Highway Improvement

1.

Earth Roads and Culverts

By E. F. Ayres
Highway Engineer
Assistant Professor of Civil Engineering.
Highway Improvement

1.

Earth Roads and Culverts

_by E. F. Ayres_
Highway Engineer
Assistant Professor of Civil Engineering.

The bulletins of the Oregon Agricultural College are free to all residents of Oregon who request them.
INDEX.

INTRODUCTION .................................................................................................................. 7
ADMINISTRATION ............................................................................................................... 11

LOCATION ........................................................................................................................ 15
1. Tractive resistance on different grades ........................................................................... 15
2. Section line roads ........................................................................................................... 15
3. Maximum and minimum grades ..................................................................................... 17
4. Balancing quantities ....................................................................................................... 19
5. The reconnaissance ......................................................................................................... 21
6. Vertical curves ................................................................................................................ 23

DRAINAGE ........................................................................................................................ 26
1. Table of crowns ............................................................................................................... 26
2. Width of highways .......................................................................................................... 27
3. Underdrains .................................................................................................................... 30

CULVERTS AND PROTECTIVE WORK .............................................................................. 34
1. Leeching basins ............................................................................................................... 34
2. Skew culverts .................................................................................................................. 35
3. Wooden box .................................................................................................................... 38
4. Log culvert ...................................................................................................................... 39
5. Vitrified clay pipe ........................................................................................................... 39
6. Cast-iron pipe .................................................................................................................. 41
7. Corrugated metal ............................................................................................................ 41
8. Rubble masonry .............................................................................................................. 44
9. Brick ............................................................................................................................... 45
10. Concrete ........................................................................................................................ 45
11. Specifications for concrete ............................................................................................ 48
12. Protective Work ............................................................................................................. 52

SAND CLAY ROADS .......................................................................................................... 54
1. Construction on clay subsoil ............................................................................................ 55
2. Construction on sand subsoil ........................................................................................... 58

OILED EARTH ROADS ....................................................................................................... 66
1. Mixing method .................................................................................................................. 66
2. Surface treatment .......................................................................................................... 67

BURNT CLAY ROADS ......................................................................................................... 68

MAINTENANCE .................................................................................................................. 70
The road drag ....................................................................................................................... 71

MACHINERY ....................................................................................................................... 76
1. Graders ............................................................................................................................ 76
2. Elevating graders ............................................................................................................. 77
3. Harrows ........................................................................................................................... 78
4. Plows ............................................................................................................................... 78
5. Scrapers ........................................................................................................................... 78
# INDEX TO ILLUSTRATIONS.

## PLATES.

<table>
<thead>
<tr>
<th>Plate.</th>
<th>Page.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Good Roads Exhibit—Oregon Agricultural College</td>
<td>Frontispiece</td>
</tr>
<tr>
<td>II. Hon. Samuel Hill's Road at Maryhill, Washington</td>
<td>8</td>
</tr>
<tr>
<td>III. Willamette Valley Highways</td>
<td>13</td>
</tr>
<tr>
<td>IV. Plan of Road at Union</td>
<td>20</td>
</tr>
<tr>
<td>V. United States Government Map</td>
<td>24</td>
</tr>
<tr>
<td>VI. Fig 1—A type of Culvert to be avoided</td>
<td>36</td>
</tr>
<tr>
<td>Fig. 2—Road in Rogue River Valley</td>
<td>36</td>
</tr>
<tr>
<td>VII. Fig. 1—Destruction of Culvert constructed without Wing Walls</td>
<td>40</td>
</tr>
<tr>
<td>Fig. 2.—Culvert with substantial Abutments and Wing Walls</td>
<td>40</td>
</tr>
<tr>
<td>VIII. Design for Box Culverts</td>
<td>42-43</td>
</tr>
<tr>
<td>IX. Wooden Forms for Concrete Pipes</td>
<td>46</td>
</tr>
<tr>
<td>X. Improper location of Highway Bridge</td>
<td>50</td>
</tr>
<tr>
<td>XI. Mixing Sand and Clay in Florida</td>
<td>56</td>
</tr>
<tr>
<td>XII. Sand Roads of Eastern Oregon</td>
<td>60</td>
</tr>
<tr>
<td>XIII. The Road Drag</td>
<td>72</td>
</tr>
<tr>
<td>XIV. Fig. 1.—A Road in Arkansas that has not been Dragged</td>
<td>74</td>
</tr>
<tr>
<td>Fig. 2.—A Road in Arkansas that has been Systematically Dragged</td>
<td>74</td>
</tr>
</tbody>
</table>

## TEXT FIGURES.

<table>
<thead>
<tr>
<th>Fig.</th>
<th>Page.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Section Line Location</td>
<td>16</td>
</tr>
<tr>
<td>2. Correct Method of Reducing Grade</td>
<td>18</td>
</tr>
<tr>
<td>3. Balancing Quantities—Side Hill Work</td>
<td>21</td>
</tr>
<tr>
<td>4. Cutting Out Unnecessary Culverts</td>
<td>22</td>
</tr>
<tr>
<td>5. Vertical Curves</td>
<td>23</td>
</tr>
<tr>
<td>6. Too Wide to Maintain</td>
<td>27</td>
</tr>
<tr>
<td>7. Cross Section for Narrow Roads</td>
<td>28</td>
</tr>
<tr>
<td>8. Standard Cross Sections</td>
<td>29</td>
</tr>
<tr>
<td>9. Stone and Tile Underdrains</td>
<td>31</td>
</tr>
<tr>
<td>10. Leeching Basins</td>
<td>34</td>
</tr>
<tr>
<td>11. Skew Culvert with Stop Wall on Inlet End</td>
<td>35</td>
</tr>
<tr>
<td>12. Corrugated Metal Culverts</td>
<td>44</td>
</tr>
<tr>
<td>13. Concrete Head Walls for Pipe Culverts</td>
<td>47</td>
</tr>
<tr>
<td>14. Relation of Length of Culvert to Height of Fill</td>
<td>48</td>
</tr>
<tr>
<td>15. Guard Rail</td>
<td>53</td>
</tr>
<tr>
<td>16. Correct Mixture of Sand and Clay</td>
<td>57</td>
</tr>
<tr>
<td>17. Poor Mixture; not enough Sand</td>
<td>58</td>
</tr>
<tr>
<td>18. Petrolithic Roller</td>
<td>67</td>
</tr>
<tr>
<td>19. Grader</td>
<td>76</td>
</tr>
<tr>
<td>20. Elevating Grader</td>
<td>77</td>
</tr>
<tr>
<td>21. Road Plow</td>
<td>78</td>
</tr>
<tr>
<td>22. Drag Scraper</td>
<td>78</td>
</tr>
<tr>
<td>23. Wheeled Scraper</td>
<td>79</td>
</tr>
</tbody>
</table>
INTRODUCTION.

The roads of a country are accurate and certain tests of the degree of its civilization.—Gillespie.

When some progressive antediluvian shocked his contemporaries by bringing his game to camp on a horse, the Good Roads movement was inaugurated. Had he shown proper respect for precedent he would have shouldered his load, although custom sanctioned the use of rude boats in case he was fortunate enough to be near a stream.

Other members of the tribe soon appreciated the many advantages of the new method, and well-defined trails were opened through the wilderness. These were laid out by the animals themselves, the only assistance rendered by their drivers being the occasional removal of a tree which fell across the path.

No further progress was made until the advent of wheeled vehicles. These required a wider path, and the trail began remotely to resemble a road. No attention was paid to proper location, grades or drainage, but even the slight amount of work required was bitterly opposed by the owners of the pack teams, who foresaw that their business would be ruined if the newer transportation gained a foothold. They claimed that the wide roads were unnecessary; that the new contraption was simply a passing fad, suitable for a rich man’s toy, but impossible as a practical vehicle; that the taxes would ruin the country unless the wagon men were forced to pay the entire cost of the improvement; in short, that the roads which had sufficed for their fathers should be good enough for them. These same arguments were revived on the advent of the bicycle and the automobile, the teamsters in the meantime having forgotten their early trials and joined the reactionaries.

So far, each advance in transportation had rendered obsolete the preceding method, and when the railway came, it was assumed that there would be no further use for wagon roads. The Federal Government stopped work on its system of military highways, the states preferred to finance any railroad project rather than improve their roads, and the counties and townships followed suit with great
HON. SAMUEL HILL'S ROAD AT MARYHILL, WASHINGTON,
Bottom: Before Improvement.
Top: Hauling Grain Over Improved Road.
unanimity. The railroads were only too glad to foster this sentiment, until it became evident that they could not properly perform their functions without a better system of primary transportation.

The highways of America remained as horrible examples until 1885, when the modern Good Roads movement rode in on a bicycle. Few there were to befriend it, and a campaign of education had to be waged before any legislature would risk the wrath of its constituents by voting money for any such foolish notion. New Jersey finally took the plunge in 1891, Massachusetts followed in 1892, and since then the different states have adopted similar systems until only 15 remain which do not in some form give state aid. Some of the commonwealths give no money, simply appointing an engineer to act in an advisory capacity, while others pay from 25% to 100% of the cost of improvement.

No issue before the American people affects the entire country more than better highways. An excessive tariff is burdensome to the many, but at least it is satisfactory to a few, while bad roads injure all alike. To the cities, better roads mean increased prosperity, on account of greater commerce with the country districts, without which no city can maintain her supremacy. To the railroads, good roads mean more traffic and less freight congestion, as the farmer can haul his produce when it suits him instead of having to wait for good weather. Better roads also bring more settlers, more tourists and more industries, all of which the railroad must have to live.

To the automobilist, the improved roads mean opportunities to get the full use of the car every day, instead of being obliged to wait until the highways happen to be in passable condition.

To the farmer, better roads frequently mean the difference between affluence and bankruptcy. To illustrate: A Wisconsin farmer held 1,000 bushels of potatoes in his cellar, waiting for a good price. He was offered 92 cents in March, but the potatoes must be delivered in town, and the roads were in such condition that delivery was impossible. When the roads finally dried out, he took his potatoes to market and got 30 cents a bushel. The bad roads cost him $620; as a consequence, he is now an ardent booster for any movement which promises better facilities for marketing.

While the farmer receives as great financial gains from good roads as anyone, he has an added advantage in the social benefits involved. Under present conditions it is frequently impossible for his children to go to school regularly, his family to attend church,
his physician to reach him in time to be of greatest assistance, or
his mail to be delivered daily. With better roads, all this can be
changed, for graded schools and larger churches always follow these
improvements.

In order to secure the advantages of better transportation
facilities, it is not necessary that a great deal of money be spent
on our highways, but what is spent should be spent carefully and
intelligently. A very few dollars invested at the right time will
save repairs costing hundreds, and most of the roads of Oregon on
which there is not any heavy through travel can be improved in
this way.

This bulletin simply gives the first steps in road building; but
it should be remembered that this work must be done before any
surfacing is laid, no matter how much money is to be spent. The
foundation must be prepared, and in doing this a very fair road is
made.

In compiling this booklet the author has borrowed liberally
from all sources of road information. Particular acknowledgement
should be given the United States Office of Public Roads, for
to its excellent and untiring work the country owes much of
its advance in highway improvement. The reports of the dif-
ferent states have also been drawn upon largely, and thanks are
due them for the pioneer work they have undertaken, and their
liberality in giving the results of their experiments to the rest of
the country.

Corvallis, Ore., July 1, 1912.  

E. F. Ayres,  
Highway Engineer.
ADMINISTRATION.

In the times which are so frequently referred to as the "good old days," the household was practically sufficient unto itself. Nearly everything needed was made on the farm; the clothing, furniture, utensils, machinery, and last of all, the roads. Today, all of these but one are made by others, the farmer exchanging his product for that of the manufacturing establishment; as he has found that it pays him best to attend strictly to his own line of work and let others specialize in theirs. The one exception is the roads. These are still built by local supervision, and until 1891, when New Jersey passed her State Aid Law, it was a bold man who dared suggest that others might be able to do the job better.

