Part One.

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Thesis: The Construction of Bituminous Macadam Roads by the Penetration Method, According to Virginia Practice.

Part Two.

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Professional Experience of George D. Felix.

# Part One.

# The Construction
# of
# Bituminous Macadam Roads
# by the
# Penetration Method
# according to
# Virginia Practice

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Thesis Presented for the Degree of
Civil Engineer
by

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Washington and Lee University
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# The Construction of Bituminous Macadam Roads, by the Penetration Method. According to Virginia Practice.

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## I Introduction.

Each State has its own specifications and methods for building roads. These methods are fundamentally more or less the same, but differ because of different weather conditions, different soils, different kinds of rock (or lack of rock), and other factors. These all play a very important part in road construction. Conditions vary in different portions of each State and allowances must be made for them, both in design and construction. Textbooks and specifications can serve at best, only as a guide for the general methods of design and construction, and the engineer in charge of the work must consult his own judgement for the details.

The Shenandoah Valley of Virginia presents its own peculiar conditions in the matter of soils and rocks, which must be met by the highway engineer. Each section of the Valley has different soil conditions, and these different soil conditions require different methods of grading. They also affect the drainage.

Good alignment.

Though limestone is the predominant rock, other kinds are encountered, which affect the construction of the macadam, or surface course. The type of pavement generally used in this region is Bituminous Macadam, Penetration Method.

Construction of roads may be divided into three parts: grading, drainage, and surface. Discussions often arise as to which of these is the most important in the building of a first class road. The fact is that all three are of equal importance and so related that poor work in one is bound to affect the others.

Before the actual work of construction commences there are several steps to be taken. The first, of course, is the location of the road by survey, and the preparation of accurate plans. The next is the securing of the right-of-way, where necessary. It is not the intention to go into these subjects fully, but only to present some few items, which should be watched, but are often neglected.

In locating a highway the locating engineer should keep in mind that he is not providing for the present generation alone, but also for future generations. To this end he should endeavor to secure the best alignment possible, with the best opportunities for good drainage. He should endeavor to secure as straight a line as possible, and avoid blind curves. The amount of money available may make economy necessary, and there-

fore not permit of building on the best line, but it is false economy to build on an extremely crooked line, with many blind curves.

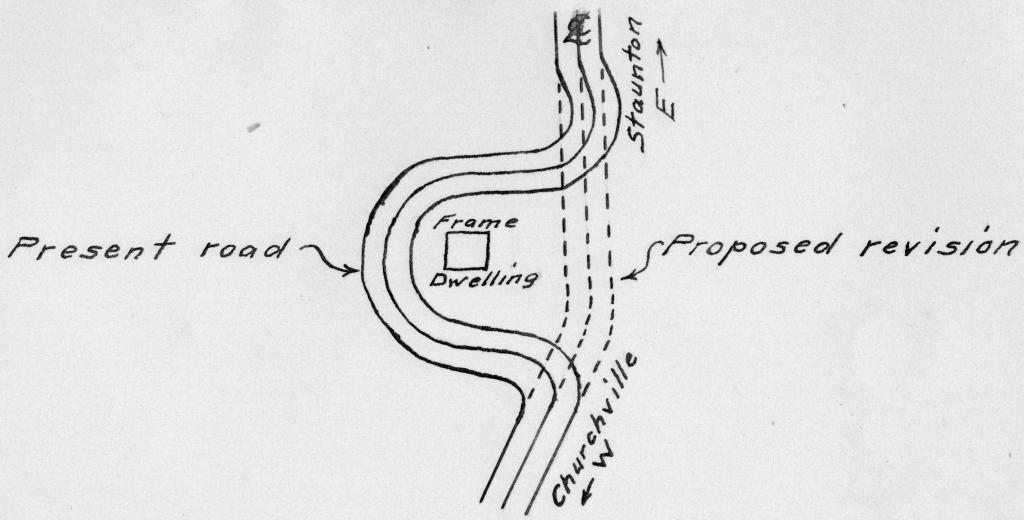
Rather than build on a poor line it would be much better to cut down the mileage to be built, and build on the best line. Examples of bad practice in this regard are to be found on many stretches of county-built roads taken into the state highway system. The counties have merely surfaced the existing old road, rather than buy a little expensive right-of-way, with the result that there are stretches of very dangerous road. The illustrations on pages 4 and 5 show two such stretches, and the sketch under each shows how each error could have been avoided.

The tendency has been, and still is to a great extent, to cut down speeding. This will in time change somewhat, for the demand in transportation to-day, as in business, is for speed. Of course this must mean "speed consistent with safety", but nevertheless speed is demanded, and this fact must be realized. Toward accomplishing this the highways must be built to allow fast driving, and safety for the careful driver. There will always be the reckless fool, who will insist on driving carelessly, and endangering not only his own life, but also the lives of others. The highways can not be designed for him.

An illustration of the realization that speed

Looking west.

