THE GRADING OF EARTH ROADS

BY

WILBUR M. WILSON

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BY

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THE GRADING OF EARTH ROADS

I. INTRODUCTION

1. Preliminary Statement.—Illinois is engaged in a program of hard road construction. With the present rate of construction, however, the greater number of highways in the state for many years to come will continue to be earth roads, for even if one thousand miles of hard roads were built each year, it would be a century before all the roads in Illinois would be paved. Since the demand is insistent for good roads, obviously one solution includes improving the earth roads.

Nearly all experimental investigations on highway surfaces have been concerned with pavement, and scarcely any attention in a scientific way has been devoted to improving earth roads. The pressing need for more good roads makes it desirable that an effort be made to ascertain the possibilities of earth roads in order to answer the question: Can an earth road, at a comparatively small annual expenditure, be maintained so as to give satisfactory service through the year for light to moderate traffic?

2. Purpose of Circular.—In order to study the possibilities of earth roads, the Department of Civil Engineering of the University of Illinois, in cooperation with the authorities of Champaign County, has undertaken an experiment on an earth road approximately twelve miles long, subject to normal traffic.

Although there is nothing essentially new about the way in which the grading on the experimental road was done, the operators were so successful in constructing a good earth road at a moderate expense that it seems advisable to give road officials and grader operators information concerning the operation of the grader.

Grading the road was only an incidental part of an investigation that was planned to determine: first, the proper way to oil a road; second, the proper quantity of oil to use; third, the relative merits of various kinds of oil; fourth, the number of days of good roads per year that can be obtained by properly maintaining an oiled road; and fifth, the cost per year of a well-maintained oiled road. Thus, the investigation will probably extend over a period of at least three years. Considerable time must also elapse before any report can be made of the results obtained by the use of different kinds and quantities of oil. Progress reports may be issued from time to time as data of value are
collected. In the meantime, a description of the method of grading the road, and an analysis of the grading cost, which this circular gives, will prove serviceable.

3. Acknowledgments.—The investigation conducted on the experimental road is a part of the research work of the Engineering Experiment Station of the University of Illinois, and was carried on under the general supervision of Professors I. O. Baker and C. C. Williams, successively Heads of the Department of Civil Engineering. Mr. C. C. Wiley, Assistant Professor of Highway Engineering, rendered valuable service as consultant in all stages of the work. Mr. C. B. Schmeltzer, Instructor in Surveying, was in charge of the surveying.

Experimental work on so large a scale was made possible only by the cooperation of the road officials of Champaign County and by the assistance of the commercial organizations interested in road improvement. The Holt Manufacturing Company, Peoria, Illinois, furnished a 10-ton caterpillar tractor and an operator to grade the road; J. D. Adams and Company, Indianapolis, Indiana, supplied a 12-ft. grader and an operator to grade the road, in addition to a 6½-ft. patrol grader to maintain it; the Bayne Manufacturing Company, Bushnell, Illinois, contributed a 6-ft. drag equipped with a two-edged cutting blade for maintaining the road; the Nelson Concrete Culvert Company, Pontiac, Illinois, furnished the concrete culverts at one-half price; the Russel Grader Company, Cicero, Illinois, and the Illinois Corrugated Metal Company, Springfield, Illinois, each provided nine corrugated steel culverts.

The following oil companies each donated a car of road oil, f. o. b. Champaign, Illinois: the Empire Refineries Company, the Standard Oil Company, and the Asphalt Sales Corporation, of Chicago, Illinois; the Roxana Petroleum Corporation, and the Cabell Petroleum Company of St. Louis, Missouri; and the Indian Refining Company of Lawrenceville, Illinois.

Mr. John Batemen, Fisher, Illinois, applied part of the oil without charge.

Mr. R. F. Fisher, County Superintendent of Highways, Champaign County, assisted in planning and executing the work. Champaign County bore the expense of improving the road, exclusive of the labor, equipment, and material contributed as previously stated. The County also provided a patrolman to maintain the road.
II. Work Preliminary to Grading

4. Aligning Ditches.—Although a good grader operator can run a fairly straight ditch without the assistance of a staked line, an accurate survey is desirable in order that the roadbed may be properly located on the right of way. If a survey is made, line stakes should be set on the center lines of the ditches. Laths set at intervals of about three hundred feet make a good line.