It is only recently that we have come to realize that it is as necessary to have a specialist to look after our highways as it is to have a man properly trained to look after the health of our children. So-called natural doctors have made many wonderful cures, but they have also made mistakes—so many, indeed, that we have passed laws to prevent them from practicing. In the same way, men who have had no training have often built excellent roads; but on the other hand so many have simply wasted the money entrusted to them that we should no longer take these chances.

The movement for better highways is so new in the United States that we have had no opportunity to train men for the positions, with the exception of the few who have learned through practical experience in some or our eastern states. The salary of such men is not princely, but it is more than the road district can afford, even if there were enough of them to fill the places. The county is no better able than the district to shoulder the burden of this expense. It remains for the state to pay the bills.

It is undoubtedly true that a large percent of the money spent on the roads of Oregon and other states is wasted; but it is palpably false to assume that our road officials are dishonest or even careless in its expenditure. We would not dream of appointing our health officers without regard to their education or fitness for the positions, and yet we select our supervisors in this way. A good, conscientious official may learn considerable about roads during
his term of office, but he knows that he must spread the money out thin in order to get a second term. If not, another man is given an opportunity to learn the business at the expense of the community.

Even assuming that our supervisor knows how to build a road, he is handicapped from the start by the lack of an organization. As soon as his men have worked long enough to cover their indebtedness to the county and district, they are obliged to leave in order to attend to their own duties, and the unfortunate supervisor must break in a new crew. This not only takes time, it costs money. Under our present system, however, it is unavoidable.

Another trouble lies in the fact that it is practically impossible for the supervisor to get any gang at all until it is too late to work the roads. To produce the best results the work should be done at the time when the farmer needs all his teams for spring work and even the supervisor does not want to go on the roads. Since he is not paid enough to live on, he, too, must depend on the farm for his income; and so the roads are treated as a side issue.

The supervisor is frequently criticised because he does not obtain the same results as are secured in other sections of the country. The officials west of the Cascades are handicapped by lack of information as to the best way in which to improve the roads to withstand the long rainy winters and the long dry summers. This problem has not confronted the road men of the Eastern states, and yet all the literature on the subject is based on experimental work carried on east of the mountains.

This is a problem which we must solve for ourselves. Experimental roads must be constructed in the different counties to determine the methods of construction and maintenance adapted to the soil and climatic conditions. Much can be learned in the laboratory, but the real test must be on the highway itself. This booklet does not pretend to have solved the questions, but if the instructions given herein are followed, a great improvement will be noted in our country roads, and the taxes will not be materially increased. Later bulletins will be issued to keep the highway officials of the state informed on the progress of the experiments which will be carried on in the near future.

The greatest objection to the district method lies in the fact that the residents of the district pay all, or nearly all, the cost of the work. The old idea that the farmer should pay the entire expense of the road over which he hauls his produce to market is dead. Once in a while it is resurrected by its friends and made to
WILLAMETTE VALLEY HIGHWAYS
go through the motions of a real live issue, but it cannot long stand the strain and soon retires to its well deserved rest. It must be remembered that the farmer hauls his purchases back to the farm over the same highway, and that the city has paid for his produce plus the cost of transportation. If this is doubted, remember how the price of any perishable merchandise soars when the roads are in such shape that the farmer cannot get to town to sell direct to the consumer.

If all our roads were in good condition the cost of hauling would be reduced by at least 10 cents a ton per mile, and the farmer could either sell his goods so much cheaper or have that much more money to put in the bank to finance city projects. In either case the city wins, and should be obliged to pay a portion of the gain by assisting in the construction and maintenance of the road.

Under the district plan of improvement the city pays nothing toward the cost. With the county bonding system, the county in which the large city is located gets the chief benefit, while the other counties suffer. Under the state system only, can the largest taxable valuation be obliged to pay its share of the cost all over the state. And it is no more than right that this should be done. The financial center of any state benefits by every foot of improved road constructed anywhere in the state, and it can be demonstrated that New York and Chicago benefit by improved roads anywhere in the country. National aid is a thing of the future, but until we get it, we cannot tax these cities for Oregon's road system.

It is undoubtedly true that the district should pay a larger percentage of the cost than outside communities, but these should be obliged to help. Without this assistance, no comprehensive plan of road improvement can be worked out, and no permanent benefits can accrue. No private business could live a year without a definite plan of action, nor could it live long if this plan were changed every year. And yet we wonder why our roads seem to remain in the same condition as before, when we neglect the simplest business methods in their construction and maintenance.
LOCATION.

"The fundamental principle of road location is common sense."—Instructions to Engineers, Washington State Highway Department.

The first law in the United States granting permission to different townships to locate new roads was passed by the Massachusetts Bay colony in 1639. It provided that adjoining communities could appoint representatives to lay out the highways, the only limit to their powers being that they could not go through a man's house or his garden. These routes were established with no regard to the engineering problems involved, the lines usually following the old Indian trails, which were laid out on the assumption that a straight line is the shortest distance between two points, forgetting that frequently the distance over the top of a hill is greater than that around the base.

The eastern states are now spending millions in putting these roads in the valleys where they belong. The loss occasioned in hauling over these hills cannot be computed, though the following table, showing the tractive resistance offered by different grades, will give some idea of the tremendous waste of energy since these highways were built.

<table>
<thead>
<tr>
<th>Rate of Inclination</th>
<th>Tractive Force, Pounds Per Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>38</td>
</tr>
<tr>
<td>1 in 500—</td>
<td>0.20 per cent</td>
</tr>
<tr>
<td>1 in 100—</td>
<td>1.00 per cent</td>
</tr>
<tr>
<td>1 in 80—</td>
<td>1.25 per cent</td>
</tr>
<tr>
<td>1 in 60—</td>
<td>1.66 per cent</td>
</tr>
<tr>
<td>1 in 50—</td>
<td>2.00 per cent</td>
</tr>
<tr>
<td>1 in 40—</td>
<td>2.50 per cent</td>
</tr>
<tr>
<td>1 in 30—</td>
<td>3.33 per cent</td>
</tr>
<tr>
<td>1 in 25—</td>
<td>4.00 per cent</td>
</tr>
<tr>
<td>1 in 20—</td>
<td>5.00 per cent</td>
</tr>
<tr>
<td>1 in 15—</td>
<td>6.66 per cent</td>
</tr>
<tr>
<td>1 in 10—</td>
<td>10.00 per cent</td>
</tr>
</tbody>
</table>

Some western states have added a new complication by providing that the section lines shall be public roads. This law always
carries with it a proviso giving the county authorities the right to deviate from the line wherever deviation will improve the grade; but this privilege is rarely used and the section line is held to tenaciously. The following example shows a road in a middle western state where the contract was awarded for improvements costing about $7,000 a mile.

Fig. 1
SECTION LINE LOCATION.

The section line location has a grade of 10 and 12 per cent. By swinging the line 400 feet to the south the grade can be reduced to 3 and 2½ per cent. The owner of the property on the south side of the line has offered to give the necessary right of way and the property owner on the other side has agreed to interpose no objections to the change. The county court, however, decided on the first location because it was directly on the section line, and would have improved the old road had not the taxpayers stopped the work by an injunction.

This is probably an exceptional case, for it is seldom that so much better grades can be secured with such slight variation from the existing line. It shows, however, the necessity for the services of a competent highway engineer.

The location of a new road compared with the relocation of an old one, is a simple matter. In the latter case, there are usually homes on the tops of the hills, and it is manifestly unfair to take away the transportation facilities of these settlers. On the other
hand, it is equally unfair to make succeeding generations climb that unnecessary grade for the accommodation of a few people. The solution of the problem must be governed by local conditions; but in any event, the new road should be placed in the valley. This done, either the old road should be maintained indefinitely by the county for the benefit of the first settlers, or a new one should be built which will give them access to the relocated highway.

That the grade of a road limits the load that can be hauled over it, most people understand; but few understand that this is one of the least of the disadvantages caused by steep grades. With new roads, or in the improvement of old highways, the cost of construction is much higher.

It is much more difficult to drain a highway in the hills than in comparatively level country, for the rain cuts deep gullies in the center of the road before it finds its way to the side ditches. Culverts are needed more frequently and the expense of maintenance is greatly increased. The question of drainage will be more fully treated in a later chapter. The only consideration that is of interest here is that its cost is much higher for poorly located than for well located roads.

The discomfort and even danger of travel is very great on steep hills. While this disadvantage can not be estimated in dollars and cents, it is, nevertheless, very real.

Were it not for the fact that the level road can not be properly drained, the ideal highway would be perfectly straight and level. There is, however, a minimum as well as a maximum grade which must be provided, the minimum being one in two hundred and fifty. Water will hardly flow in the ditches if the grade is much less than this, although if great care is taken in construction, a grade of one in three hundred may be used. The maximum grade for most of the roads in Oregon should be fixed at 5 per cent. Where this is used for short distances, horses can haul a full load. In our hills and mountains it will be frequently difficult to secure a 5 per cent grade without exceeding the cost warranted by the benefits attained, and here 10 per cent should be used.

As an illustration of proper location contrasted with haphazard work, the following example taken from Gillespie may be interesting:

An old road in Angelsea, Wales, 24 miles in length, had a total rise and fall of 3,540 feet. As relocated by Telford the road was only 22 miles long with a total rise and fall of 2,257 feet. Two
miles were saved in distance and over a quarter of a mile in hills by intelligent relocation.

Too much emphasis cannot be placed on the importance of a careful survey and a comprehensive plan before starting any improvement. It makes no difference whether a road is to be macadamized at once or whether an earth road is to be crowned and drained, not one shovelful of earth should be removed until the whole plan has been worked out. Much money spent on grading is wasted because so many yards of the material have to be moved more than once. If it is impossible to reduce a grade entirely in one year, the work can at least be so arranged that next year's work can be carried on without disturbing any material already in place. The accompanying sketch illustrates this point.

![Fig. 2 CORRECT METHOD OF REDUCING GRADE](image)

The heavy line shows the grade to which the road will eventually be built. The dotted line shows the extent to which the work can be carried under one year's levy. It will be noted that the material which has been moved will not have to be disturbed when next year's excavation is made.

While the problem of proper location is directly one for the highway engineer, the following are a few points which may well be noted by the supervisor when it is impossible for him to secure the services of an expert. In the first place, do not make the usual mistake of assuming that the road must be straight, either in line or grade. No one ever saw a path across a field perfectly straight. Examination of the wheel tracks in any road, whether automobile or horse-drawn vehicle, shows that these tracks are never straight. There is no sense in cutting a corner off a hill if one can secure an
easy curve around it, for a curved road is more beautiful and easier on traffic, while the increased length is practically negligible. The curves should be as flat as possible, none being laid out with less than 300 feet radius around the brow of a hill. Where the driver can see across the curve there is no danger in reducing the radius, but where the hill intervenes, a smaller radius would be dangerous, as it will be impossible for automobiles and teams to see each other until too close to avoid possible disaster.

The grade should be rolling, not alone to afford proper drainage, but for the ease and comfort of the traveller. Every bicyclist knows that he can ride much farther and easier over a gently rolling country than on perfectly level roads. A horse likes a rolling road, the automobile alone preferring a straight line and grade.

Another problem in road location which should properly be referred to a highway engineer is the balancing of quantities. But little attention is given to this important consideration by many engineers, and for this reason roads cost a great deal more than they should. By balancing quantities we mean laying the grade so that the excavation will exactly form the embankment, no more and no less. Where macadam roads are being graded and the soil is unfit for a foundation, the material may have to be borrowed from a gravel pit or other convenient place, but even here this should be figured, and only enough material excavated to make the necessary embankment.

The amount of material necessary to make one yard of fill varies with different soils and with the depth of excavation and embankment. Where the fill is over three feet deep the sod and poorer material may be used in the road at the bottom; but where it is less than this depth, the sod, roots, etc., must be separated from the good material and removed from the road. With light excavation, or a “skin cut,” a much larger percentage of material will have to be wasted than where large quantities are to be moved. In no case will a yard of earth excavation make one yard of embankment, since the earth, as it now lies, is full of moisture and air-voids, which are excluded under rolling. In general, the following figures can be used in making up the estimate:

<table>
<thead>
<tr>
<th>Excavation</th>
<th>Embankment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic Yards</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Rock—1 cubic yard will make</td>
<td>1</td>
</tr>
<tr>
<td>Earth, heavy cut—1.25 cubic yard will make</td>
<td>1</td>
</tr>
<tr>
<td>Earth, light cut—1.50 cubic yard will make</td>
<td>1</td>
</tr>
</tbody>
</table>
PLAN OF ROAD AT UNION. EXCAVATION AND EMBANKMENT BALANCED.
In a side hill country the line and grade should be laid so that the cut and fill at any point will just balance as shown in the following figures:

This saves a large expense in the construction of the road, as no material will be moved far enough to require a team. Most of it can be thrown by shovels directly into place.