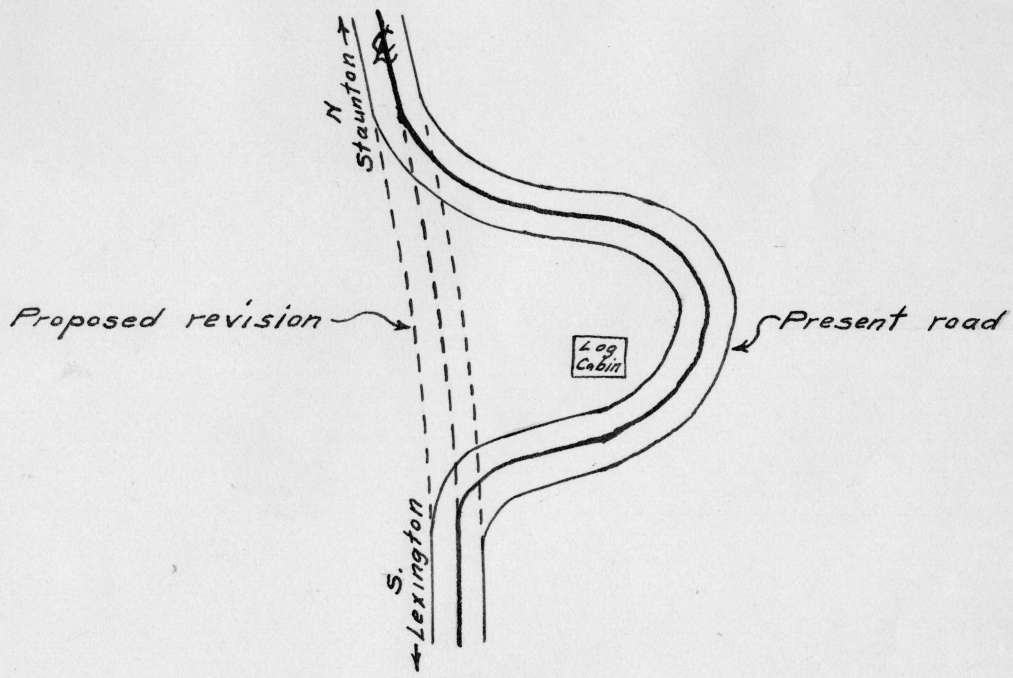
Looking east.




Road near Churchville and sketch.

Looking south.

Looking north.




Road near Mint Spring and sketch.

must be provided for, is the fact that curves are being widened and superelevated. Several years ago the idea prevailed that if a curve was not "banked" there would be no fast driving around it. The result was many accidents; the idea did not take into account human nature, or the demands of the times.

The locating engineer should also keep in mind the question of obtaining the right-of-way. Not that this is his duty, but the man following him must secure it, and the locating engineer can often help. There are often two or three possible lines, each one as good as the others, but on one the right-of-way may be obtained considerably cheaper than on the others. This line should be chosen. It is not unusual for the locating parties with the Virginia State Highway Commission to have to return to a project two and three times to make revisions in the line. This because of the impossibility of obtaining the right-of-way on the original line; which fact the locating engineer could have ascertained, by making a few inquiries at the time of locating the first line.

The Virginia State Highway Commission uses the following system in constructing their projects. The location is made by a locating engineer with a survey party, the right-of-way is secured by a right-of-way agent, and the construction is handled by an engineer on the job, called Inspector. Thus at least three

different men are on the job at different times, and unless the first two are careful in their work, the Inspector's job is hard indeed.

The right-of-way agent should endeavor to secure the right-of-way with as few conditions attached, as possible. By conditions is meant promises to have certain things done when the road is constructed. The carrying out of these promises is both expensive and unsatisfactory, as the agent and property owner seldom seem to have had the same thing in mind. The right-of-way agreement will stipulate certain things to be done, and this is what the construction man must be governed by. When these stipulated things are done, it is seldom what the property owner thought was going to be done, and the inspector reaps the blame. Hence it is more satisfactory to allow some figure as damages, and promise nothing. The amount asked as damages will seldom be as much as the work would cost, if done during construction.

It is surprising how few people will think about their entrances to home and fields; how the construction of the road will affect these entrances. That is they do not think about these entrances until the construction work begins, then the trouble begins. The construction man has an approximate estimate of the cost of the project which he must not exceed; this is especially true on Federal Aid projects. If there is

a specific right-of-way agreement to provide for the entrances, he can go ahead, and that work is charged to right-of-way. Where there is no agreement his hands are tied, and special authority must be secured before he can do any work on a private entrance.

Free right-of-way should, as a rule, be avoided, as it never turns out to be "free". The property owner almost invariably wants work done, when construction passes his place, which costs more than the right-of-way damages would have amounted to. From the fact that he "gave" the right-of-way, he can not understand why the inspector will not do a thousand and one things he wants to have done. The most satisfactory project, from the construction side, was one near Bridgewater, Virginia, where the right-of-way was secured without any strings attached. The owners were paid damages and they were given the responsibility of fixing their own entrances.

An example of the above was a well on a project near Gore, Virginia, The owner cut off twenty-five dollars from the amount of damages asked, and the State in return agreed to take care of the well. To do so would have cost one hundred and fifty dollars, but a settlement was finally made for fifty dollars. The State was loser by twenty-five dollars.

