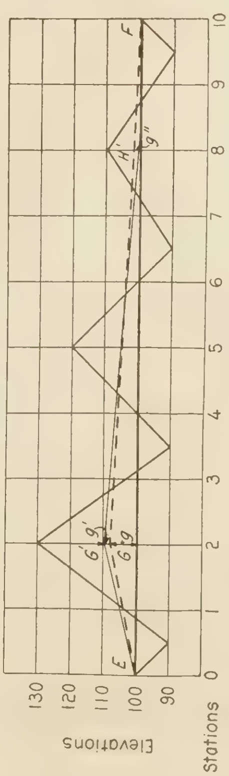
PROFILE
FIG. 4.



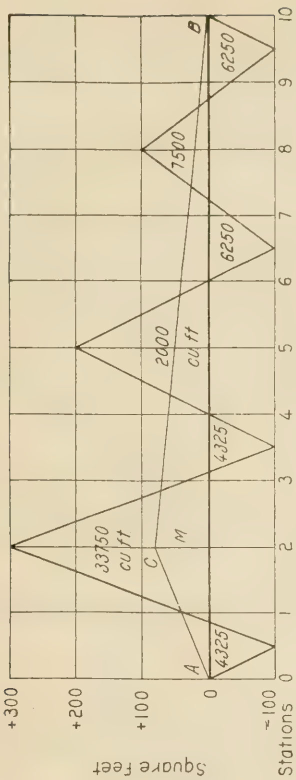
EXCESS AREA DIAGRAM
FIG. 5.



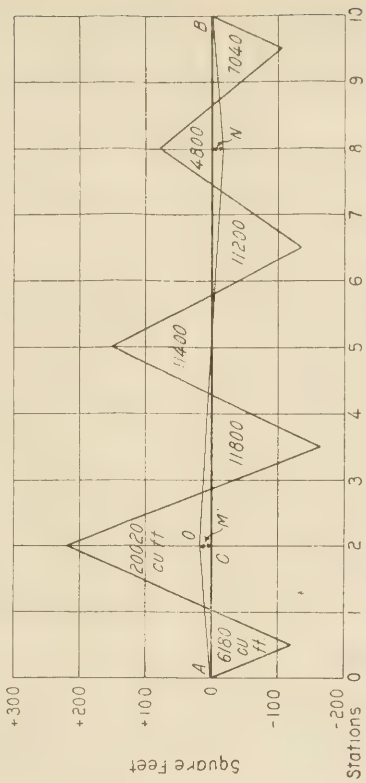
FINAL EXCESS AREA DIAGRAM
FIG. 6.



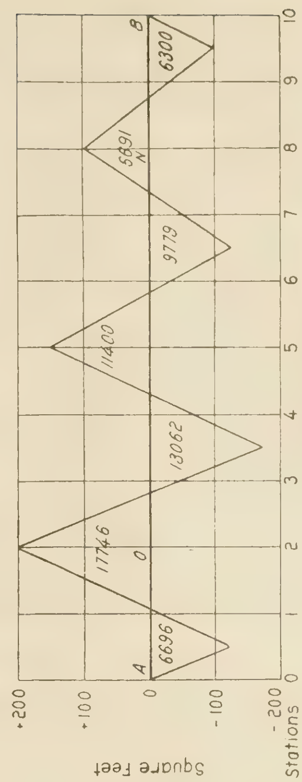
PROFILE
FIG. 7



EXCESS AREA DIAGRAM
FIG. 8.



EXCESS AREA DIAGRAM
FIG. 9.



FINAL EXCESS AREA DIAGRAM
FIG. 10.

hauled and the center of volume of the corresponding embankment may be approximately determined by inspection from the excess area diagram and a close approximation of the overhaul readily calculated.

If it is desired to determine the center of volume of any excess either of embankment or of excavation, the excess excavation or embankment may be divided by vertical lines, and the areas on each side of each line can be measured by a planimeter. In this way an approximate center of volume can be quite rapidly calculated. Overhaul is the distance between the center of volume of the excavation and of the corresponding embankment less the free haul multiplied by the quantity moved. This method is much easier and quicker to apply than that of the mass diagram, and while, as stated above, not legal for computing final estimates, is satisfactory for grade adjustments, estimates, and even for intermediate vouchers.