**RECONNAISSANCE**

The first step in the proper location of any road is to make a careful reconnaissance. Until this has been done, it will be useless to send an engineering party into the field. The instruments needed are a good hand or pocket compass, a pedometer, a hand level, and, if the road is to pass through a mountainous country, an aneroid barometer. One man alone can make the reconnaissance as well as an entire surveying party, and by finding the best locations, or by determining two lines, one of which will be the better, much money is saved in the cost of engineering. The following points should be noted.

1. *The Nature of the Soil.* The inspection notes should show whether the soil is heavy or light, wet or dry. If an earth road is to be graded, crowned and drained, or if surfacing is to be applied, it is essential that the nature of the soil be determined before the proper method of improvement can be decided upon. It is also important to know whether the road will be exposed to the direct rays of the sun or whether it will be shaded part of the time each day.

2. *The Distance to Acceptable Road Building Material.*—This information is hardly necessary in earth road construction except
where sand or clay is to be used, but notes taken on the reconnaissance should cover all points so that the field will not have to be gone over again when increase in the traffic necessitates the use of a more expensive type of construction.

3. The Location and Size of Streams.—These are among the most important considerations and ample notes should be taken on all points relating to drainage. If possible, determine the maximum highwater point of the stream during the past 10 or 15 years; for the bridges and culverts must be designed to meet the greatest amount of water they must carry rather than the average flow.


5. The Possibility of Saving Culverts or Bridges.—It is frequently found that by swinging the stream into a new channel or moving the location of the road slightly, it is possible to save the cost of one or more structures. The following sketch shows a case in an Eastern state where three culverts had been placed in a road:

![Diagram of cutting out unnecessary culverts](image)

The expense of changing the channel was less than the cost of the three culverts would have been. Remember to cross the stream wherever possible at right angles, for a skew culvert is much more expensive than a straight one of the same capacity.

6. The Nearest Supply of Cement, Stone, etc.—Notes taken here will inform the engineer of the cost of walls, culverts and all protective work. The distance to the nearest railroad station and the freight rate from the nearest distributing point should be determined.

7. The Number of People Benefitted.—The people benefitted by a new road are not those only who at present live along the line. Notes should be taken on the probable growth of the country and the amount of traffic which will be diverted from other highways. Upon this estimate can be based the amount of money which should be spent on the improvement.
The elevations should be roughly determined with a hand level, so that an approximate contour map can be sketched. Where the United States Government has surveyed the territory and issued maps, it will hardly be advisable to make the reconnaissance, as the only items to be looked up are the nature of the soil and the distance to a supply of road and culvert materials. This can be done by a surveying party on some other trip. The best line can be determined in the office from the maps, but for many sections of Oregon none are issued.

Do not sacrifice too much to shorten the road, as the only advantage thus gained is to bring two market points nearer together. A much greater service is rendered by reducing grades. In mountainous districts the grades should in no case be increased above the maximum in order to shorten the road. The final location, with transit and level, should be in charge of an engineer. Avoid cuts and fills in front of houses. Do not swing away from a house unless it is necessary to preserve the alignment, in which case another road must be built to the house.

There are only three methods of reducing grades:
- First—Go around the hill.
- Second—Zigzag up the hill.
- Third—Go through the hill.

The last method is practicable only for short distances.

Wherever the grade changes over 2 per cent, the angle formed should be rounded off by a parabolic vertical curve, the change in elevation being figured by the following formula:

Let
- \( A \) = the algebraic difference in grades.
- \( L \) = the length of curve in 100 feet.
- \( D \) = the correction for elevation at center of curve. (Point where grades intersect.)

\[
\frac{A \times L}{8}
\]

Then \( D = \frac{A \times L}{8} \)

The following sketch illustrates how the formula is used:
In all three cases, the summit, the valley, and the change of grade on the hill, the algebraic difference is the same, viz., 4 per cent. Assume that these grades are to be connected by a vertical curve 200 feet long. Then the correction at the center will be

\[
\frac{4.0 \times 2}{8} = 1.0 \text{ foot.}
\]

This correction will be subtracted from the elevation at the summit and added in the other two cases. It is always advisable to sketch the grades roughly on a piece of paper to indicate whether the change is to be plus or minus.

To determine the change in elevation for any intermediate point, find its distance from the end of the curve and use the following formula:

Let \( d \) = the correction for the intermediate point.

\( l \) = the distance from the end of the curve. (Equals one half the length of the curve minus the distance from the intersection.)

Then \( d = \left( \frac{l}{2} \right)^2 \times D. \)

For example, find the change in elevation for a point 25 feet from the summit in the first case above.

\[
\frac{L}{2} = 100 \text{ feet.}
\]

\[
100 - 25 = 75 \text{ feet. (Distance from end of curve.)}
\]

\[
D = \frac{(75)^2}{(100)^2} \times 1.0 = \frac{5625}{10000} \times 1.0 = 0.56 \text{ feet.}
\]

Twenty-five feet from the summit on a 2 per cent grade will be 0.5 feet below the summit. From this elevation subtract 0.56 feet, and the elevation of the curve at that point will be given.
DRAINAGE.

The most important consideration in the improvement of any highway is proper drainage. A large proportion of our earth roads do not have sufficient traffic to warrant the expense of hard surfacing, but if well drained they will give good service the greater part of each year. Water is the natural enemy of earth roads, with the exception of those built in the sand belt. Shifting sands are passable only when the particles are bound together by the rains; hence the drainage system should be designed to keep the travelled way moist as long as possible. Side ditches and culverts are necessary, but the cross section should be flat or even slightly dished to hold the surface water.

In the construction of any road in the heavy soils, whether it be a mountain trail or a city pavement, there are three rules which must be followed:

First—Get the water off the road.
Second—Get the water away from the road.
Third—Get the water out from under the road.

In order to get the water off the road it is necessary to provide a good crown and keep the surface smooth so that the rain will find its way quickly to the side ditches. The amount of crown must be determined for the different soils as well as for the surfacing material. The following table shows the approximate amount required for the highways of Oregon:

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Crown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay or Gumbo</td>
<td>1 to 1 1/2 inches per foot.</td>
</tr>
<tr>
<td>Sand Clay</td>
<td>1 inch per foot.</td>
</tr>
<tr>
<td>Oiled Earth</td>
<td>3/4 inch per foot.</td>
</tr>
<tr>
<td>Gravel</td>
<td>3/4 inch per foot.</td>
</tr>
<tr>
<td>Macadam</td>
<td>5/8 to 3/4 inch per foot.</td>
</tr>
<tr>
<td>Bituminous Macadam</td>
<td>3/8 to 1/2 inch per foot.</td>
</tr>
<tr>
<td>Stone Block</td>
<td>1/4 inch per foot.</td>
</tr>
<tr>
<td>Wood Block</td>
<td>1/4 inch per foot.</td>
</tr>
<tr>
<td>Brick</td>
<td>1/4 inch per foot.</td>
</tr>
<tr>
<td>Asphalt</td>
<td>1/4 inch per foot.</td>
</tr>
</tbody>
</table>

On steep grades the water will follow the center of the traveled way.
road before finding its way to the ditches, unless the crown is greatly increased. As this makes the road slippery and dangerous for traffic, it should never be done where it is possible to avoid it.

The depth of the ditch depends upon the width of the roadway. The following table shows the usual practice in the United States and in other countries:

<table>
<thead>
<tr>
<th>Widths</th>
<th>Right of Way</th>
<th>Roadway</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>49 to 66</td>
<td>16</td>
</tr>
<tr>
<td>England</td>
<td>66</td>
<td>20 to 22</td>
</tr>
<tr>
<td>Holland</td>
<td>38</td>
<td>14</td>
</tr>
<tr>
<td>France—National Roads</td>
<td>66</td>
<td>22</td>
</tr>
<tr>
<td>&quot;Departmental Roads</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>&quot;Provincial Roads</td>
<td>33</td>
<td>20</td>
</tr>
<tr>
<td>&quot;Neighborhood Roads</td>
<td>26</td>
<td>16</td>
</tr>
</tbody>
</table>

The width of surfacing on Massachusetts highways is usually 15 feet for the main travelled roads, the shoulders being three feet wide in cuts and five feet in fills. This gives a total width of 21 feet in through cuts, 23 feet in side hill country, and 25 feet where the road is higher than the land on both sides. New York builds her roads from 24 to 32 feet between ditch lines, with 16 feet of surfacing. Many roads in Oregon are laid out for the full width of roadway, from 60 to 100 feet. It is impossible to keep them in good condition, and the money spent in repairs spread over so wide a territory is practically wasted.

The following sketch shows a road in Eastern Oregon built in a sandy loam soil, the very best material for the construction of a first class earth road.

![Fig. 6]

TOO WIDE TO MAINTAIN

Traffic followed the center of the highway until this was worn down below the ditch lines. The result was that two roads were formed with a ditch between that drained from both sides. As it was impossible for the water to get away, it soaked back under the
highways, keeping them in poor condition most of the time. If these roads were well maintained the money which should cover two miles from town would reach only one mile, not including the funds necessary to build culverts to take water from the center ditch. It is impossible to construct this road properly with the money available, and even were there sufficient funds it would be foolish to waste them on a greater width than the traffic requires. Thirty feet between ditch lines is ample for any Oregon country highway, giving a crown of 15 to \(22\frac{1}{2}\) inches for the ordinary earth road. The purely local roads should be even narrower, although it is rarely advisable to build them less than 18 to 20 feet.

The mountain trails should have a ditch at least 12 inches deep. It is rarely practicable to build these roads 16 feet wide, and it is inadvisable to increase the crown to secure the required depth. The proper cross section is shown in the following diagram, a crown of \(1\frac{1}{2}\) inches to the foot being carried to the ditch line and the ditch being deepened at a \(1\frac{1}{2}\) to 1 inch slope.

![Cross Section for Narrow Roads](image)

Much discussion has been waged whether to use the parabolic, the curved, or the straight line cross section. For the Willamette Valley, the straight line section will probably give the best results. If the road is not continually maintained in first class condition, free from small depressions, the parabolic section will hold water in the center, whereas the same amount of wear in the straight line section would not prevent the water from reaching the side ditches. The curved section is better than the parabolic, but is not as good or as easy to construct as the straight line. The three forms of construction are shown in Fig. 8.

The straight line is slightly rounded off in the center of the road, but it will be noted that the drainage is more nearly perfect than in either of the other two types. The parabolic section is too flat in the center for any but the most perfect forms of hard surfacing, and even in this form of construction the curved or a very flat straight line section will probably give much better results.
The grader or road machine should be used in the construction of our highways, the heavier machine being the best for this purpose. The drag should be used to smooth the road after the grader has finished. The best time to build is in the spring when the soil is moist and can be easily worked, dragging thoroughly after the first fall rains to put the road in good condition for the winter. Do not attempt to build up a road just before the rainy season starts, as it will be impossible for the material to pack before the following spring. It is also a waste of money to attempt much improvement during the long dry summers.

To get the water away from the road it is necessary to provide good ditches and ample culverts. The depth to which the ditch should be dug has already been considered. It should have a grade of at least one foot in 250, the minimum slope allowed in proper location. Where it is impossible to secure the necessary grade the ditches themselves can be sloped, cutting them very shallow at the summits and considerably deeper than the ordinary cross section at the culverts.

Where the road is properly maintained the best results can be secured by sodding the ditches and shoulders. Sow the seed, ordinary hay seed, in early spring and cut it frequently. In a year or two a good sod will have formed, one that will not disturb the flow of
water but will save the bank from undue wash. Banks in both cut and fill may be sodded in this way and will hold the material in place, preserving the road during the heavy rains. The cost of this work will not exceed $15 per mile and the benefits derived more than justify the expense.