Another case occured on the same project. A property owner had a stone wall in front of his property,

which would have to be torn down in constructing the road. He asked one hundred dollars damages, but the right-of-way agent agreed to replace the wall on the right-of-way line. This replacement would have cost two hundred dollars, but settlement was finally made for one hundred and fifty. The State lost fifty dollars.

Still another example occured on a project near Greenville, Virginia. Here the property owner gave the right-of-way, which was a strip about five feet wide for four hundred feet. The damages would have been about fifty dollars. When construction reached his property it was necessary to build him a seventy-five foot, waterbound macadam entrance, which cost one hundred dollars. The "free" right-of-way was bought in the end. These examples show that the best way to handle the situation is to pay reasonable damage charges, and have no conditions.

Graded road.

## II Grading.

Clay is a soil which presents difficulties in grading, especially if the surface is to follow closely after this part of the work. It does not absorb moisture easily; that is, it will absorb a gentle, steady rain, while most of a heavy downpour will run off. On the other hand, once soaked thoroughly, it does not dry quickly, and when soaked, it presents a problem to the road builder not easily solved. A sandy loam on the other hand will absorb moisture freely, and dries as quickly. It does not present the same difficulties as clay, and is much easier handled.

On the Lee Highway, twelve miles south of Staunton, Virginia, both of the aforementioned types of soil were encountered. The grading was largely done during the fall and winter months, and the difference in the absorbent qualities of the two soils was clearly demonstrated. The clay cuts were difficult to loosen in order that the slips and wheel scrapers could move the material, during the fall months. There was a crust which had been baked by the summer sun until it was hard as brick. Plows could not be used, and it was necessary to use "rooters". These could not be pulled by mules, but were drawn by traction engines.

The heavy showers in the fall loosened this crust

but did not soak to any depth. The loose fills however absorbed the moisture freely and early became impassable. To accommodate traffic, and provide for the passage of the United States mail carrier, it was found necessary to corduroy the clay fills with slabs, obtained from local sawmills. Following a rainy spell or snow the clay cuts could not be worked, not because of the conditions in the cuts, but on account of the condition of the fills. The fills being loose, absorbed water, with the result that the teams and scrapers mired up, and the work at these points was stopped.

Wherever sandy soil was encountered, however, work progressed all winter. This soil though absorbing moisture quickly, dried out rapidly, and at no time became impassable. In the spring the sandy stretches dried out rapidly, and surface could be layed on these places when the clay fills were still too soggy to permit of rolling. Across the Blue Ridge in Albemarle County, the red clay is especially tenacious in holding moisture and the laying of surface there is fully two weeks, to one month, later in the spring, than in the Shenandoah Valley.

This matter of the absorbing and retaining of water by soils, is of very great importance in building bituminous roads. This type of road, the top course being elastic, requires a firm, solid base, which in turn must rest on a solid subgrade. If conditions are

such that a solid subgrade can not be obtained, special treatment of the surface is required. This will be taken up later.

In mountainous sections the dry subgrade is not so hard to obtain, for there the drainage is good, as a rule. That is, the ground being steep, with natural water courses, the only thing necessary is to provide sufficient drainage structures of adequate size. On the other hand, in the valleys it is not unusual to find places where it is difficult to determine in which direction water would flow. Here care must be taken to provide ditches to lead the water away from the roadbed, and avoid ponding.

Another problem in grading is the packing of the fills at time of placing, so as to avoid later settlement. This ideal condition can not be realized completely, but care must be taken to reduce the subsequent settlement to a minimum. Several methods are used to obtain this result; (1) by using wheel scrapers to make the fills; (2) by using wagons; and (3) by rolling the fill with a ten ton roller. No matter how placed, or whether rolled or not, the fills should be made in layers, and these should not be over fifteen inches deep.

The steel tires of the wheel scrapers or wagons, as they pass back and forth over the fills, pack the material to greater advantage than a roller. If the fill

is more than five feet deep, and the surface is to be laid within six months, it should be made in one foot layers and each layer rolled thoroughly. Too much emphasis can not be placed on this compacting of the fills, as a smooth macadam surface can not be maintained if there is any subsequent settling of the fill. The pictures on pages 14 and 15 illustrate the above.