APPLICATION TO AN ACTUAL CASE.

Figure 11 is the profile from station 475 to station 495 of the Canyonville-Galesville section of the Pacific Highway now under construction. This section is a complete balance within itself, as the material up to station 474 + 80 hauls back. The actual working out of this method is shown in figures 11, 12, 13, and 14.

Figure 11 is the profile, figure 12 is the quantities diagram, and figure 13 is an excess area diagram for this section of highway, as calculated from the tentative grade shown by the dashed line in figure 11. This tentative grade line failed to give a balance of excavation, as is seen from the quantities diagram, figure 12. Before revision to balance excavation and embankment the location of excess excavation and of excess embankment was examined with respect to both quantity and haul. From this examination it was evident that, for economy, the embankment from station 475 to station 485 and from station 487 to station 490 + 50 (see fig. 12) should be decreased. This defect was corrected by making two changes in grade line.

THE FIRST CHANGE.

This change of grade line extends from station 475 to station 485. Assuming that half of the fill at station 484 is to be hauled from the cut at station 486, the excess embankment from station 475 to station 485 equals (27,050 + 16,150 + 9,700) cubic feet = 52,900 cubic feet total.

The excess excavation on the same section equals (15 + 3,600 + 7,200) cubic feet = 10,815 cubic feet total.

52,900 − 10,815 = 42,085 cubic feet which is the deficiency in excavation.

On this subsection of line it was decided to lower the grade parallel to itself, as shown in figure 11. The resulting effect is shown by figure ABDC in the excess area diagram of figure 13. In order that the excavation may balance, the area of ABDC must represent 42,085 cubic feet of earthwork, which is the amount of the deficiency in the excavation. The lengths of the two sides AB and CD of the figure ABDC are determined from figure 13. Then, if, as above, M represents the average change in area of cross section (vertical ordinate) in square feet needed in order to adjust the balance,

$$\mathrm{M}=\frac{42{,}085 \text{ cubic feet}}{\frac{\mathrm{AB}+\mathrm{DC}}{2}}=\frac{42{,}085}{800}=52.6 \text{ square feet.}$$

Next, the average effective width of the cross-sections involved, determine by scaling and averaging all stations from 475 to 485, was found in this case to be 26.3 feet.

Then g, the amount the grade is to be lowered, is equal to $\frac{52.6}{26.3}=2$ feet.

This change in grade line having been made as shown in figure 11, the resulting excess area diagram was shown as C. D. B. F. in figure 13.

THE SECOND CHANGE.

This change in grade line extends from station 481 to station 494 + 50. The quantities were balanced by lowering the grade line near station 492 + 50 as shown in figure 11 by g'. The effect is shown in figure 13 by the line EGF. It is noticed that the change represented by EHB, which is a part of EGF falls in the figure representing the first grade change just described. The line DHK represents a further shifting of the axis of balance CDB which resulted from the first change, the axis finally becoming CDKGF.

To determine the grade change from station 481 to station 494 + 50 the following calculations were made. The excess embankment includes one-half of the fill at station 484 and is, therefore (9,700 + 21,730 + 212 + 12 + 13,150), cubic feet = 44,804 cubic feet total.

The excess excavation is equal to (15,700 + 334 + 650 + 1,600) cubic feet = 18,284 cubic feet total. But 44,804 cubic feet − 18,284 cubic feet = 26,520 cubic feet which is the total deficiency in excavation.