5. Clearing Right of Way.—Tall grass and weeds can be handled with a grader, but they are usually discharged in bunches which make the road surface rough. Moreover, bunches of vegetation which have been covered with fine earth will later decay, causing a depression in the road, even though the road, when finished, is perfectly smooth. If, therefore, tall grass or weeds cover the right of way they should be mowed early so that the vegetation can be burned, or raked and hauled away before grading is begun. This will result in a better road; and the cost of clearing the surface of the road will be recompensed by the amount of labor saved in grading.

As bushes and small trees can be torn out by the grader blade, they will cause no delay, provided the grader crew includes a helper who can remove the brush. Trees too large to be removed with the grader, but under six or eight inches in diameter, can be pulled out by the tractor with a cable. Larger trees should be cut down, and the stumps blown out with explosives.

With the equipment now available, it is poor economy to use hand labor for clearing bushes and trees except to remove the resulting brush.

6. Road Cross-section.—The typical cross-section for the experimental road is represented in Fig. 1. Although this cross-section has not been taken as a whole from any one standard, it is approximately the same as has been successfully used on the patrolled earth roads of Nebraska and other central states. The crown was purposely made very flat; the shoulders were well defined in order to separate the side ditches from the wearing surface. Nevertheless, the inside face of the ditch is flat enough to prevent the overturning of a car that has

![Fig. 1. Typical Cross-section of Experimental Earth Road](image)

Experience during the first season indicates that the road would be improved by increasing the crown from six to nine inches.
A shallow cut produces thin, pliable sods that can be cut up by the tractor and covered.
got into the ditch. The outside face is inclined instead of being vertical as in most earth-road construction. By having the back face inclined, the bank does not crumble down, nor does the ditch fill as rapidly as when the usual type of ditch with a vertical back face is used.

As a result of experience with the experimental road during the summer of 1922, it is believed that the crown as constructed was a little too flat. Traffic produces a depression which, in the case of a flat road, will not drain satisfactorily. Increasing the crown from six to nine inches would probably be beneficial. However, the excessive crown which is used very extensively in Central Illinois is distinctly detrimental.

III. Work of Grading Road

7. Successive Rounds of Grader.—The figures used to illustrate the method of grading an earth road are reproduced from photographs of the University of Illinois experimental earth road. While one section of the road was being graded, a photograph was taken from the same point after each passage of the grader.

Fig. 2 shows the condition of the road just before grading was begun at 10 a.m. June 26, 1922. The road had not been graded for a number of years, and there was no sign of side ditches. This particular piece of the road had good longitudinal drainage; and, as there had been no rain for some time, the narrow track actually in use was in fairly good condition.

The cut taken by the grader on the first round is shown in Fig. 3. For this first cut on a road, the blade is set practically parallel to the existing surface, and is swung around until it is nearly parallel to the edge of the road.

When the grading has been completed, the surface of the road should be free from sods. This requires that the sods be reduced to a minimum and that the quantity of fine earth be a maximum. As most of the sods come from the first cut of the grader, this cut should be as shallow as possible without permitting the blade to come out of the ground; under ordinary conditions this will mean a cut two or three inches deep. The resulting sods will be thin and pliable; in addition, the total volume of sods will be small, and they can be easily cut up and covered.

In making the first cut, the point of the blade should be kept a few inches inside the outer edge of the finished ditch. Then, by having each of the successive ditch-cuts a little deeper and a little nearer the center of the road, the roughed ditch will have a stepped back
face as shown in cross-section by the dotted lines of Fig. 4. With the point of the blade located as described, and with the stake-line at the middle of the ditch, the operator will be in a position to sight along the stake-line when he makes the first cut.

![Diagram of cross-section showing cuts taken by successive passages of grader]  

**Fig. 4. Cross-section Showing Cuts Taken by Successive Passages of Grader**  
As the point of the blade is lowered for the successive rounds, the heel is raised so as not to disturb the shoulder AB. For successive cuts the point of the blade is kept away from the finished back slope.

It is very important that the first cut be straight, as the succeeding cuts are governed by the first, and any curve which appears in the first cut is likely to persist in the finished ditch.

The second cut of the grader is illustrated in Fig. 5. For this cut, the point of the blade was set a little deeper than the heel in order that the ditch might be deepened without disturbing the earth which forms the shoulder. The dotted lines in Fig. 4 represent a section of the second ditch-cut. It is to be noted that the second cut does not extend as far to the right as the first, and that the stepped face of the rough back slope becomes apparent. The second ditch-cut should be as heavy as the equipment will stand in order that the maximum of grading can be done with the minimum number of rounds.