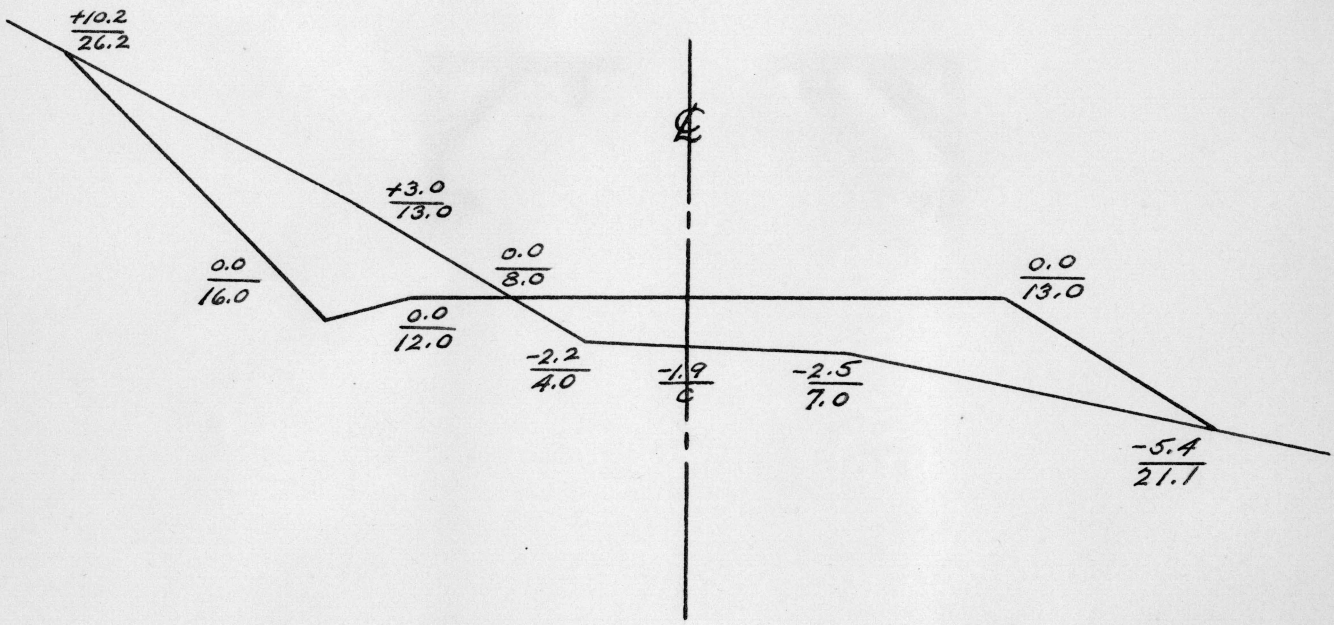
The first illustration shows the rough surface, even after patching, caused by the fill being made in deep layers and not rolled until compacted. The other picture shows the surface very little distorted by settlement, due to the fill having been made in two foot layers with wheel scrapers, and thoroughly rolled.

In mountainous sections, where the cuts will run from fifty to one hundred per cent rock, the danger of settlement is not so great, depending on the kind of rock. Some rocks, such as a form of slate and shale, disintegrate very rapidly when exposed to the air, and action of the weather. Here, of course, no amount of rolling will prevent settlement. The tendency now is to grade these mountain roads and allow them to stand a year or two, before placing the surface.

Especially is this a good practice when there is much "side hill" work (Figure 1). Here the tendency is for the fill to slip on the old ground and give a resultant poor surface, as shown in the picture on page 17. The fill was made as the figure (Figure 1)

Rough surface due to bad grading.

Good surface on deep fill.




Cross section; side hill work.

Figure 1

C.D.F.

Settlement of surface due to fill settling.

shows and the surface placed one month later.

In the mountains fills of thirty, or thirty-five feet are not unusual. Since the amount of settlement is five, or ten per cent of the depth of the fill, sometimes more, it is easily understood why roads in these sections should be left a year or two, before placing a macadam surface on them.

The present system under which Virginia is building roads, "the pay-as-you-go method", is especially conducive to this "delayed surface" construction. A limited amount of money is available each year, under this plan, which must be proportioned over the entire state. This means that many projects can only be graded and the drainage structures built; the surface being placed one or two years later, as the funds become available. To the layman this does not seem to be accomplishing what is desired, but as a matter of fact it is the best possible arrangement. The Highway Department has shown good judgement in only grading the mountain roads at present, and confining to a large extent, the surface work to the valley sections.

Care should be taken in making a fill not to allow any thoroughly soaked material, or muck, to be placed in it. Clay, thoroughly soaked, is a long time in drying out, especially if placed in the middle layers of a fill. Muck, or earth with partially decayed vegetable matter, can not be used at all. It is very

A thirty-five foot fill.

spongy and can not be gotten in shape to lay a surface on. Both the above materials, should they be placed in a fill, must be removed and dry material, free of partially decayed vegetable matter, substituted. The grading should be done with the fact in mind, that the surface can be replaced, but that the grading is usually done but once.

Concrete bridge.

## III Drainage.

Of equal importance with careful grading is the proper drainage of a road. Here engineers often practice the theory of "false economy" effecting a saving by the ommission of a pipe line, or cutting down the size of a box culvert. But the resultant damage during a heavy rain may cost more to repair than the saving amounted to.

Some engineers have an arbitrary rule of a pipe line every three or four hundred feet. A more reasonable method is to study the drainage channels and place a pipe, or box culvert, of sufficient size to carry the runoff. Large bridges are, of course, designed with reference to the drainage area by the Bridge Engineer, and are not left up to the man in the field.

Pipe lines should be placed ahead of the grading, if possible, and at least at the same time that the grading is done. If they are not placed in time, it may result in the cut or fill becoming soaked and unfit for surfacing, thus delaying the work. The staking out of pipe lines should be done with two points in view. First, of course, that of serviceability, and second that of adding to the general appearance of the road. This last point is often neglected, and pipe headwalls stick out glaringly, as if monuments to poor

judgement.