Water should be taken out of the ditches frequently, at least every 1,000 feet in rolling country. In very flat locations it may be necessary to carry it a much greater distance.

If water is allowed to stand in the ditches it will soak under the roadbed and soften the travelled way; where it is carried too far it will cut the ditches badly. On slopes of over 5 per cent, ditches should be paved about 3 feet wide with cobble stones. This is expensive, and as a general rule, a better location can be found which will cost less than the paving. Water should be removed from ditches on grades of 4 to 5 per cent at least every 500 feet. This also costs money, as it is necessary to carry the water across the road by skew culverts. These are more expensive than those built at right angles for the same width of road and as they must be put in more frequently, a great deal of money is wasted which could be better used in securing a lighter grade in another location.

The back bank of the ditch should be cut back to a slope of $1\frac{1}{2}$ to 1. Many roads are correctly constructed, the surfacing well laid, ditches cut true to line and grade, but the high bank is left standing where it is a menace to the road. It will cost much less to move this extra material when the road is being built than to shovel it out of the ditches when it fills the drainage system. This excavation should be figured in the estimate to make a large part of the embankment, so the cost of cutting it is negligible.

It is frequently possible to turn water away from the road on one side; and in some cases ditches can be drained on both sides of the highway without carrying the water across. Dig these outlet ditches as frequently as possible, as they will save the road wonderfully during heavy rains.

To get the water off the road and to get the water away from the road is comparatively easy; the main difficulty arises in getting the water out from under the road. Since a large part of the highway improvements are carried on during the summer, the soft spots caused by underground water do not show. Subsequent rains will develop bad places which were not suspected during construction. Even when macadam is laid the road will frequently cut through in spots that appeared hard and unyielding during
construction. In earth roads, proper under drainage is of vital importance. Thousands of yards of gravel, stone, and other materials have been dumped into the mud holes of our country roads, with the result that the next year the material had disappeared and the work had to be done over again. If these holes had been first drained and then filled, the improvement would have been permanent.

There are three objects to be attained in the under-drainage of highways: First, to lower the water level below the foundation line; Second, to dry the ground quickly, if it has been frozen; Third, to remove the underground water.

The ordinary farm drain tile is the best for this purpose. It should be laid as shown in the following diagram.

![Diagram of Stone and Tile Underdrains](image)

A ditch is cut from three to four feet deep and four to six inch tile is placed in the bottom. Great care should be taken in back filling not to allow the earth to get into the pipes and obstruct the flow.

A first class drain can be built of stone laid in the form of a small box, and where this work is well done the improvement is as thorough and permanent as where tile is used. Where a large number of round stones are found, the ditch may be filled with large cobbles, the smaller ones being used nearer the surface. The stone should come to within about six inches of the finished grade and then be covered with sod laid upside down. The earth is filled in over this to the finished grade. The sod will keep the loose earth from sifting down into the stones; by the time this has rotted, the earth is compacted sufficiently to keep out of the drainage system.

The roads of the Willamette Valley need a large amount of underdrainage. Where the trouble is caused by an underground spring, the drain should be laid to its source and then carried to some convenient outlet. This end of the pipe should be laid in a concrete or stone head wall, and the opening should be covered.
with a screen to keep out leaves, dirt and small animals which sometimes get into the pipe and obstruct the flow.

Where the trouble is caused by seepage water, the pipe should be laid at the side of the road nearest the heaviest cut. Two lines of tile may be laid, one on each side of the road, but a single line will do. By lowering the single pipe six or eight inches, the same results are obtained as with the two lines, at much less cost. This tile should be carried the full length of the excavation and emptied into some convenient outlet.

Another method of draining this seepage water which will prove very satisfactory where stone can be found in abundance is to use a stone drain, carrying the water across the road at frequent intervals. This is most satisfactory for side hill work where the water can be disposed of about every hundred feet. There is no necessity for using tile in this form of construction, the water being carried across the road in stone drains and allowed to flow away down the hillside.

It is rarely advisable to put the tile in the center of the road. When located here it is necessary to make a deeper excavation, as the depth of the drain is measured in both cases from the ditch lines. The travelled way will be left in bad condition for some time after the ditch is installed, and if the road is to be hard surfaced later, no repairs can be made on the drain without tearing up the macadam.

In all cases the tile must be laid straight, both in line and grade. A slight variation from the alignment will not block the drain, but a sag will quickly fill with sediment and obstruct the flow. If this is greater than the diameter of the tile, the earth will soon collect in sufficient quantities to fill it and the drain will be useless.

Where the material is very fine and there is danger of its getting into the pipe during back filling, tarred paper or cloth may be used to cover the joints. By the time this has rotted away the earth will have solidified sufficiently so that no trouble may be anticipated from this source. It is not necessary to use collars.

There will be no trouble about securing the necessary grade to carry the water, if the road has been properly located, as the minimum grade needed for the ditches is ample for the water in the drains. Four inch tile will be adequate for practically all cases, although six inch may be used where there are high banks on both sides of the road.
Some experiments made at the University of Illinois by Professor Ira O. Baker illustrate the benefits of underdrainage. Two sections of the same road were improved, one being properly graded and given a good coating of gravel. No attention was paid to the underdrainage. The other section was carefully underdrained, but nothing else done to it. The following winter the underdrained road remained in good condition while the gravel road went to pieces.

It is evident that there is no better way of spending money on our highways than in installing a thorough system of drainage. The other improvements can come later when we get the necessary funds. The surface drainage can be looked out for with the road drag at a nominal cost, but the culverts and underdrains should receive the lion's share of the funds. This work, when properly done, is permanent, and there will be no criticism of the expenditure of money, as is frequently the case when an attempt is made to construct hard surfacings without proper attention to the preliminary work required.
CULVERTS.

Few roads are provided with enough culverts, and those already installed are frequently too small. Each one must be designed to carry the maximum amount of water that may come to it, rather than the ordinary supply, for a single freshet will damage the road many times the cost of a larger structure.

It is also of little use to build good culverts and fail to provide proper outlet ditches. Where there is no stream, it is usually necessary to dig a trench to some lower point. Where the outlet crosses valuable land, a cheap pipe or stone box drain may be laid.
and the earth filled back over it; but the open channel can usually be placed where it will not damage the property seriously.

It is simply a waste of funds to place a culvert where it carries the drainage from one side of the travelled way to the other, with no provision for its escape from the road.

In sandy and gravelly country fewer culverts are needed than where the soil is clay or gumbo. Much of the rainfall will soak into the ground where it falls, and the excess may be taken care of in leeching basins. The following diagram shows two methods of construction:

Where plenty of large stone is at hand, a first class basin may be built at low cost. The stones should be laid dry, i.e., not bound with mortar, and the bottom may be left open. Where this material is not available, concrete may be used. Holes from two to three inches in diameter should be left in the walls as shown in the plan, and the base left open. The ordinary farm drain may be used for

---

Fig. 11
SKEW CULVERTS WITH STOP WALL ON INLET END

(35)
FIG. 1.—A TYPE OF CULVERT TO BE AVOIDED

FIG. 2.—ROAD IN ROGUE RIVER VALLEY
the holes, and these can be left in the concrete after the wooden forms are removed. The basins should be built of ample size to hold the excess water during the rains. This will percolate into the soil during dry weather.

On steep hills more culverts are needed, and these should always be placed at an angle, with a stop wall on the inlet end to prevent the water from running past. The accompanying sketch shows the method of construction:

To build a "skew" culvert is much more expensive. The one shown above, placed at a 30 degree angle, is 15 per cent longer than a culvert of the same capacity placed at right angles with the center line of the road. When the cost of the stop wall is estimated, it is found that the extra expense is practically 20 per cent. Twice as many structures are needed as in a gently rolling country, and when the estimate is fully made up it will usually be found cheaper as well as better to relocate the road.

The following formula is the one usually used to determine the required area:

\[ X = \frac{C}{A^3} \]

- \( X \) = Area of the required opening in square feet.
- \( A \) = Drainage area in acres.
- \( C \) = Co-efficient. This is generally taken as 1-3 for flat farm lands, 2-3 for rolling lands, and 1 for steep slopes.

In building a road through a 'settled country' it is usually possible to determine the required size without using this formula. "The oldest inhabitant" can usually tell whether the old bridges and culverts have always taken care of the water, or, if not, about how much went over the road. In any event, do not try to use the formula until a careful survey has been made to determine the acreage to be drained.

While it is very necessary that the culverts be large enough, it will sometimes be found that a very small pipe will take care of the drainage. In this case, another element enters the problem. All culverts must be large enough to permit easy cleaning. Enough fall should be provided so that the culvert will scour properly, but with the best precautions the smaller pipes will at times become clogged.

Culverts must be provided at all low places in the grade, to take care of the ditch water. These need not be very large, a 12-
inch pipe being ample in most cases. They should be given a drop of at least six inches in every 25 feet length so that sediment will not be deposited.

The laws of different states distinguish culverts from bridges by the span, the maximum varying from four to 15 feet. In this discussion we shall assume that the culvert is any structure having a span of eight feet or less and that anything greater is a bridge.

Before any construction is attempted, each district must decide what material will give the best satisfaction. One general consideration should govern in every case; do not build any structure which will not resist the weather. The materials in common use include:

- Wooden box.
- Log culvert.
- Vitrified clay pipe.
- Cast iron pipe.
- Corrugated metal pipe.
- Rubble masonry box or arch, laid dry or in mortar.
- Brick arch, box with stone or reinforced concrete top.
- Concrete box or arch, plain or reinforced.

**WOODEN BOX.**

This type, which is most extensively used throughout the United States, is the most expensive form of construction. Its life, under the most favorable conditions, is only four or five years, as against a hundred years for concrete and other materials. Its use is absolutely indefensible except in cases of emergency, and even then the structure should be replaced as soon as possible with some permanent material. Wood will decay, giving no sign until some horse puts his foot through it and the irate owner comes down on the district for damages. No defense can be made and the damages awarded amount to enough to build several permanent structures.

In the early days of road building, when lumber was cheap and cement and other materials were dear, there was some warrant for this type of structure, but under present conditions, when lumber has increased in price and deteriorated in quality, there is no excuse for using wood except as a temporary expedient.
LOG CULVERTS.

Where a road is being constructed in a mountainous country, far from the nearest freight station, the log culvert may be advantageously employed. While this is a form of wooden culvert, the timbers are large enough so that there is little danger, provided the floor is made of heavy material. The following are the specifications of the Washington State Highway Commission for this structure:

"Log culverts up to two feet in width shall consist of two logs, either fir or cedar, entirely sound throughout, of not less than 16 inches in diameter at the top end, trimmed smooth of all knots and knobs, and long enough to extend to the center of ditches or toe of banks and laid parallel and not closer than 10 inches apart. Logs to be notched four inches on top side every four feet to receive stringers for covering.

"Log culverts of larger dimensions up to four foot waterways shall be built of sound logs not less than 16 feet in length, nor less than 14 inches in diameter, with tie logs at intervals of eight feet, and between all courses properly notched into the face logs extending across the full width of the embankment, and anchored where necessary. Top logs to be notched as in smaller culverts. Stringers or floor joists to be not less than eight inches in diameter, flattened on upper sides for all sizes of log culverts. Covering to consist of 4x12 inch planks of the same length as the logs.

"Planks to be sound and free from all decay or bad knots and acceptable to the engineer."

It will be noted that the logs used for the side walls and the stringers are so large that it will be years before decay and weathering will weaken the structure sufficiently to make it dangerous for traffic. The weakest point is the 4-inch plank covering. If these planks could be hewn instead of sawed they would last much better, as a sawed plank has a rough surface which opens the grain so that the water soaks in to the fiber much more rapidly than is the case where the plank is shaped with the axe. Railroads have found that sawed ties are much more expensive on account of this rapid deterioration.

VITRIFIED CLAY PIPE.