Therefore

$$M=\frac{26{,}520 \text{ cubic feet}}{\frac{EF}{2}}=\frac{26{,}520}{\frac{1{,}350}{2}}=39.29 \text{ square feet.}$$

The average effective width of the cross sections involved (as determined by scaling the plotted sections) is 28 feet; therefore, $g=\frac{39.29}{28}=1.4$ feet,

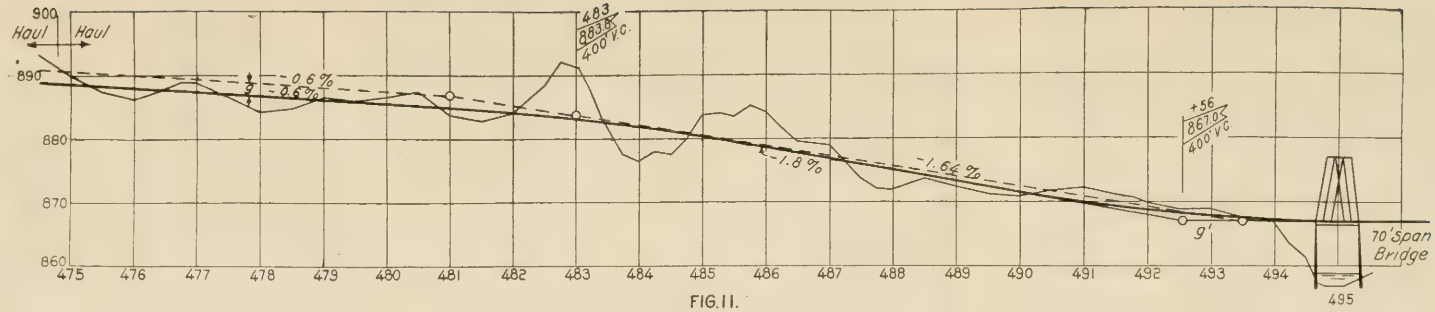


FIG. 11.
PROFILE

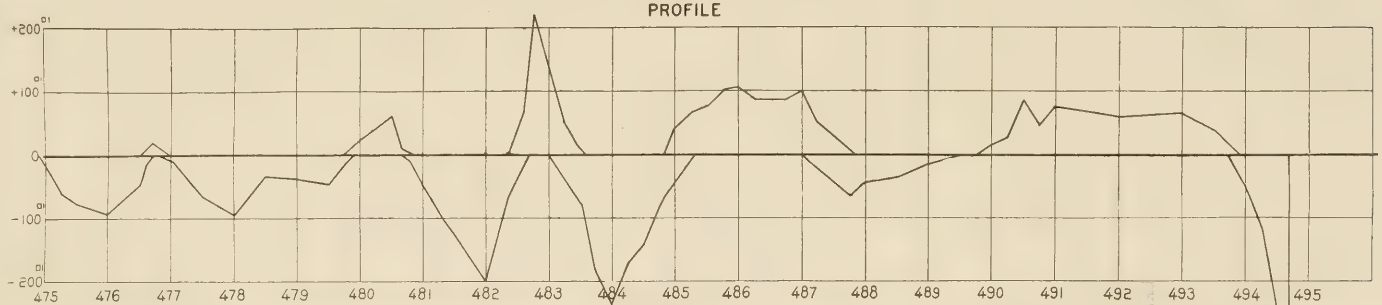


FIG. 12.
THE QUANTITIES DIAGRAM

Change "1" involves sections from Sta. 475 to 485.
Average width of affected area between Stations
475 and 485 is 26.3 ft = V.

Change "2" involves sections from Sta. 481 to 494 + 50
Average width of affected area between stations
481 and 494 + 50 is 28' = V.