There are numerous formulas and tables which may be used to determine the size of pipe required, according to the area drained and the slope of the land. these may be used, or the local residents may be asked as to how much water the different channels usually carry. This is not bad practice, for it will be found that they are inclined to give a slightly larger volume than ordinarilly runs off. But this is on the safe side, and takes care of exceptional rains, or wet spells.

As stated before, the main consideration in mountainous country is that of getting a sufficient number of openings of adequate size. In the valleys, however, this is changed. Here there is often no clearly defined drainage way, and one must be made. It is not unusual to find places where the ground is apparently level, with no opportunity of leading the water away, even after it is taken from one side of the road to another.

A pipe line sometimes gives the impression that that is all that is being done; just changing the water from one side of the road to the other. Here though a little time with a level will very probably disclose a slight difference in elevations. A ditch carefully cut to a grade line, will solve the problem. Even a very slight grade of one or two tenths per cent, will be sufficient to lead the water.

An example illustrating the above occured just

north of Greenville, The plans called for the placing of a pipe line at a point, where there was no apparent way of disposing of the water which would flow through it. A line of levels was run over the strip of ground adjacent to the roadbed, however, and it was found that a ditch, with slight fall, could be easily cut here. This was done and the water followed this course without giving any trouble.

Another example occured at Luray. Here a pipe line was placed across the road, which flooded a man's garden. There was no way to carry the water away from his garden, due to a railroad embankment on the other side. By running a line of levels though, it was found that the pipe line could be removed, and the water carried along the road for a distance of several hundred feet to another pipe line.

To return to the second point to be considered; that of adding attractiveness to the road. This long neglected point is coming more and more into prominence. Since a large proportion of the population of the United States have taken to touring the country in automobiles, the idea of "scenic highways" has developed two meanings; the natural scenery of the surrounding country, and the beauty of the road itself. Just as one false touch in a picture ruins the whole, so an ugly headwall along a highway can ruin it's whole appearance.

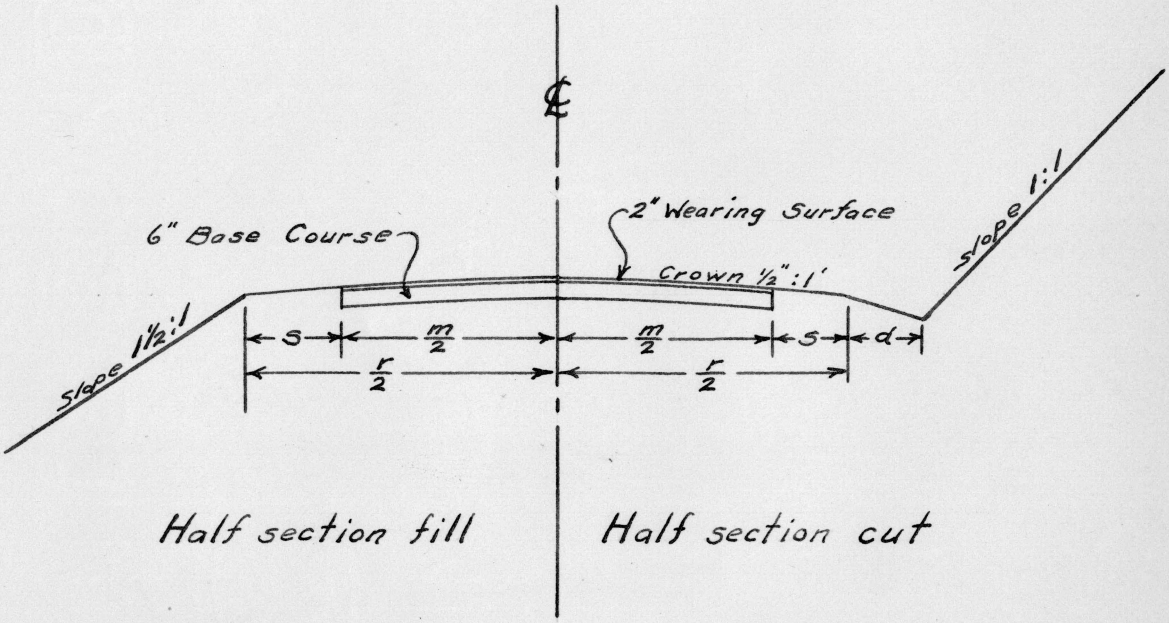
In order to secure this good effect, the pipe lines must be staked out intelligently. The Virginia standard cross section calls for a three foot shoulder in a cut, between the edge of the macadam and the beginning of the ditch (Figure 2). The pipe line should be staked out to extend one foot beyond this shoulder line. Then when the one foot thick headwall is placed, the top of it will be even with the edge of the macadam, and it's back side on the line of the edge of the shoulder. Thus it will not obstruct the roadway, or project up above the road as a monument.

In a fill the same practice should be followed. If the fill is shallow the back of the headwall should be on the shoulder line, and the top even with the edge of the macadam. For deep fills the pipe should be staked, so that the back of the top of the headwall will catch the slope of the fill (Figure 3).