This material will give excellent results for small culverts from eight to 24 inches in diameter. Some state highway departments permit the use of pipe up to 30 inches in diameter, but this is expensive. The material, if protected from the frost, is practically indestructible. Great care must be taken in installing it, for a slight blow is sufficient to break the pipe; but once in place it will last indefinitely. Sewers built of this material have been unearthed
FIG. 1—DESTRUCTION OF CULVERT CONSTRUCTED WITHOUT WING WALLS

FIG. 2—CULVERT WITH SUBSTANTIAL ABUTMENTS AND WING WALLS
at Pompeii and Herculaneum, and the pipes are still in good condition. For culvert use, the factory seconds are as good as the firsts and the saving is considerable. The pipe should be double strength, salt glazed and ring true when struck with a hammer.

The pipe must have a good fall to allow the water to run out quickly, and an ample outlet ditch should be provided. Water should never be allowed to freeze in or around the pipe. The trench should be dug true to line and grade, the bottom being shaped to fit the pipe and excavations made for the bells. The joints should be filled with cement mortar, mixed one part of cement to two parts of sand. Back filling should be thoroughly tamped under and around the pipe, care being taken that no large stones come in contact with the pipe. For back filling gravel is the best material, as it drains rapidly and keeps the frost away from the tile. The pipe should be laid low enough so that there is at least 24 inches of earth above the top in the center of the road. This amount is sufficient to protect the culvert from the blows of traffic. Head walls, of concrete or masonry, should be used with this type of culvert.

CAST IRON PIPE.

This material is one of the best for culverts, but its great expense renders its use impractical except in localities near a foundry. It should be laid with cement joints.

CORRUGATED METAL.

This material was devised to take the place of cast iron pipe, retaining the advantages without the excessive cost of cast iron. Where practically pure iron is used in its manufacture, the metal will give excellent results, and at low cost. Steel pipe, on the other hand, will rust rapidly and should never be used.

Corrugated pipe is made in two styles, one requiring rivets, the other not. The latter, being made in half sections, one fitting over the other, forms a joint tight enough for ordinary culvert use. Where the pipe runs over half full of water a good part of the time, the riveted sections will doubtless give better satisfaction, but where ditch water only is to be carried off, the other form will probably be preferred, since it is more easily installed and can be transported cheaply. It is fairly long lived and while more expensive than vitrified clay, it can be laid much nearer the surface, a very important consideration in the flat districts of the state.
Log or Plank foundation when ordered by Engineer.

Drop Inlet.
DESIGN FOR BOX CULVERTS.
Corrugated iron head walls may be used with this pipe, although concrete or masonry will probably prove more satisfactory.

**RUBBLE MASONRY.**

Road districts having an abundant supply of stone can use this material in their culverts. The cost is very light, and the structure, if the work has been well done, is absolutely permanent. Great care must be taken to secure a good foundation, even more care with this material than with pipes. The stone may be laid dry or in cement mortar, with either an arch or box type of construction. In general, the box will be more satisfactory for small culverts, while the arch will be better for larger openings. With the arch the entire culvert may be laid dry. With the small box the side walls may be built dry, with reinforced concrete top. Head and wing walls must be built as shown on the plans for concrete culverts, or the structure will be undermined during freshets.

Great care should be taken to secure a good bond between the successive layers, whether mortar is used or not. The headers should extend through the entire width of walls. The mortar should
be made of one part Portland cement to two parts clean sharp sand. If hydraulic cement is used, mix it with sand in equal parts.

The designs shown for concrete culverts can be used for rubble masonry. The side walls should be built somewhat thicker, the minimum width being 18 inches. The covers, for all sizes over three feet span, should be built of reinforced concrete.

**BRICK.**

Where the road is located near a brickyard, and where there is little or no stone suitable for rubble masonry, brick may be used. The structure is permanent, but like cast iron, is too expensive for ordinary use throughout the state.

The arch type is the one usually employed, although the box, with a reinforced concrete top, will give excellent results. The following specifications, taken from a bulletin on Highway Improvement issued by the Kansas Agricultural College, can safely be followed in work of this character:

“A five foot clear span should have two rings of brick, which would make a thickness of about nine inches; five to seven foot spans should have three rings, making a thickness of about 13 inches; seven to 10 foot spans, four rings should be used, which will give a thickness of about 18 inches. The inside ring of brick should be vitrified, and all the bricks should be laid in mortar composed of not less than one part cement to three parts sand. It will require from 450 to 500 bricks, with quarter-inch mortar joints, per cubic yard.”

**CONCRETE.**

This material was used by the ancient Greeks, Romans and Egyptians, and many of the structures in which it was used are still in an excellent state of preservation. These ancient monuments are sufficient answer to those who claim that concrete, even though properly mixed and laid, will last only a few years in our culverts.

Where only unskilled labor can be found, the results will be unsatisfactory, unless some one with experience in this class of work can be employed to supervise the construction. Like the artists’ paints, concrete must be mixed with brains.

For the smaller openings, a box with reinforced top will give the best results. Plates VIII-A and VIII-B show the designs for structures under eight feet span, and the accompanying table gives the dimensions. The arch is rarely satisfactory for smaller spans than 10 feet on account of the high cost of the forms.

The box, on account of the difficulty of cleaning, should never be built less than 18 inches high and 24 inches wide. For the smaller
WOODEN FORM FOR CONCRETE PIPES. ILLINOIS HIGHWAY COMMISSION
sizes pipes should be used. Side and wing walls built of reinforced concrete may be used, instead of the heavier walls as shown in the plan; but this is rarely satisfactory unless experienced men can be secured for the work. Reinforcing bars must be placed exactly as designed, or the whole system is useless. To keep the bars in place in the covers is easy, but to keep them in place in the side walls is difficult. The expense per cubic foot is much greater for the reinforced walls, and it will usually be found that the heavier walls are cheaper as well as being nearer "fool proof."

There are two methods of fixing the bottom of the culverts. In one, the concrete is carried across, making a closed box. In the other, the side walls are widened to secure a better footing, and the center is left open or paved. Both are satisfactory for the larger culverts and in good foundations, but in all structures of less than five feet span, very little is gained by leaving out the floor. In soft foundations, the floor will give much the best results.

The pipe, whether vitrified clay, iron or concrete, is the type best adapted for small drainage areas in poor foundations. The objection to the concrete in the past has been the great cost of forms, but there are now on the market several kinds of collapsible forms for each of the sizes desired. Some of the forms will build but one size; others are adjustable within certain limits. Most of them are built of steel, and give excellent satisfaction where the amount of work to be done warrants the expense of buying them. Plate IX shows a wooden form, designed by the Illinois Highway Commission, which can be used for any size up to 48 inches in diameter. Concrete pipes less than 18 inches in diameter will usually cost more than the other materials.
Never install any concrete culvert, pipe, box or arch less than 24 feet long. Leave ample room for future improvement. The final grade to which the road will some day be built must be determined before the culvert is designed. Remember that this is permanent work, and it is foolish to put the structure where it will later have to be torn out or rebuilt.

Head, wing and toe walls must be provided as shown in the plans. For some unknown reason, only explainable on the theory of the perversity of inanimate objects, water seems to prefer to go around or under the place provided for it rather than through it. It will soak into the ground around the culverts and then freeze, and no material has yet been found that can withstand the pressure of freezing water.

Give the culverts a fall of at least six inches to every 25 feet of length. The accompanying sketch shows how the length should be figured in fills; for the higher the fill, the longer the culvert:

Drop inlets are required for culverts in places where it is impossible to build the ordinary wing walls at the inlet end without too much excavation. An iron grating should be provided to keep out leaves, dirt and other debris which might clog the culvert. A plan of this inlet will be found in Plates VIII-A and VIII-B.

Well made concrete improves with age, requires no repairs or painting, and if the culvert has been built large enough, will need little maintenance. The following specifications may be used:

**SPECIFICATIONS FOR CONCRETE CULVERTS.**

*Cement.* 1. All cement shall be tested by the methods adopted by the American Society of Civil Engineers. (Tests will be made at the laboratory of the Oregon Agricultural College, if desired.) Any standard brand of Portland cement conforming to these requirements will be accepted. No cement shall be used in any part of the work until these tests have been completed.
2. All cement shall be hauled directly from the train or boat and stored in a weather-tight building having floors raised from the ground. It shall be stored in such a manner as to afford easy access for inspection and sampling.

3. Cement failing to meet the seven-day tests may be held pending the results of the 28-day tests before rejection.

Sand.—Sand for concrete shall be clean, dry, free from dust, loam and dirt, moderately coarse, and made up of grains of varying size so as to produce a low percentage of voids. No wind drifted sand will be allowed.

Broken Stone. 1. All stone for concrete shall be of good quality, preferably a "trap rock." It shall be crushed so as to measure not over 2\(\frac{1}{2}\) inches in its largest dimension, nor less than \(\frac{1}{4}\) inch in its smallest dimension.

2. When stored on the roadway, it shall be placed on lumber floors to keep it clean and free from dirt.

Gravel.—Where gravel is used, it must be free from injurious materials, clean, and of the same size as specified for broken stone. Unscreened gravel may be used if the proportions of sand and the coarser aggregate are correct.

Water.—The water used in mixing the concrete shall be clean and free from oils, strong acids and strong alkalies.

Ratio of Materials.—Two classes of concrete shall be used as shown on the plans, to be known as first class and second class concrete.

First class concrete shall consist of one part Portland cement, 2\(\frac{1}{2}\) parts sand and five parts broken stone or screened gravel between the sizes of \(\frac{1}{4}\) and 1\(\frac{1}{2}\) inches, all measurements to be made by volume.

Second class concrete shall consist of one part Portland cement, three parts sand, and six parts broken stone or screened gravel between the sizes of \(\frac{1}{4}\) inch and 2\(\frac{1}{2}\) inches, all measurements to be made by volume.

Mixing.—Machine mixing of the concrete will be preferred, provided the machine used secures equal accuracy in the proportioning of the materials and as good a mixture as the hand method. The mixture must be delivered from the machine on to wooden or metal platforms, or into barrows, and thence shovelled into place in the forms.

If mixed by hand the concrete shall be mixed on wood or metal platforms of sufficient size to permit the proper manipulation of the materials. The stone or gravel must be thoroughly washed long
enough before mixing to allow time for the surplus water to drain off, and yet to be still moist when brought to the platform. The sand shall first be spread over the platform and the cement evenly distributed over it. These two materials shall then be thoroughly mixed dry until the voids in the sand are completely filled. Sufficient water shall then be added to form a stiff paste, and the materials shall again be mixed until a mortar of uniform consistency is secured.

The stone shall then be spread over this mortar, and the materials mixed until each stone is coated with the mortar, enough water being added to make a wet mixture. The materials shall be turned at least three times after the stone is added, and if the stone is not thoroughly coated more turns shall be made at the discretion of the engineer.

Concrete shall be mixed wetter for reinforced walls or slabs than in the base and side walls of the culvert.

**Placing.**—The concrete shall be placed immediately after mixing, care being taken that the stone and mortar are not separated. Immediately after placing, it should be thoroughly tamped until it quakes. As fast as the concrete is put into place, the stone shall be spaded back from the forms so as to leave a smooth surface. Great care shall be exercised in tamping reinforced concrete that the reinforcement is not disturbed. The concrete shall be placed in continuous horizontal layers in all wall structures. In arch construction, the full thickness shall be laid at once, the end being bevelled to secure proper bond with the next batch.

**Connecting Old and New Work.**—In connecting old and new concrete, the surfaces shall be roughened, cleaned and mopped with a mortar consisting of one part Portland cement and one part sand.

**Protection.**—When it is necessary to lay concrete in hot weather, the surface shall be kept moist until the material shall have had ample opportunity to set.

When the concrete is laid in freezing weather, the water, cement, sand and stone shall be heated, and the temperature of the material shall be maintained above freezing until the final set is developed.

**Measurement.**—Concrete will be measured in place as completed, the dimensions in each case being those shown on the plans. The contract price includes the cost of materials, mixing, placing and tamping concrete, keeping it protected for the necessary period, and finishing the exposed surfaces. Concrete will be paid for by the cubic yard.
Centers and Forms.—Forms satisfactory to the engineer shall be provided by the contractor. If made of lumber, they shall be planed, well braced, and shall fit the outlines of the work. All lumber shall be tongue and groove, laid tight before depositing the concrete.