Figs. 3 and 5 show the spoil from the ditch-cuts being delivered on the line of the finished shoulder. The grader should be hitched to the tractor with just enough offset to insure that, with the grader making a ditch-cut, the outside wheel (or track, in the case of a caterpillar tractor) of the tractor will run on this spoil. The relative positions of the grader and tractor are shown in Fig. 14.

There are three distinct advantages in having the tractor run on the shoulder when the grader is in the ditch. First, the tractor is clear of mud and water, and it can, therefore, deliver a maximum drawbar pull. Second, the sods during the first ditch-cut are cut to pieces and rolled down during the second cut so that the grader, in transferring earth from the shoulder to the center of the road, does not
FIG. 5. SECOND DITCH-CUT
The spoil is delivered at the heel of the blade.

FIG. 6. THIRD ROUND OF GRADER
The loose earth is transferred from the shoulder toward the center of the road.
move the sods. Thus, the sods are not only kept off the center of the road, but by the time the road is finished, they have been for the most part entirely cut to pieces. Third, since successive passages of the tractor pack the shoulder, by the time the road is finished, the shoulder is solid and more stable than a shoulder of loose earth would be.

The third round of the grader is illustrated in Fig. 6. The purpose of this round is to move the excess earth from the shoulder toward the center of the road. For this work the blade should be set a little straighter across the road than for the ditch-cuts. This is done in order that the earth may be transferred a maximum distance with a single passage of the grader.

The blade should also be placed low enough to transfer the loose earth resulting from the second ditch-cut, but high enough to slip over and scatter the sods of the first ditch-cut, without actually bringing them to the left-hand end of the blade. If this is done, and it can be done with a high degree of success by a competent operator, the loose earth will be in the center of the road, and the sods will remain at the shoulder where they are further ground up and packed down by successive passages of the tractor.

Transferring the earth from the shoulder toward the center of the road necessitates a much smaller drawbar pull than the ditch-cut does so that, if a tractor having three speeds is used, it can be run in "intermediate" or even possibly in "high" for this round, thus expediting the work.

Fig. 7 shows the fourth round of the grader, which was the third ditch-cut, the earth removed from the ditch being represented in cross-section by the dotted lines of Fig. 4. For this cut, the blade was again set nearly parallel to the edge of the road; the point of the blade was set down while the heel was kept up so as to clear the solid ground at the shoulder and to deliver the spoil just inside the shoulder line; the point was kept back from the back face in order to cut another step in the rough back slope. This passage of the grader left a ridge of mellow earth on top of the sods just inside the shoulder line.

Fig. 8 presents the fifth round of the grader. In this operation the loose earth was transferred from the shoulder toward the center of the road. As in the third round, the blade can be set a little more across the road than for the ditch-cut; and the tractor, if it has three speeds, can be run in "intermediate" or "high."

During the sixth round (Fig. 9), the loose earth was brought still nearer to the center. The blade was set as in the previous round, while the tractor was run in "high."

On its seventh round the grader made the fourth ditch-cut (Fig. 10), the blade being in a position similar to that in the former ditch-cut except that the point was lower and the heel higher. The earth
The ditch is deepened, and the spoil is delivered onto the shoulder.

The loose earth is transferred from the shoulder toward the center of the road, and a ridge is formed at the heel of the blade.
FIG. 9. SIXTH ROUND OF GRADER
The earth in the ridge formed by the previous round is transferred toward the center of the road.

FIG. 10. SEVENTH ROUND OF GRADER AND FOURTH DITCH-CUT
The ditch is deepened, and the spoil is delivered onto the shoulder.
FIG. 11. EIGHTH ROUND OF GRADER
The loose earth is transferred from the shoulder toward the center of the road, and a ridge is formed at the heel of the blade.

FIG. 12. NINTH ROUND OF GRADER
The earth in the ridge formed by the previous round is transferred toward the center of the road.
moved with this cut is represented in cross-section by the dotted lines in Fig. 4. The earth taken from the ditch was deposited as a ridge a little inside the shoulder line.