An interesting situation arises in mountainous sections, as to the laying of pipe lines; whether they should be layed on the original ground (Figure 4a), or on the fill (Figure 4b). In the first case a long length of pipe is required, while in the second case the length of pipe is reduced, and a rip rap spillway protects the fill from scouring. Comparative costs show the second, or "b", to be the cheaper. This method has the further advantage, that a short pipe line is more accessible, being near the top of the roadbed,

# TYPICAL SECTION
# BITUMINOUS MACADAM.

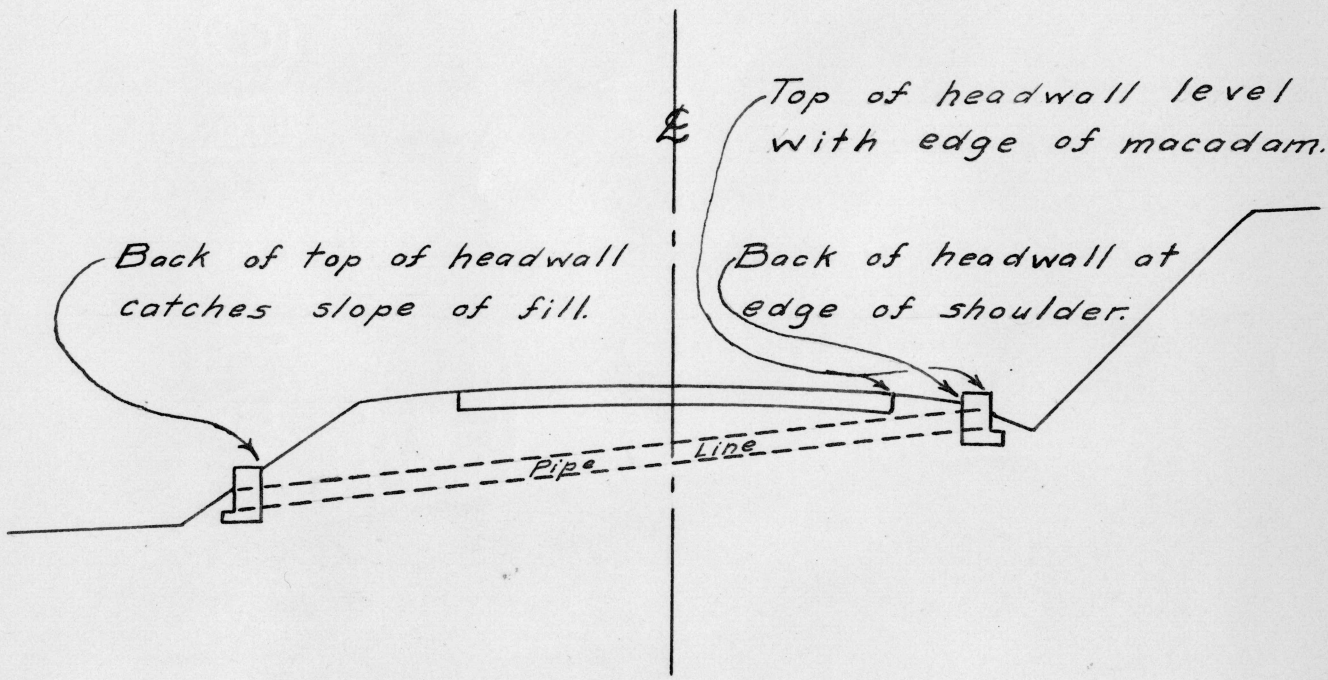
Virginia State Highway Commission.




m = macadam
r = roadbed
s = shoulder
d = ditch

Figure 2

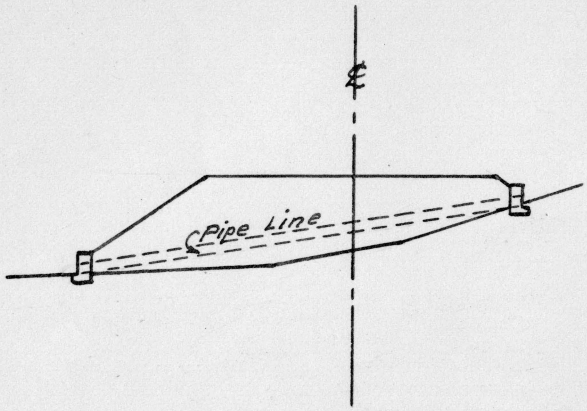
G.D.F.



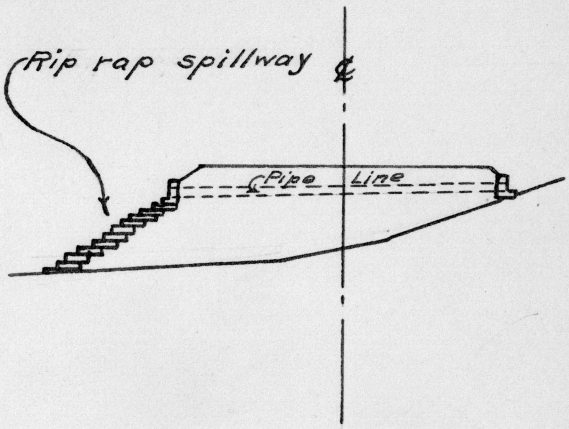

Method of placing pipe to obtain good appearing headwalls.