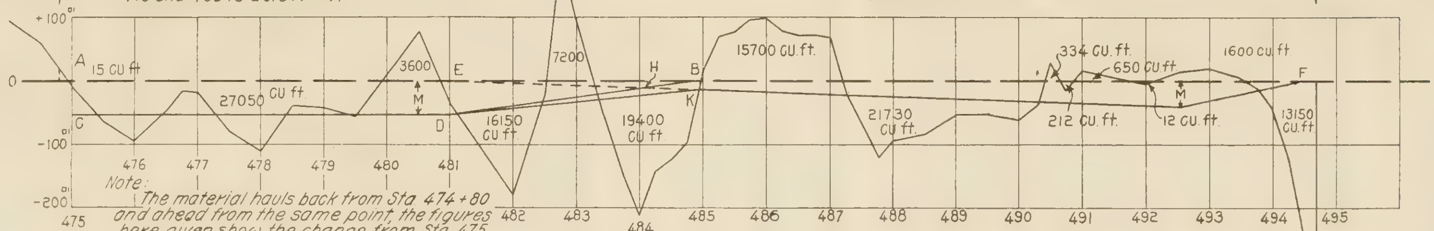


FIG. 13.
THE EXCESS AREA DIAGRAM

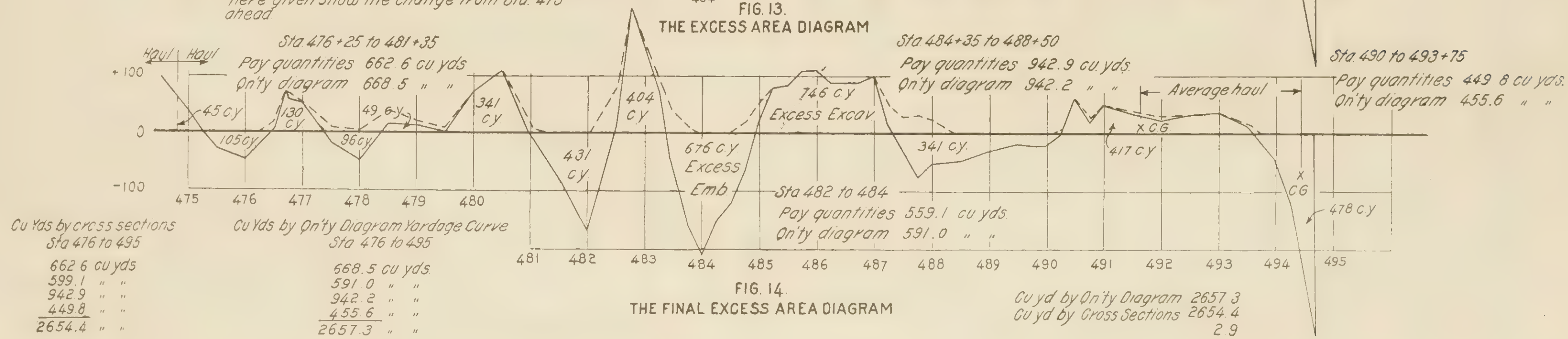


FIG. 14.
THE FINAL EXCESS AREA DIAGRAM

which is the change in the elevation of the grade line at *g*.

Figure 14 is the final excess area diagram plotted after the grade line was revised and shows a balance of earthwork quantities. In this figure the quantities diagram is also shown by dashed lines. Comparative results of measurement of quantities and of computation of quantities for the line as finally laid in are also shown.

At first thought the use of such a method as this may seem tedious and expensive but an examination of the results obtained on this short section of highway, a length of about 20 stations, or roughly two-fifths of a mile, will serve to justify thoughtful consideration of this system. The line as originally laid in (see fig. 11) was a carefully laid line but computation shows that it produced about 2,500 cubic yards less cut than fill. The revised line, on slightly better grades, shows 2,657.3 cubic yards to be paid for as excavation (shrinkage allowed for in drawing quantities diagram and excess area diagrams). The net saving in earthwork which resulted from the changes shown was approximately 1,500 cubic yards or, at 50 cents per cubic yard, the tidy sum of $750.

It is confidently believed that similar savings can be made by all who will familiarize themselves with this method and that these savings will be more than sufficient to justify a thorough mastery of the ideas here outlined.

PENNSYLVANIA MOTOR LAW.

Pennsylvania's new motor vehicle law provides that no motor vehicle can be registered which has an outside length exceeding 336 inches and an outside width exceeding 90 inches. The provision does not apply, however, to vehicles registered or contracted for prior to the passage of the law. The gross weight is limited to 26,000 pounds. Registration fees are 40 cents for each horsepower, with a minimum of $10.