The eighth and ninth rounds are illustrated in Figs. 11 and 12. These operations carried the loose earth from the shoulder toward the center and distributed it in such a way that at the end of the ninth round the road approximated the finished section. These two rounds as a rule do not differ essentially from the fifth and sixth ones; but in the case of unbalanced roads there is a difference, for the balancing of the cross-section, which should be begun at this point, occurs in the eighth and ninth passages of the grader. The method of balancing the cross-section is described in Section 9.

Fig. 13 shows the tenth round, which was the fifth and last ditch-cut. For this operation the back-sloper was attached to the blade not only to deepen the ditch and cut the shoulder face, but also to trim the back face of the ditch. The grader moved a much larger quantity of earth with this cut than with any other. In order to deliver this earth to the shoulder, the blade should be tipped forward at the top. This cut deposited on the shoulder a great amount of loose earth, which was in excellent condition for distributing over the road in order to form the finishing surface.

By cutting the back slope smooth and at an easy grade, the grader makes a ditch much less likely to fill than if the back slope is left rough or vertical. Besides, the smoothly-cut back slope gives the road a finished appearance. Fig. 14 shows the grader with the back-sloper attached.

As a result of the eleventh and twelfth rounds (Figs. 15 and 16) the loose earth was again transferred from the shoulder toward the center of the road, and the road was brought to a finished surface. Fig. 17, made from a photograph taken at 5 P.M. on June 26, 1922, shows a portion of the road after the twelfth and last round had been completed.

A study of Figs. 2 and 17 will show the amount of work done on this 1400-foot section of the road between 10 A.M. and 5 P.M. of the same day.

8. Use of Patrol Grader.—As the large grader leaves the earth in the road loose, the traction of vehicles is heavy. The road will gradually consolidate under traffic, but if no maintenance work is done, ruts, which will be difficult to eliminate, will form. Experience on the experimental road demonstrates that a patrol grader can be used to advantage after the work of the heavy grader has been performed.

A 6½-ft. horse-drawn patrol grader was used to complete the construction. The patrol grader was put on the road when the big
The ditch is deepened, and the back slope is trimmed.

Although the grader is direct-connected with the tractor, it is offset from the tractor so that the tractor is on the shoulder and the grader is in the ditch.
The earth is transferred from the shoulder toward the center of the road, and a ridge is formed at the heel of the blade. The back-sloper is used for this round to prevent the loose earth from rolling into the ditch.

The earth in the ridge formed by the previous round is transferred toward the center of the road.
The photographs from which Figs. 2 and 17 were made were taken on the same day.

The earth is rolled back and forth across the road, the clods are broken, the earth is compacted, the holes are filled, the ridges are eliminated, and the road is shaped generally.
grader had finished its work. The most satisfactory results were obtained by setting the patrol grader so that it carried nearly two-thirds of a bladeful of earth ahead of the blade and delivered a small ridge of loose earth at the heel. In this way, successive rounds rolled the loose soil back and forth across the road, broke up clods, compacted the loose earth, and shaped the section generally. The operation of the patrol grader is illustrated in Fig. 18.

Work on the road indicates that it is profitable to use the patrol grader about one day on each mile of new grade. In addition to this, the road should be patrolled from time to time as ruts are formed by traffic.

Fig. 21 shows a portion of the experimental road before it was oiled and six weeks after it was graded.

As previously stated, twelve rounds of the grader were required to grade the road. The number of rounds necessary in any particular case, however, will depend upon the initial condition of the road and upon the depth of ditch desired, but in general the number will vary from ten to twelve. However, this number does not provide for any longitudinal hauling or for balancing a road which has one side considerably higher than the other.

9. Balancing a Cross-section.—If one side of a road is higher than the other, the road is said to be unbalanced. In grading such a road, it is necessary to transfer earth from one side to the other. To do this the operator often makes extra rounds at the point where the road is unbalanced, but he can balance the cross-section without additional rounds if he manipulates the grader properly.

The heavy full lines of Fig. 19 represent the cross-section of an unbalanced highway after the third ditch-cut has been made; the dotted lines indicate a section of the same road after an additional round for transferring the earth toward the center of the road. On the low side, the grader has been adjusted so that the blade just scrapes the top of the spoil and leaves most of the loose earth from the ditch on the low shoulder. On the high side, the grader is set so that practically all the spoil is carried toward the center and very little is left on the high shoulder. If the same operation is repeated in transferring the soil toward the center after the fourth and fifth ditch-cuts, a considerable lack of balance can be eliminated without additional rounds of the grader.