Figure 3

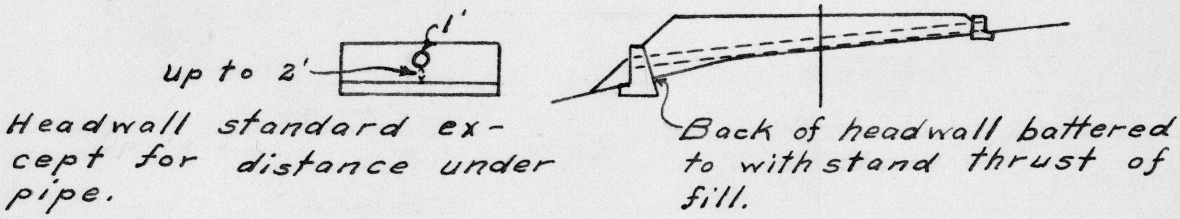
G.D.F.




a. Pipe line laid on original ground; requiring long pipe.




b. Pipe line laid on fill; with rip rap spillway; requiring less pipe.




c. Modified headwall for pipe line in fill.

Pipe lines and headwalls in deep fills.

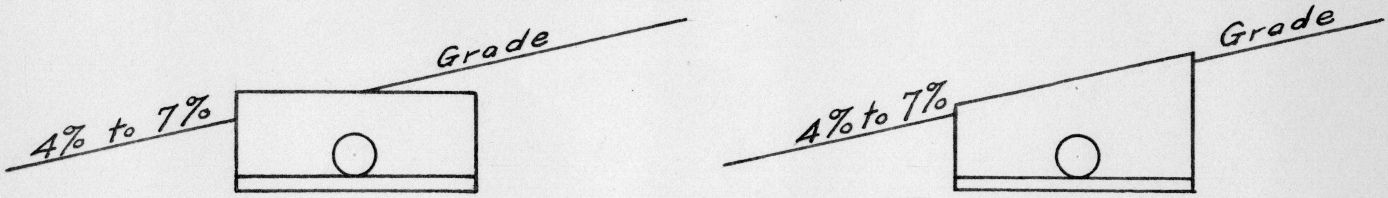
Figure 4

and is more easily kept clean, or repaired.

Figure 4c illustrates a condition where it is advantageous to lay the pipe line on the original ground with the end up in the slope of the fill. If this distance above solid ground is not over two feet, the height of the headwall can be increased below the pipe and thus take care of it. Needless to say that headwalls must rest on solid foundations to serve their purpose. If the pipe is over two feet above solid ground the rip rap spillway method should be used.

As a further aid in securing attractive roadways the tops of headwalls, and the handrails of culverts and bridges should be built to conform to the grade of the road. This makes them blend into the general picture and not stand out glaringly as "bucking horses" (Figure 5a-b).

Bridges are designed by the Bridge Engineer and the man in the field has no responsibility other than that of good workmanship, except in the foundations. The specifications and plans require that the "foundations shall be approved by the Engineer". As solid rock is not always obtainable, other materials must be made to serve as a foundation. Solid clay, or gravel, well below possible scour, are excellent foundations. For smaller bridges only ordinary footings would be required on this kind of material, but for large struc-




a.

Headwall not conforming to grade; "bucking horse".

b.

Headwall conforming to grade; pleasing.

Headwalls on grades.

Figure 5

Headwall not conforming to grade.