Registration fees for commercial vehicles are:

Class AA, weight of chassis 2,000 to 2,999	$20
Class A, weight of chassis 3,000 to 4,499	25
Class B, weight of chassis 4,500 to 5,999	30
Class C, weight of chassis 6,000 to 6,999	50
Class D ,weight of chassis 7,000 to 7,999	75
Class E, weight of chassis 8,000 to 9,999	100
Class F, weight of chassis 10,000 and over	150

No registration is required for a trailer weighing less than 500 pounds For trailers weighing 500 to 749 pounds the fee is $2, 750 to 999 pounds $5, 1,000 to 1,999 pounds $10, 2,000 pounds or more $15. For all vehicles equipped with metal tires the fee is double.

Motor cycle dealers must pay a license of $5 for each certificate and number plate and motor vehicle dealers $10 for each certificate and two number plates.

All operators of cars must have a license. A driver's license is $2, an operator's $1, and a learner's 50 cents. Drivers and operators must be over 18 years of age and learners over 16.

No commercial vehicle may be operated on the public highways the weight of which with load exceeds 7,000 pounds for class AA, 11,000 for class A, 15,000 for class B, 20,000 for class C, 24,000 for class D, and 26,000 for classes E and F. The weight of trailers must not exceed 26,000 pounds nor 19,200 on any axle nor 800 on any one wheel for each nominal inch of width of tire, or which exceeds 336 inches in length over all or 90 inches width over all.

Extreme speed of cars is limited to 30 miles an hour, classes AA and A commercial cars to 20, class B 18, classes C and D 15, class E 12, and class F 10 miles.

MAY LET SEPARATE CONTRACTS.

In reply to an inquiry from the State engineer of New Mexico relative to the construction of a Federal-aid project through two contracts, one for all the work except the surfacing and a second contract for the surfacing, instead of providing for the work through a single contract, it has been ruled that the plan is permissible, provided that the two contracts are so let that the project may be completed within a resonable time. The plans, specifications and estimates should show the project as being surfaced and include the necessary items in the detailed estimate upon which the project agreement will be signed. The plans, specifications and estimates can then be put through in the ordinary way, and all the work advertised except the surfacing, and that contract completed and a second contract let for the surfacing.

MAINE VOTES BONDS.

On September 8 Maine, by a vote of about 5 to 1, indorsed the proposal to raise the bonded indebtedness for State highways from $2,000,000 to $10,000,000. This will give $8,000,000 additional to be spent on the State road system.

NEBRASKA ROAD DISTRICTS.

The Nebraska State highway department has created five districts for the administration of road work and made an allotment of the State funds to them. The allotments run from $1,373,886.73 to $3,346,666.99.

COMPREHENSIVE INVESTIGATIONS IN HIGHWAY ENGINEERING NEEDED.

By T. R. AGG, Iowa State College.

THE highway engineers of the United States face the necessity of undertaking an enormous construction program immediately. Economic pressure and popular demand alike necessitate a vigorous campaign of road building, both in the States that have been actively building roads for years and in those States that have heretofore seriously neglected road improvement. Not only will the program, as tentatively outlined for 1920, seriously tax the engineering organization if suitable plans and specifications are prepared, but highway contractors and material supply companies are likely to find that their capacities will be taxed to the limit.

NO ADEQUATE BASIC THEORIES.

During the past 10 years, the transition from horse-drawn to motor traffic has been so nearly complete that horse drawn-traffic can no longer be considered a controlling factor in highway design; yet practically all of the basic principles of highway construction were evolved for horse-drawn traffic. These have been modified from time to time as experience has indicated defects, but for the most part local conditions have been so large a factor that types and designs which have been satisfactory in one State have proven entirely unsatisfactory in another.

To a large extent, the tests for the materials used in highway construction were developed under horse-drawn traffic conditions and these also have been revised and new tests devised to meet the new conditions, and yet it is now recognized that many of the tests in current use are not entirely satisfactory.