10. Length of Grading Unit.—The length of road to be graded as a unit depends upon the equipment and the local conditions on the road. Inasmuch as roads while being graded are almost impassable, it is desirable to grade the road in short sections wherever feasible so that the amount of poor road will be a minimum. On the other hand, if the equipment is of such a nature that each turn requires several
minutes, it may be preferable to grade the road in long sections in order to reduce the time lost in turning.

With the equipment used on the experimental road, a complete turn could be made in considerably less than a minute, and the time lost in turning had practically no influence upon the selection of the length of the section to be graded as a unit. With this type of equipment, a section one mile long is recommended as a maximum.

On the experimental road, nine units had an average length of 1.08 miles and six units an average length of 0.33 miles. In computing the grading time in hours per mile, it was found that the average for the nine long units was exactly the same as for the six short units. The rate of moving the earth was 109 cubic yards per hour for the nine long units and 126 cubic yards for the six short units, due to the fact that the grading conditions were a little more favorable for the short units than for the long ones. The unit of length, however, furnishes a better basis of comparison than yardage in considering grader performance under the conditions existing on the experimental road. Apparently, therefore, the time required to grade a road is but little affected by the length of the grading unit when the latter varies between one-third mile and one mile.

A length of one mile is recommended as a grading unit except where local conditions such as corners, bridges, and material changes in the section require the use of a shorter unit. Proper regard for the convenience of the traveling public should prevent the use of a grading unit in excess of one mile except under unusual conditions.

11. Equipment.—By referring to Section 15, it is seen that the largest single item in the cost of grading a road is the fixed charge against the machinery. This being true, it is essential that the equipment be well suited to the work to be done.

With a total operating cost of approximately $50.00 per day, it is important that the equipment be operated full time every day. One of the essential requirements in the equipment is accordingly reliabil-
ity, that is, it should be free from parts which break, wear out, or fail to function. In addition to reliability, the grader should have strength and capacity commensurate with the work to be accomplished, and it should be easy to manipulate. Next to reliability, probably the most important feature in a tractor is flexibility of operation—large drawbar pull at low speed and high speed at small drawbar pull. In addition to these requirements, the ability to operate on all kinds of uneven ground and to turn quickly in a small space is highly important. The ability of a grader to stay true to line when offset from the tractor and directly connected with it, as illustrated in Fig. 14, is also a valuable characteristic. The best equipment is that which combines these desirable features with a moderate cost.

12. Operator.—In addition to selecting good equipment, to build good roads at a moderate expense it is necessary that the equipment be operated efficiently. A good grader operator is a skilled mechanic and not an unskilled laborer. The inability to appreciate the importance of this fact often causes high costs in road construction. An operator should be chosen because of his skill and energy in operating good grader machinery and not, as is too often the case, for other reasons. County and township officials cannot encourage earth-road improvement in any better way than by paying wages which will command the services of good operators, and by seeing that the operators hired are skillful and energetic.

IV. Initial Cost of Road

13. Items Included in Initial Cost of Road.—Records have been kept from which the initial cost of the experimental road has been computed. This initial cost includes the cost of surveying, grading, finishing the road with a patrol grader, the cost of culverts and other miscellaneous items. In arriving at the figure given, the cost of all labor and material has been treated as if it had been paid for instead of having been contributed.

14. Surveying.—In order to locate the center-line of the ditch, a transit line was run on the center-line of the right of way from section monument to section monument, and offsets were measured in both directions from this transit line. Along each ditch center-line so located, a line of stakes consisting of laths four feet long were set at intervals of three hundred feet. Cross-section measurements were taken at every hundred feet before and after grading to provide data from which the yardage could be computed; this was necessary as a part of the test, but as it was not essential to the construction of the road, its cost was not included in the general statement. The survey-
ing charged against the road, therefore, pertains only to the running
of the transit line and the setting of the two stake-lines for the ditches.

A four-man party at $21.00 per day set on the average approximately 2½ miles per day at a cost of $8.40 per mile. If the cost of
the stakes was taken as $1.00 per mile, the total cost of surveying chargeable to the construction of the road was thus $9.40 per mile.

15. Grading.—The road was graded in sixteen units varying in
length from one-fourth of a mile to one and one-half miles. Records
were kept giving the number of days and also the number of hours
the grader outfit worked on each unit, and the quantity of gasoline, oil, and grease used each day.