Reinforcement.—Reinforcing steel shall be made of twisted or deformed bars of medium steel. No bars shall be used in which the net cross section has been reduced below that called for on the plans. Care shall be taken that the bars are placed exactly as shown on the plans and that they are not disturbed when the concrete is deposited.

Finishing.—All exposed surfaces shall be rubbed down, and painted with a wash composed of Portland cement and water mixed to the consistency of whitewash. No plastering will be allowed. Defective concrete must be removed and replaced before the finishing is commenced.

PROTECTIVE WORK.

In most cases it will hardly pay to spend much money on protective work for our earth highways. It will usually be possible to secure an alignment which will avoid the use of retaining walls until some form of hard surfacing is laid. In side hill country, it is sometimes necessary to build a wall on the up hill side of the road, and where the bank is washed by a river or lake, it may be necessary to build stone or log structures to keep the highway from being washed away during high water. The expense of this work, however, is usually greater than can be afforded on the rural highways.

There is one item of protective work which is neglected throughout the Northwest both on the earth and macadam roads. Guard rails should be provided wherever there is the slightest danger of injury to traffic in case the horses or machines get off the travelled way. It makes little difference how wide the road has been constructed; there are still a few horses that cannot be driven safely past an automobile.

Where the embankment is less than four feet high, the earth should be built out on a 4 to 1 slope, instead of the 1 1/2 to 1 used on higher fills. The cost of the extra material is less than that of maintaining a guard rail.

Wherever the slope of the earth is greater than 1 1/2 to 1, and at the ends of all culverts, guard rails should be provided as shown in the plan. The posts should be at least 6 1/2 feet long with a mini-
imum diameter of six inches at the smaller end. They are set eight feet apart, parallel to the center line of the road. The planks should be long enough to cover three posts and be laid with broken joints. The entire structure should be painted with two coats of white lead and oil to protect it from decay.

On the larger bridges and culverts, an iron pipe rail should be built into the parapets during construction. The smaller ones are protected by 24 feet of wooden guard rail.

It will be readily seen that this rail is not strong enough to stand a direct blow from an automobile or heavily loaded wagon, but in nearly every instance the shock comes at a very flat angle. The lower rail is built at a height where it will catch the hubs of the wagons, a position in which a very slight force is sufficient to turn the team back into the traveled way.

The cost of the guard rail may seem excessive, but one team over the bank will be awarded damages enough to pay a large amount of protective work.
SAND CLAY ROADS.

Although the sand clay road has given excellent satisfaction in the Southern and Middle Western States, little has been built in the Pacific Northwest. Since it has proved successful in soils and climatic conditions similar to those in Oregon, there is no question as to its value for our rural highways. The saving in expense of construction is no small item, the average cost for the 24,601 miles in the United States being but $723 per mile, as compared with $4,989 for macadam. In other words, nearly seven miles of sand clay road can be laid for the price of one mile of plain or waterbound macadam. The maintenance expense is less than for any other form of improvement with the exception of the earth road, and both horse and automobile traffic prefer it to any of the hard surfacings.

Short stretches of experimental road should be constructed in each county to determine the proper proportions of the materials and the cost of the improvement. Where both sand and clay can be found near together, this should not exceed $500 per mile in the clay soils, or $1,000 in the sand belt.

There is little choice between a dry clay and a wet sand road, either being the equal of the best gravel when properly graded. Reverse the conditions and we have the two worst roads in the state, both being practically impassable. The wet clay forms a regular quagmire, and the dry, shifting sand offers a tractive resistance of nearly one-quarter of the load. The so-called sandy loam roads are usually in fair condition all the year, the reason being that Nature has here mixed the sand and clay in proper proportions.

It is quite possible to imitate Nature in this work, combining the sand and clay in such a manner that the small voids between the grains of sand are each just filled with minute particles of moist clay. The sand is bound together into a compact mass, and the clay is prevented from balling or caking. The following extract from a bulletin on Highway Improvement issued by the Kansas Agricultural College illustrates the condition of a properly bound sand road.

"At Palm Beach, Fla., there is an excellent example of a natural sand clay road. The sea shells have been washed back and forth on the beach until
infinitesimal particles of the shells have been ground off and they fill the voids in the sand and cement the grains of sand together. The beach is almost a perfect natural boulevard, where automobile races are held and where a record of one mile in 27 3-5 seconds was made."

CONSTRUCTION OF SAND CLAY ROADS ON CLAY SUBSOIL.

The most careful consideration should be given the highways of the clay districts, for here is found the best agricultural land. It is little satisfaction to the farmer to raise large crops if he cannot market them advantageously, and when obliged to wait the pleasure of the road he must accept lower prices for his produce.

The road must first be carefully graded and drained. It should be crowned about one inch to the foot and smoothed with the drag. The road can be greatly improved by adding sand, even if no grading has been done, but the expense will be much greater.

Great care should be exercised in the selection of the sand. It is usually necessary to haul this quite a distance and it will not pay to import inferior material. It must be sharp and coarse, but it need not be as clean as would be required for concrete. Bank sand is better than river sand, as it is much sharper, but the latter can be used to advantage where a good bank cannot be found within a reasonable distance. Any sand will improve a clay road, but to get the best results it is necessary to choose carefully.

The sand should be brought to the road and piled along the shoulders during dry weather. The rains must soften the clay before construction can begin, but the cost of teaming is much less when the roads are hard and firm.

The cheapest method of improvement is to spread the sand from four to six inches deep over the wet clay and let the traffic mix the materials. There is but one possible argument in favor of this plan—its economy—and as more sand is usually required to fill the ruts and holes formed by the heavier teams, even this advantage is sometimes lost. The road is well nigh impassable for heavy loads until the sand and clay are thoroughly mixed, and while it will eventually be as good as when the work is done with plow and harrow, the wear and tear on vehicles, harnesses, horses, and on teamsters' tempers, is usually sufficient to warrant the more expensive system.

The better way is to spread the sand evenly over the surface for a width of 12 to 16 feet, depending upon the nature and amount of traffic, mixing well with plow and harrow. The depth must be governed by the nature of the traffic, six inches being ample for
light vehicles and 12 inches for heavily loaded wagons. A certain amount of mixing can be done dry, but the road must be wet enough to puddle the clay before the materials will amalgamate thoroughly. If a herd of cattle, or, better still, a flock of sheep, can be driven over the road when it is saturated with water, the mixing can be accomplished much easier and quicker. The road drag should be used frequently to maintain the crown and fill the ruts which will form during the first few months.

The best time to improve the roads of the Willamette Valley is in the spring, during the last part of the rainy season. Enough water will be secured to mix the sand and clay, and the long dry summer will give the road an opportunity to pack. If built during the first rains in the autumn the materials will be mixed perfectly, but the road will not pack well before the following summer. Whenever the construction is undertaken, one thing must be borne in mind, a sand clay road cannot be built without plenty of water.

It is impossible to determine the amount of sand required for the clay roads without experiment on the highway itself. The proportions will vary from 60% to 75% of sand, the latter quantity being needed in the “buckshot” soils. Many of the clays have a certain amount of sand mixed with them, and in the estimate this must be taken into consideration. The sandy loam and alkali roads will need a very light application of sand in most cases, and the traffic can easily mix this without the aid of plows or harrows.
Do not assume that your road is a failure because it does not compare favorably with gravel or macadam as soon as the sand is added. Its construction is a gradual process and the surface will not reach its best condition in less than six months. If it gets muddy during the long rains, add more sand; if it becomes too dry and dusty during the summer, add more clay to fill the voids.

All that is needed for maintenance is the addition of a little more sand each year, and the occasional use of the drag. The use of an asphaltic oil would probably prove beneficial, but like all oiled earth roads, this is still in the experimental stage.

Any form of construction which costs so little, needs so inexpensive a plant for its construction, and can be maintained so cheaply, should be adopted throughout the Northwest. It will solve the problems of those road districts where good sand can be found in abundance near the highways. Its very simplicity and low cost have seemed to prevent its use in many places, but a single experimental piece will convince anyone that it is far better to have seven miles of sand clay road than only one mile of macadam.

CONSTRUCTION OF SAND CLAY ROADS ON SAND SUBSOIL.

The worst highways of the state are to be found in the shifting sands of the semi-arid portions of Oregon. They rarely receive enough moisture to bind them properly, and when dry they are impassable to any but the lightest traffic. Many attempts have been made to improve them at low cost, the most common
method being the spreading of sage brush over the surface. This sustains traffic for a short time, but the road soon reverts to its original condition.

The sand roads of the Middle West are just as bad as those encountered in our state, and the same experiments have been tried there for years. Straw, sawdust and other materials have been used to hold the moisture, but none of them have worked much better than the sage brush. No permanent benefits were attained until the sand clay process was adopted. This has proved uniformly successful. It seems even better adapted to the deep sands than to the heavier soils, the road lasting longer and costing less for maintenance, although the first cost is usually somewhat higher than on a clay subsoil. The clay rarely gets too wet, but holds sufficient moisture to bind the road.

In deep sands, even greater care should be exercised in the location of the highway than is necessary in the heavier soils. In both cases, the grades should be low enough to permit heavy teaming, but in the sand hills the surfacing must be protected from the winds. Never build on top of the hills, no matter how light the grade, for the sand will soon drift over the unprotected highway, leaving it in as bad condition as before improvement. Always locate on the lee side of the hills, building fences wherever necessary to keep the sand dunes from covering the new surface.

The U. S. Office of Public Roads has issued a bulletin on this type of construction for the highways of the Middle West. The procedure is equally applicable to Oregon conditions, and the following instructions are taken from this pamphlet:

"After the location has been selected, a roadway not less than 30 feet wide should be laid out. All inequalities should be graded out so as to give a smooth road with a uniform cross section. When this has been done stakes should be set for the center line of the road, and for this purpose plaster laths serve excellently. With a turning plow a furrow should be run up one side of the row of stakes. In this way a ridge is made exactly in the center of the road. Then a roadbed should be thrown up to the width to be clayed by backfurrowing to this ridge. A drag or harrow should be used to smooth this bed and the crown should be carefully made to conform to the proposed finished road: A good practical width for this bed is 14 feet. After the central section has thus been prepared and smoothed with a harrow or drag, the shoulders should be backfurrowed on both sides of this clay bed with the turning
PLATE XII

SAND ROADS OF EASTERN OREGON
plow. To do this the plow should be set so that it will discharge the material in a ridge just outside of the last furrow made in forming the bed. Thus by several rounds with the plow the shoulder is raised sufficiently to form a protection to the sides of the clay when placed in the prepared bed. Usually five such furrows on either side complete a 30-foot road to the ditch line. When this is done the sand bed is ready for the clay to be hauled upon it.

"If in the foregoing operation any stakes have been misplaced from the center, they should now be restored in order to maintain the center line of the road definitely. The first six or eight loads of clay should be dropped exactly in line with these center stakes. The next loads are dropped on one side of the center loads, inside of the shoulder, but only about half as many should be dropped on the side as were dropped in the center. Clay should then be dropped on the other side in the same manner. This work should be done in such a way that the center line is some 50 feet in advance of one side line and the first side line about the same distance in advance of the other—an arrangement by which three loads can be unloaded at once. With this plan the teams will not be blocked in hauling, and, furthermore, by keeping the center line well in advance of the sides it is an easy matter to keep the road true and even.

"After 200 linear yards of the road have been covered the clay should be spread. It is important not to begin to spread the material immediately after being dropped upon the road. The reason for this will appear later. Nothing is better for the purpose of spreading the clay than a two-horse two-wheel grader. The spreading is begun by pushing the side loads toward the center to fill in the space between the center and the side loads which has already been rolled by the wheels of the loaded wagons. After this has been done the hauling should be continued until the material has been thoroughly packed by the wheels of the loaded wagons passing over it. The center may then be brought toward the sides with the grader and the entire road smoothed. Travel may now be freely allowed on any part of the surface of the road. If the loads of clay average one cubic yard each they should be dropped touching each other in the row, but if less than one cubic yard they should be slightly lapped. The person in charge of this part of the work should exercise his judgment in the matter of dropping the loads according to the size in order to secure the desired depth of clay, which should not be less than six inches, while it may be as much

(61)
as 12 inches when very heavy loads, such as traction engines, are to pass over it.