The situation then is this: The United States is entering upon a very extensive highway construction program without an adequate, acceptable economic theory or group of theories upon which to base design, selection of routes, and types of construction. Knowledge of tests and properties of materials have not advanced to the extent necessary to enable highway engineers to proceed with certainty.

It seems imperative that investigation in the field of highway engineering be prosecuted with the utmost vigor during the next few years, else it will be found that much of the money expended for highway improvement has not secured highways of the maximum serviceability because the design and the requirements for materials were based on unsound theories or inadequate tests.

TO SECURE SERVICEABLE ROADS.

Basic theory, if there is any, for a science as complex as the building of a system of highways for a nation can not be evolved overnight except in the fertile brain of the professional good roads enthusiast of the parasite type, and no two of them agree. Years of painstaking research on the part of many men are required to secure the data upon which theories may be based. Likewise, the correlation of tests for materials with actual results obtained with the materials under service conditions requires the accumulation of data for years before dependable conclusions can be reached.

There is at the present time an urgent need for the inauguration of a far sighted, comprehensive program of investigation of materials and methods of construction now employed in highway improvement. How can such a program be arranged for with reasonable certainty that it will be carried through?

DIFFICULTIES OF THE PROBLEM.

Nearly all of the State highway departments are loaded down with the practical problems involved in carrying through successfully a large construction program. Some have done excellent research work in limited fields, and a few are still attempting to maintain some experimental work.

Through the standing committee on tests and investigations of the American Association of State Highway Departments, an attempt is being made to make available to all State highway departments the results of any investigations completed by any one of the departments. But at best the State highway departments can scarcely touch the field.

Many of the land grant colleges maintain agricultural experiment stations, which are at least partly supported by Federal appropriations, and these stations, in cooperation with the United States Department of Agriculture, have done excellent work. There seems to be no reason why engineering experiment stations should not be maintained in the same way, and if they were interested in the investigation of highway problems, they should be able to contribute enormously to the solution of the many problems now confronting the road builder. Some States now support engineering experiment stations that have done splendid work, and the only bar to similar results at other institutions seems to be lack of financial support.

The recently organized National Research Council is making an effort to stimulate research in the highway field, and should prove to be an important agency in directing efforts so as to prevent duplication and in interesting investigators in the problems requiring solution.

HOW THE WORK MAY BE DONE.

But none of these agencies seem to possess the permanency and financial backing necessary to prosecute a program of investigations adequate to the present needs in the highway field. It is highly important that there be a continuing policy, for a term of years, through an agency of sufficient prestige to secure cooperation throughout the United States, and having sufficiently close connection with the actual construction activities of the several States to insure a wise selection of projects.

The Bureau of Public Roads of the United States Department of Agriculture would seem to be the logical agency to take the lead in this work. The bureau has already done a large amount of research work in this field and has trained investigators for carrying on the work and for passing on projects submitted for action. Through cooperation with the National Research Council, the bureau could probably secure the active participation of engineering experimental station laboratories.

But most important of all, the bureau is in close touch with the highway work in the various States and is in a position to judge as to the problems most imperative of solution and to secure the assistance of the State highway departments in those problems requiring the actual construction of surfaces or structures.

Surfaced highways of the maximum serviceability can not be constructed if engineers are compelled to guess at the basic principles involved nor if they are unable to determine accurately the suitability of materials. The Bureau of Public Roads can do no more valuable service than to secure, by whatever means it can devise, the scientific investigation of the various problems requiring solution before engineers can proceed with certainty in the construction of public highways.

MEMORANDA ON MR. AGG'S ARTICLE.

I have read with very great interest the short but inclusive article by Mr. Agg on the present great American highway problem, and the necessity of extensive investigations if some or all of the States are not to spend unwisely in the prosecution of the present tremendous road programs.

I agree thoroughly with Mr. Agg in his statements that the present facilities for highway engineering investigations are not adequate to meet the situation, or to develop the theories upon which the future science of highway engineering should be based.

It is to my mind certain that unless the United States Bureau of Public Roads builds up a good and extensive organization to prosecute these inquiries, that nothing of value can or will be done by any other existing organization.