The tractor used on this work retails at $6050 and the grader,
including back-sloper, at $1573, both prices being for the machinery
delivered in Champaign County; this equipment is shown in Fig. 20.
The life of machinery cannot be exactly determined, but a reasonable
estimate for the equipment used would be to assume that it would
last five years, working 120 days per year, at the kind of work and
under conditions prevailing on the experimental road. The fixed
charges have, consequently, been estimated as follows:

<table>
<thead>
<tr>
<th>Initial Cost of Machinery</th>
<th>Annual Cost of Machinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor ................. $6050.00</td>
<td>Depreciation at 20% .... $1524.60</td>
</tr>
<tr>
<td>Grader .................. 1573.00</td>
<td>Interest at 6% ........... 457.38</td>
</tr>
<tr>
<td></td>
<td>Repairs at 4% (estimated) 304.92</td>
</tr>
<tr>
<td>Total ..................... $7623.00</td>
<td>Total ..................... $2286.90</td>
</tr>
</tbody>
</table>

Daily Cost of Machinery, based on 120 days per year ........ $19.05
Hourly Cost of Machinery, based on 9 hours per day .......... 2.11

The grading crew consisted of two machinery operators who re-
ceived $6.00 per day each and a helper who received $3.00. Thus, the
total cost was $15.00 per day, or, for a nine-hour day, $1.66 per hour
for labor.

In the computation of the costs, the operating time was considered
as extending from the time the machinery started in the morning until
it stopped at night exclusive of the dinner hour. No deductions were
made because of stops for repairs, adjustments, demonstrations, etc.

As the machinery companies donated the services of the operators,
there was no special incentive for the men to work a large number
of hours per day, and the average daily operating time for the entire
road was approximately seven hours. If the work had been done by
contract, the working day would have been much longer. With a helper on the crew to do the oiling, greasing, and other odd jobs in the morning and evening, and during the noon hour, a contractor should be able to realize an operating time of nine hours per day. For this reason the costs have been reduced to an hourly rate on the basis of a nine-hour day and the job charged with the actual operating time expressed in hours, instead of using the actual daily rate and the actual number of days worked.

A summary of the data governing the cost of grading the entire experimental road, as taken from the daily records, is given in Table 1, and the total operating cost per hour in Table 2. It is believed that a liberal allowance for overhead is included in the machinery cost and in the item of fifteen per cent for supervision.

**Table 1**

<table>
<thead>
<tr>
<th>Item</th>
<th>For 12.33 mile</th>
<th>For 1 mile</th>
<th>For 1 day</th>
<th>For 1 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days Worked</td>
<td>29.50</td>
<td>2.40</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Hours Worked</td>
<td>210.00</td>
<td>17.03</td>
<td>7.12</td>
<td>...</td>
</tr>
<tr>
<td>Gasoline, gal.</td>
<td>867.00</td>
<td>70.30</td>
<td>29.40</td>
<td>4.140</td>
</tr>
<tr>
<td>Engine Oil, gal.</td>
<td>55.00</td>
<td>4.45</td>
<td>1.86</td>
<td>0.262</td>
</tr>
<tr>
<td>Track Oil, gal.</td>
<td>70.00</td>
<td>5.67</td>
<td>2.38</td>
<td>0.334</td>
</tr>
<tr>
<td>Grease, lb.</td>
<td>50.00</td>
<td>4.65</td>
<td>1.70</td>
<td>0.238</td>
</tr>
</tbody>
</table>
The total cost of grading being $5.91 per hour, and the total operating time 210 hours, the cost per mile of grading the 12.33 miles was $100.65.

The total quantity of earth moved in grading the 12.33 miles, as given by surveys before and after grading, was 22,000 cubic yards or 1,780 cubic yards per mile. The average cost of moving the earth was, therefore, 5.7 cents per cubic yard.

16. Patrolling.—As stated in Section 8, it was found advantageous to work the surface of the newly graded road with a patrol grader. The first work with the patrol has accordingly been charged to initial cost, instead of to maintenance. The unit cost of operating the patrol grader is shown as follows:

Salary
One man and team per month .......... $125.00
Cost per hour on basis of 23 days of
10 hours each per month ............... $0.55

Machinery
Initial cost
Patrol grader ......................... $137.00
Drag .................................. 35.00
Slip .................................. 10.00
Spade, shovel, and other small tools. 10.00

Total initial cost ...................... $192.00

Cost per year
Depreciation .......................... 20% or $38.40
Interest ............................... 6% or 11.52
Repairs and maintenance
(estimated) ......................... 14% or 26.88

Total cost per year .................. 40% or $76.80

Cost per hour on basis of 200 days of
10 hours each per year ............... $0.04

Total cost per hour ................. $0.59, or say $0.60
The records kept during the construction of the road show that the patrolman worked 179 hours in finishing the road with a patrol grader, at a cost of $107.40, or $8.70 per mile when the hourly cost is taken as 60 cents.