"The side loads should be pulled toward the center first, for the purpose of preserving the crown and keeping the material well toward the center; since it is easier to cut down the crown later, if too high, than to build it up. This is also important for the reason that the teaming must be depended on to do the rolling, since it is not expected that a roller will be used. Moreover, if the center is left undisturbed the teams will naturally follow on each side of the crown and, in consequence, the wheels of the loaded wagons will roll in the proper place to give the greatest rolling effect to that part of the road which will afterwards bear the heaviest burden of travel, leaving the material of the center loads in condition to be handled by the grader when the center is to be dressed. Then, last of all, the surface is finished with the grader. Especial care has been taken to make this detail clear, for upon careful attention to it depends the smoothness of the road when completed. Perhaps no part of the construction is as important as the matter of providing an even texture and a surface in the outset free from small depressions. For the semi-arid sand hills this is especially important, because it is not the purpose ever to break the bed of clay up entirely in the application of the sand. If by neglect or other cause the clay has been dropped improperly, causing a thin place, the necessary repair should be made at once and all the material should receive the same rolling in construction. It is quite important in the semi-arid territory to have the clay fairly well compacted before the sand is added, and to add sand only on top of the clay, in the manner described above for sticky soils. Indeed, the construction is identically the same, after the clay has been placed on the deep sand, as that described for gumbo or any other clay district, with this exception—the sand, in the case of the sand-hill road, will not have to enter as deeply into the clay or form as large a percentage in the composition, except for the upper inch or two of the surface. The greater part of the clay remains undisturbed as when placed on the sand. It is expedient and proper, however, to have at all times a coating of sand on the road. After the road has been properly smoothed the grader may be reversed with good effect to bring a covering of sand from the sides of the road, which have been previously plowed up for the shoulders during the preparation of the roadbed. It may happen that by hauling over it the clay will be pulverized to such an extent that an
inch or more of dust may form on the surface. In this case the fine, mechanical separation can be used to advantage by incorporating an abundance of sand with the dust. Sufficient sand, fully twice as much as the amount of dust, if gumbo, should be added and thoroughly mixed by means of a tooth harrow. When the rains come, only mucking and settling remain to complete the composition.

"There is one important thing to avoid in this dry climate. The clay should not be disturbed deeper than there is moisture to reunite it at the time that sand is added. The road should be built of clay, covered with sand, and left to the rains to soften the clay so that it can absorb the sand. The clay should never be pierced to the sand base, for the reason that, if it should be continuously dry for a long time, the loose sand would work up from below and cause sandy pockets and sandy places in the road, not unlike mudholes in a clay road in effect. This is quite important in drift and very fine sand.

"After the clay has been placed upon the road, sanded, and treated as above described, the turning plow should again be used to build up the sandy shoulders until nearly level with the clayed part. In this way a trap will be set for all the clay that blows or washes to the sides. This is not only permissible in a sand-clay road, with deep sand, but desirable. It is not so in a road entirely of clay, and this distinction should be noted. Another reason for lifting the sand shoulders so high is to conserve moisture, the opposite of what is necessary in the case of sand-clay construction on a clay sub-soil. It must be carefully observed that this last suggestion applies to deep sand only and never to shallow sand, where the rain is not at once absorbed. Every effort should be made to conserve moisture in deep sand and a dry climate, because the moisture prevents dust and the consequent blowing away of the road. It is therefore a matter of necessity, if the greatest success is to be attained, that these local conditions be carefully considered in every detail of the construction. The building up of the shoulders is of advantage to the road when it is to be dragged, because then it is an easy matter to get from the shoulders the sand needed on the softened sand-clay roadway.

"While it is customary to use the sand along the road, yet if it is very fine and there is coarse sand near by, it will often pay to haul a slight covering of the coarse quality upon the clay. This is particularly advantageous where the winds are very strong, be-
cause the coarse sand is far more resistant to the winds and far less disposed to break up the clay bond. It acts in the same way that coarse sand does with cement. The shoulders should be plowed out to the ditch line and, as far as possible, vegetation of some kind should be encouraged to grow on the sandy berm. All these points should be observed to prevent the sand from blowing away and leaving the sand-clay road unprotected. If much rain should come and the clay should soften, as much sand should be added as the softened clay will mix with well and the sanding should be followed with a drag until the road is again dry and firm.

“The maintenance of the road is of the utmost importance for one or two years after construction. Proper care at the right time often saves a whole road from failure. There is nothing permanent about a road except its location, and nowhere is that saying truer than in the sand hills. Even the location is often in jeopardy.

“Nothing has been said so far about the choice of the material to be used as the clay part of the sand-clay road in the sand hills. The choice is usually limited to gypsum, alkali soil, or gumbo. Sometimes only one is available, but when more than one can be had it is important to know how to select the best.

“Gypsum varies from a chalklike, non-binding, easily pulverized mass to a composition of semi-plastic gypsum and clay, which, under travel, hardens on the road like cement. This latter is quite useful as a road material, while the former is practically worthless, because it lacks binding power. The binding power is one of the properties to be sought for most carefully. If the material packs readily and pulverizes slowly when dry, or softens slowly when set, it may be safely accepted as a suitable material for making the surface of a road hard. This characteristic alone can be relied upon. Color has little or no significance as to its value.

“The alkali soils are more or less variable in composition, usually containing a certain proportion of sand, silt, clay and organic matter. In some respects they are very much like the loams, but they contain varying percentages of different soluble salts. As a rule, very little sand need be added to an alkali hard surface material. The best results come from spreading it on rather heavily and dragging it thoroughly afterwards. Gumbo is one of the materials sometimes met with and, if it is free from grit, a large amount of sand will have to be added. This material has the peculiarity of cracking in every direction when it thoroughly dries out. This
makes it necessary to add more sand after each rain and also when the gumbo dries and cracks. These cracks should be filled with sand as often as they appear and this should be continued until sufficient sand is incorporated to stop the cracking completely. This characteristic of the gumbo splitting up into thousands of little pieces is of immense advantage for introducing sand, but it is of serious consequence in periods of extended drought, because it may cause the complete failure of the road before the necessary sand can be incorporated with the gumbo. If once the sand and gumbo are mixed and compacted by travel, little is to be feared thereafter. It is clear, therefore, that, when gumbo is used, it is important to utilize to the fullest extent every rain, in order to puddle the surface and to do everything possible to conserve the moisture in the gumbo by keeping the sand shoulders high, even above the level of the clay portion of the road. It is better to do this, for the additional reason that it will help to keep the rain water on the gumbo and soften it to a greater depth, and thereby allow a more thorough intermixing of the sand with the gumbo. It should always be kept covered with a little sand. Whatever the variety of gumbo, whether from a lake bottom, the overflow of a river, or an irrigation ditch, its characteristics are practically the same, and it will be valuable as a road material in proportion to its binding power and ability to resist washing or pulverizing and consequent blowing away."
OILED EARTH.

This method of construction is still in the experimental stage and must be studied more thoroughly before uniform results can be obtained. California has probably done more along this line than any other state, but even there some of the highways are not standing up under traffic as well as was expected.

Although good roads have been built in clay soils by mixing them with heavy asphaltic oil, the best results are usually obtained with a sandy loam. The deep sand roads can be improved in this manner and it is here that oil will probably be used the most. In certain sections of the sand belt it is almost impossible to secure any clay and oil must be used for a binder. It will certainly be inadvisable to spend much money on this form of improvement until stretches of experimental highways have been treated by this method to determine the proper amount of oil for each locality. The method which has been used most extensively in other states is as follows:

Plow shoulder furrows on each side of the center line about 16 feet apart. If the road has been previously crowned it will be necessary to plow the material for the entire width to be oiled, throwing the loose earth onto the shoulders. Great care must be taken in the preparation of the subgrade which should be given a crown of three-quarters of an inch to a foot, the same as that required for the finished road. It should be rolled thoroughly with a heavy roller until the spring is taken out of the soil and the material is thoroughly compacted.

It is absolutely necessary to use a heavy oil, one containing 85% asphaltum being the minimum allowable. Apply this at a temperature of not less than 250 degrees Fahrenheit. The amount used varies with the soil and the climatic conditions, from two to three gallons per square yard being sufficient in most cases. This is applied in two courses.

From 1 to 1\(\frac{1}{2}\) gallons of oil should be applied evenly to each square yard of the subgrade, and about four inches of earth thrown over it. This should be stirred with a disc harrow and rolled with a tamping or petrolithic roller, a cut of which is shown in Fig. 18. This machine compacts the material, tamping from the bottom.
up, until it rides on the top of the road. After this layer of earth has been thoroughly mixed with oil and compacted, another gallon or gallon and a half of oil should be spread over it evenly and another four inches of earth added. This should be stirred, mixed and rolled in the same way. If too much oil comes to the surface more earth may be added. About one inch of sand or gravel makes an excellent surfacing for this type of construction.

The road should be kept wet during construction, there being very little danger of using too much water. The materials must be mixed immediately after the oil is applied, to prevent cooling; and unless the weather is exceptionally hot the work must be rapid, as the wet earth very quickly reduces the temperature of the oil.

The cost of this form of construction should not exceed $1,500 per mile at present, and as soon as enough oil is used to warrant the California oil fields shipping material here by steamer, this cost will be reduced to about $1,000 or $1,200 per mile.

Good results have been attained in certain sections of the state by using lighter oils to lay the dust during the long dry season. In the volcanic ash, as well as in the sand belt, this work can be done for about five cents per square yard. While the road does not compare with that built under the petrolithic method, the suppression of dust is well worth the expense.

Ordinary fuel oil may be used for this purpose, applied hot
from an ordinary street sprinkler with an oiler attachment. About half a gallon per square yard should be spread over the road early in the spring, and another application should be put on in the middle of the summer. These two coatings should last through the first year and leave a slight residue of asphaltum mixed with the soil. The second year it will probably be necessary to give the highway two applications of the oil, while in each of the succeeding years one application will be sufficient to lay the dust throughout the entire season.

**BURNT CLAY.**

In certain sections of the state highways are built through sedimentary clays and gumbo where the cost of sand would be prohibitive. Experiments carried on by the U. S. Office of Public Roads show that the clinkering point of these materials is low enough so that they may be burned on the road at low cost. This process destroys the plasticity of the material and forms brick-like lumps which break up under the roller, making an excellent road at a cost of about $1,500 per mile. The gumbo or "buckshot" soils are best adapted to this treatment.

Unless timber be obtained for the cutting, the cost of this form of improvement will be greater than is warranted by the benefits obtained. One cord of wood is needed for every eight lineal feet of road, and if it is necessary to pay for this fuel it will be better to figure on macadam or some other surfacing.

When a good supply of fuel can be obtained cheaply, it should be gathered as early as possible and piled along the road to dry. Cut the wood into four, eight and 12 foot lengths, and provide plenty of chips, bark, old railroad ties, or any other dry fuel which is available.

The road should be graded to an even width between ditches, 30 feet being the maximum required in this state. Twenty-five feet will be ample in most cases, as the burned surface should never be wider than 12 feet. The road should be crowned about one inch to the foot, and then plowed as deeply as practicable, using at least four horses. This heavy soil cuts hard.

Dig furrows every four feet across the road, extending through and beyond the width to be burned. For 12 feet of roadbed the furrow should be 16 feet in length, extending two feet outside each way. Place a layer of cord wood longitudinally over the furrows so as to form a series of flues in which the fire can be started. The
best wood should be used for this layer, the pieces touching to form a floor.

The next layer of wood is thrown irregularly over the first, leaving a crib formation with spaces in which the clay is piled. Take care that the clay is in large enough lumps so as not to interfere with the draft. The third course of wood is laid parallel to the first, in exactly the same manner, and each crack must be filled with chips or other combustible material. The remaining clay is heaped over this floor and the finer portions of the material are thrown over the whole.

Great care is necessary in the arrangement of the cribbing. The fire must get well under way in the flues before the first layer, the floor, is burned through.