I trust that the Secretary of Agriculture will see the advisability of an early attack upon this most important problem, and I believe that I am safe in pledging the cordial support of the American Association of State Highway Officials to the Secretary and to the bureau in this very great and necessary work. *A. R. Hirst, President, American Association of State Highway Officials.*

$3,750,000 FOR ROADS.

St. Louis County, Mo., will spend $3,750,000 for county highways, this sum being derived from a bond issue and from State and Federal funds. The bond issue is for $3,000,000. The county highway engineer has been appointed by the county court to supervise the construction of the roads. He is now engaged in making the plans, which it is hoped will be ready to submit to the Bureau of Good Roads by October 1. Four roads are to be built. The roads will be partly concrete and partly bituminous macadam. Bids will be advertised during the coming winter so that work can start early in the s ring.

VENTURA COUNTY BONDS.

Ventura County, Calif., on August 26, voted for the issuance of $480,000 of road bonds, making a total of $1,580,000 in two years.

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ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

NOTE.—Applications for the free publications in this list should be made to the Chief of the Division of Publications, U. S. Department of Agriculture, Washington, D. C. 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 Office of Public Roads for 1914. 5c.
*Report of the Director of the Office of Public Roads for 1915. 5c.
Report of the Director of the Office of Public Roads for 1916.
Report of the Director of the Office of Public Roads for 1917.
Report of the Director of the Bureau of Public Roads for 1918.

BULLETINS.

(In applying for these publications the name of the office as well as the number of the bulletin should be given, as "Office of Public Roads Bulletin No. 28.")

*Bul. 28. The Decomposition of the Feldspars (1907). 10c.
*37. Examination and classification of Rocks for Road Building, including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.
*48. Repair and Maintenance of Highways (1913).

DEPARTMENT BULLETINS.

(In applying for these bulletins the name should be given as follows: "Department Bulletin No. 53.")

*Dept. Bul. 53. Object-Lesson and Experimental Roads and Bridge Construction on the U. S. Office of Public Roads, 1912–13. 5c.
105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
230. Oil Mixed Portland Cement Concrete.
24. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*284. Construction and Maintenance of Roads and Bridges from July 1, 1913, to December 31, 1914. 10c.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States.
387. Public Road Mileage and Revenues in the Southern States.
388. Public Road Mileage and Revenues in the New England States.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States. A Summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
463. Earth, Sand-Clay, and Gravel Roads.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests.
*555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials. 10c.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.

OFFICE OF PUBLIC ROADS CIRCULARS.

(In applying for these circulars the name of the office as well as the number of the circular should be given as "Office of Public Roads Circular No. 89.")

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Prservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*96. Naphthalenes in Road Tars. 1. The Effect of Naphthalene upon the Consistency of Refined Tars. (1911.) 5c.
*97. Coke-Oven Tars of the United States. (1912.) 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. *49. Motor Vehicle Registrations and Revenues, 1914. 5c.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
62. Factors of Apportionment to States under Federal Aid Road Act Appropriation for the Fiscal Year 1917.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
*72. Width of Wagon Tires Recommended for Loads of Varying Magniture on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.

FARMERS' BULLETIN.

(The Farmers' Bulletins are a series of popular treatises issued by the Department of Agriculture. The following list includes only numbers contributed by the Office of Public Roads, and should be applied for by numbers, as "Farmers' Bulletin No. 239.")

F. B. *239. The Corrosion of Wire Fence. 5c.
311. Sand-Clay and Burnt-Clay Roads.
338. Macadam Roads.
*403. The Construction of Concrete Fence Posts. 5c.
*461. The Use of Concrete on the Farm.
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

(In applying for these separates the numbers should be given as "Yearbook Separate No. 638.")

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
*712. Sewage Disposal on the Farm. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways.

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 Cements.
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.
Vol. 6, No. 6, D–8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
*Vol. 10, No. 5, D–12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction. 15c.
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.

* Department supply exhausted.