17. Culverts.—All culverts extending across the road, and those at farm entrances where the buildings were near the road, were precast reinforced concrete; all other entrance culverts were corrugated steel. The cost of the culverts is given in Table 3. As stated in Section 13, the cost has been estimated at current rates as if no contributions had been received.

The cost of installing the steel culverts, as indicated in Table 3, includes much miscellaneous work. This work comprises temporary filling to take the place of culverts at the time the grading was done; clearing out ditches; refilling over concrete culverts, etc.; and, therefore, the whole item is not properly chargeable to installing the steel culverts, although it is chargeable to road construction.

Table 3

<table>
<thead>
<tr>
<th>Description and Cost of Culverts Installed in Experimental Earth Road</th>
</tr>
</thead>
</table>

### Culverts Across Road

<table>
<thead>
<tr>
<th>Kind</th>
<th>Number</th>
<th>Cross-section in.</th>
<th>Length ft.</th>
<th>Cost per lin. ft. Installed</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>12 by 18</td>
<td>30</td>
<td>$3.50</td>
<td>$1365.00</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>12 by 18</td>
<td>40</td>
<td>3.50</td>
<td>980.00</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12 by 18</td>
<td>50</td>
<td>3.50</td>
<td>175.00</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>18 by 24</td>
<td>30</td>
<td>5.60</td>
<td>168.00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>24 by 24</td>
<td>30</td>
<td>7.00</td>
<td>420.00</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>48 by 48</td>
<td>30</td>
<td>....</td>
<td>693.70</td>
<td></td>
</tr>
</tbody>
</table>

| Concrete | 10 by 18 | 18 | 5.60 | 168.00 |
| Corrugated Steel | 12 in. dia. | 20 | 1.45* | 523.20 |

### Entrance Culverts

| Concrete | 12 by 12 | 22 | 2.80 | 862.40 |
| 1:45 | 2.80 | 95.20 |
| 1:45 | 2.80 | 72.80 |

| Corrugated Steel | 12 in. dia. | 20 | 1.45* | 523.20 |

Total Cost of Culverts for Entire Road .......................................................... $5355.30
Cost of Culverts per Mile of Road ................................................................. 435.00

* The cost of the corrugated steel culverts without installation was at the rate of $1.10 per ft., or for the eighteen corrugated steel culverts it was $396.00.

18. Summary of Cost.—A summary of the cost of building the road, as explained in detail in Sections 13 to 16 inclusive, is found in Table 4.
With the culverts excluded and the surveying and finishing of the road with a patrol grader included, this cost was $118.75 per mile. Although the grading was done by experts, the skill of the operators was not greater than that which can be acquired by men of average intelligence. Moreover, on the experimental road, visitors often delayed the work by interrupting the grader crew. Accordingly, all things considered, the cost given is one that can be duplicated by any well-managed and properly equipped outfit.

**Table 4**

**Summary of Cost of Constructing 12.33 Miles of Experimental Earth Road**

<table>
<thead>
<tr>
<th>Item</th>
<th>Total Cost for 12.33 miles</th>
<th>Total Cost per mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveying</td>
<td>$ 116.00</td>
<td>$ 9.40</td>
</tr>
<tr>
<td>Grading</td>
<td>1241.10</td>
<td>100.65</td>
</tr>
<tr>
<td>Finishing by Patrol Grader</td>
<td>107.40</td>
<td>8.70</td>
</tr>
<tr>
<td>Culverts</td>
<td>5355.90</td>
<td>435.00</td>
</tr>
<tr>
<td>Total</td>
<td>$6819.80</td>
<td>$553.75</td>
</tr>
</tbody>
</table>

**Fig. 21. A Portion of Experimental Earth Road Six Weeks After It Was Graded**
THE UNIVERSITY OF ILLINOIS
THE STATE UNIVERSITY
Urbana
DAVID KINLEY, Ph.D., LL.D., President

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