Prepare at least 15 to 20 flues before starting to burn. If a large force of laborers is available, more flues can be fired at once. The construction can be divided into sections by omitting the wood in one furrow, which may be covered later and burned in the same manner as the rest. The best results are obtained by firing all the flues simultaneously and keeping the fires as even as possible. Get a good supply of kindling on hand to prevent the fire from dying down in any one place. Start each fire on the windward side to get the greatest possible draft, and if any burns too fiercely, bank the mouth of the flue with clay.

The first action of the fire is to drive the water out of the clay, as clinkering cannot begin until the material is thoroughly dry. Gumbo contains a great deal of vegetable and other organic matter, which assists greatly in burning.

After the material has been well burned, not only the clay in the ridges between the furrows will be clinkered, but from 10 to 12 inches of clay covering will also be ready for the road. This will be compacted under the roller about 50%. The roadbed must be brought to a high crown before rolling by use of plow and grader. After rolling the crown may be as low as one-half inch to the foot.

The material has been entirely changed in its properties by heating and will not get muddy when wet. It is to be noted that not all the clay in the road is to be burned, simply enough to neutralize the plasticity of the other portion. In many respects this method resembles the sand clay road, the chief difference being that the lighter constituents are manufactured on the ground.

The method outlined in this section is taken from a bulletin published by the U. S. Department of Public Roads, describing their work in the Mississippi Valley.
MAINTENANCE.

There is no such thing as a permanent road. This may sound like quibbling with a mere term, but it has been found that taxpayers usually assume that no further outlay is necessary after a hard surfaced road has been finished. The time to begin the maintenance of a macadam road is the day after the contract is completed, and to a great extent this same rule holds good for other types of construction. The earth road costs less to maintain than any other form of improvement, but the work must be done at the right time and in the right way to get the best results.

Ditches and culverts must be cleaned at least once a year. The crown should also be rebuilt at this time, but this should not be done with the debris from the side of the road. The practice of breaking the sod out of the ditches and leaving it in more or less neat piles in the center of the highway just before the rainy season begins, cannot be too severely condemned. Traffic is forced into the ditches and the road is soft at the sides and “hubbly” in the center until the following summer. In Eastern Oregon where there is little rain and very heavy wind, it would be advisable to leave the sod undisturbed after the road has been properly crowned. The grass should be cut as short as possible and the sod left in place.

The chief repairs should be looked after in the spring when the soil, being moist and easily worked, will compact readily under the drag and the traffic. There is little use in attempting to do much in July and August, for the soil is so dry that it is difficult to shape properly and most of the crown will blow away in the first breeze.

Where there are holes in the travelled way, these should be filled with the grader before the drag is used. Fill all ruts and depressions with the same material of which the rest of the road is built. Gravel or stone used to repair an earth road will make hard spots in the surface, and the next rains will form two mud holes, one each side of the old slough. Sand will not injure a clay road if used to fill holes, since it will mix with the other materials, as explained in the chapter on Sand Clay Roads. It is hardly advisable, however, to use the sand before the grading is completed on account of the needless expense.
If the road is in pretty good shape, the drag will fill the ruts and raise the crown without the aid of the grader. A roller is always useful, but not absolutely essential unless heavy grading is contemplated. Where the soil is lumpy and will not break easily under the drag, the harrow may be used in maintenance as well as in construction.

Both the residents along the road and the teamsters who drive over it should take good care of the highway. If they have not pride enough to make them ashamed of poor stretches of road in their district, selfish reasons alone should show them that the money spent in assisting the supervisor will be returned many times in the reduced cost of hauling and in the abatement of the dust nuisance. They can use the drag to good advantage and remove stones from both the travelled way and the ditches. They can keep the weeds and grass mowed down and refrain from using the road as a dumping place for all the farm refuse.

DON'T DRIVE IN ONE TRACK. Nothing will ruin a road quicker. For some unexplained reason everyone seems to prefer the lead of the first man over the road, keeping the wheels in exactly the same track. Then they wonder why the ruts are so bad.

ROAD DRAG

Wherever the highways are built of clay or other heavy soils, they may be maintained at slight expense by the use of the drag. The supervisor alone cannot get the best results from this implement, each one must look out for the road in front of his own property. More depends on the time the road is dragged than on any other one consideration, and only by taking short stretches can the work be done when the soil is in proper condition.

The success of the split log and plank drag has led to the introduction of patented machines. Most of these are built of steel, some of them being so heavy as to be practically wheelless graders. All of them are excellent for filling ruts and crowning the road, and the heavier ones are particularly serviceable for spreading gravel. The theory of the drag, however, is that it deposits a thin layer of puddled clay over the surface. When this dries it leaves a waterproof layer the full width of the drag; and while this will break through easily, enough films are formed in time to sustain traffic. The heavier drags move too much material at one time, the clay does not puddle well, and the layer never dries satisfactorily.

The first road drag was built from a split log by D. Ward King, a Missouri farmer. The split log has certain advantages, but unless
one has had considerable experience with an axe it will probably be as well to use planks. Plate XIII shows a drag built from 2 to 3 inch planks, braced with 2x6 inch pieces spiked to the inner sides. The cross braces are made from 4 inch pieces shaped to fit a 2 inch hole. These should be split and wedged into place. The ditch end is braced with a piece of 2x4. A piece of iron about 3 inches wide is bolted to the ditch end of the front plank, extending half the length of the drag.

The holes for the cross pieces are bored 10 inches and 24 inches, respectively, from the ends of the planks, so that these will track when the drag is hauled at the proper angle. The hauling chain should be arranged so that the hitch may easily be adjusted, and the end nearest the center of the road should be passed over rather than through the front plank. This allows the earth to slide easily along the face of the drag. A platform of one inch boards is laid on top of the cross braces.

The drag should be used soon after a rain. Wait until the ground has lost its stickiness, when the material will slide easily along the face of the drag; but do not wait until the road is dry in any place. Dragging a dry road simply breaks up the layers formed in previous operations and actually injures the highway. Very little improvement will be noticed after the first trial; some of the ruts will be filled and some bumps may be slightly cut down. But after a few trials the benefits will become more apparent. It is perfectly true that anyone can use the drag, but the skill to get the best results will come only with practice. If you can manage to keep your feet on the platform during the first trip you are doing better than the average novice.

The following points should be remembered in the construction and the use of the drag:

Build a light drag, one that you can lift if necessary. Any drag that requires more than two horses is too heavy and should be discarded or used only on gravel roads.

Hitch so that the drag will travel at an angle of 45 degrees with the center line of the road, and do not try to cut too much material at one operation. The amount moved depends wholly upon the length of hitch and the position of the driver. A long hitch will move more earth than a short one. When a hard spot must be cut, the driver throws all his weight on the front plank; when a soft spot must be filled, he moves back. If the crown gets too high, reverse the drag and move some of the material toward the ditches,
FIG. 1—A ROAD IN ARKANSAS THAT HAS NOT BEEN DRAGGED

FIG. 2—A ROAD IN ARKANSAS THAT HAS BEEN SYSTEMATICALLY DRAGGED
Two Views Taken within 500 feet of each other.
taking care to smooth it down well. Until they have been dragged
for some time few of our country roads are apt to get too much
crown.

Drive the team at a walk and ride the entire distance. Drive
up one wheel track and back the other. Do not try to improve
too wide a section at one operation.

Do not build too long a machine. For narrow roads the drag
should be half the width of the travelled way, and a nine or 10 foot
drag is long enough for any highway.

Do not attempt to maintain too long a section. So much de-
pends on the time the machine is used that there is danger of drag-
ning the road too wet at one end and too dry at the other. This
is the reason why the supervisor cannot do the work alone; every-
one must take hold and help.

Remember the drag is only good in clay or similar soils. A
sand road will not be benefitted in the least, and if the drag is used
to form a crown, the results will be positively harmful. A sand road
needs all the moisture it can hold, and the crown drains this away.

The cost of maintaining earth roads with the drag is nominal.
Few farms would have to purchase any of the material for its con-
struction, although the district could easily afford to furnish lumber to
all who would agree to build and use one. Roads in the Middle
West have been dragged as cheaply as $2.50 per mile a year, and the
highest cost was under $10 per mile. Assuming that the roads of
Oregon would cost $10, the districts would still have sufficient
funds available for new culverts and other permanent improve-
ments. Many men would be willing to donate their time; but even
where the district pays all the bills, the saving would be decidedly
worth while.

A well dragged road will be free from mud and ruts in winter,
and comparatively free from dust in the summer. The tractive
force required to haul a load over it is as low as over the gravel,
and in most cases no further improvement will be required until
it needs macadam.

We can have good roads if we are willing to work for them.
We must decide whether we prefer to pay high taxes for stone and
gravel, or do a little of the work ourselves. Don’t blame the super-
visor; like the piano player in the music hall, “He is doing the best
he can.” Just use the drag and help both the district and your-
self, and at the end of the year take note of the difference in your
roads, your community, your bank account, and your temper.
ROAD MACHINERY.

Most road districts in Oregon require very little machinery for the construction and maintenance of their earth roads. Each one must determine what is needed for its soil and climate. Adjoining districts can unite to buy the more expensive implements. Steam and petrolithic rollers should be purchased by the counties and loaned or rented to the supervisors.

Each year sees new devices for moving earth, some good and some useless. Unless you are sure that the innovation is practicable, it is well to let the other fellow do the experimenting during the first season.

Whatever is worth buying is worth protecting. The sight of plows, harrows, scrapers, graders, etc., left standing where the last work was done, receiving the rains of winter without any shelter, is calculated to make the taxpayer wonder what becomes of the road funds.

GRADERS

If the district can afford but one machine, a good grader should be secured. Do not make the common mistake of buying a light machine, for while this will clean the ditches and do general repair work, it will be useless for grading new highways. The heavy grader will do both kinds of work and will prove more economical.

![Fig. 19](image)

Nearly all the machines now on the market are reversible, and will do excellent work if properly handled. They will cut ditches to an even grade in earth that a plow will hardly enter, and will leave the road smooth in a very few trips. Only two men are needed to operate, one to drive and the other to handle the blade. The
expense of improvement is much less than that of the old pick and shovel method, and the road is left in better condition.

In building new roads, the center and ditch lines should first be carefully staked out. Then plow a light furrow with the point of the blade along both ditches. Move more earth the second trip, carrying it toward the center of the road. The third time it will probably simply be necessary to smooth the ditches and move the earth already loosened to the center of the highway. Then set the blades so as to cut the back bank of the ditch to a 1 1/2 to 1 slope, and use this material to crown the road.

As soon as the crown has been formed, break the lumps with the harrow. The straight tooth harrow will do the work if there are no sods or hard lumps, but in new location it is usually necessary to use a disc. The road should next be rolled and all depressions filled with more earth. After this is completed, the road can be kept in first class condition with the drag, the grader being used each spring to fill the ruts and rebuild the crown.

To grade a road in this manner will not cost over $40 to $50 a mile.

ELEVATING GRADERS.

The following quotation from a report by T. H. MacDonald, Iowa State Highway Engineer, indicates the value of the elevating grader for road building.

"In a more rolling district the elevating graders can be used to good advantage to load dump wagons, but experience so far seems to indicate that it is usually not a good investment for a township to spend the large sum necessary to purchase or try to operate one of them with an unskilled set of men. There is a large sum of money tied up in such a machine which is used only during a small part of the year. Also, it requires a trained crew of men and horses and a complete camping outfit for camping on the job to prevent loss of time."

(77)
HARROWS.

These have already been considered under graders and need not be taken up again except to mention that both the straight tooth and the disc machines will be needed in the Willamette Valley.

PLOWS.

It is rarely advisable to plow an earth road when the district owns a good grader. Unless carefully used, the plow will cut too deep in soft spots which should not be disturbed, and too shallow in hard places. Once in a while a plow is necessary, but as a rule the road will be better off without it.

SCRAPERS.

The drag scraper is economical where the haul does not exceed 200 feet. It is particularly adapted to side hill work.
The wheel scraper can be used for hauls up to 500 feet. For longer distances, the self-dumping wagon will prove more economical. Do not get too large a scraper, the one-half yard size being the best for all round use.

The Fresno will hold more than the drag scraper, and can be used for hauls up to 300 feet. When emptied, it can be raised to slide on runners.
Reconnaissance Map of the Willamette Valley
Showing available outcrops of road materials in the more densely populated portion.