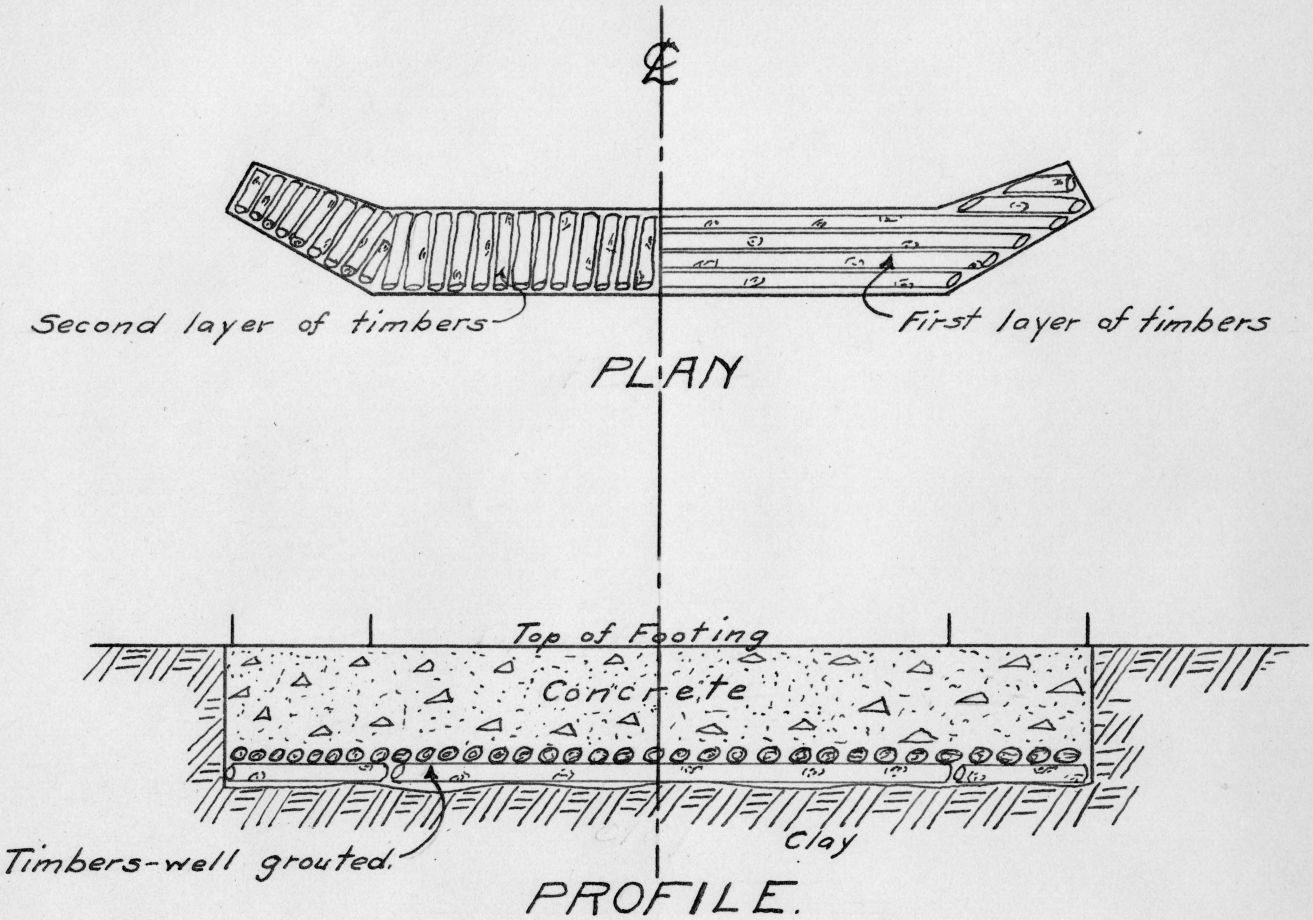
Headwall conforming to grade.

tures a "spread footing", to obtain more bearing, may be necessary.

Less solid material, such as moist sand (quicksand would of course require piles, or different treatment) requires special consideration. If not too unstable a spread footing may serve. One method that has proved practicable was the use of a grill work of large timbers, untreated, such as shown in Figure 6. This method was also used where one ledge of solid rock was struck in part of a foundation and the rest was clay. The grill work was used so that a settlement in the clay would be taken up by the timbers and not break the concrete.

Concrete construction is a subject in itself, but there are a few points which should be brought out here. These comprise the building of the forms, the mixing and placing of the concrete, and the finishing of the surface. The engineer in charge of the work is responsible for these being done correctly, and there are several points which should be stressed. So much research work is being done in the field of concrete construction, that rules laid down to-day may be considered very poor practice to-morrow.

Several years ago it was thought that any local material would do for concrete, and the methods of mixing were indeed "rule of thumb". The aggregates and cement were mixed to-gether, water added, and the




Timber grillwork for bridge foundation.

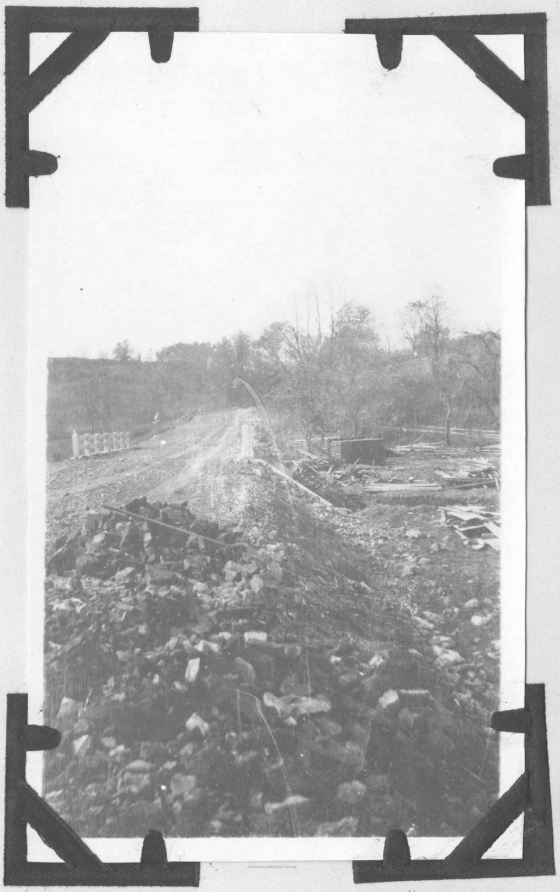
Figure 6

GDF.

quality of the mixture was judged by the color. This seems indeed primitive to-day, with our exact proportions for aggregates, cement, and water, and our methods of testing. To the old "concrete men" all this seems foolishness, but tests have shown that concrete made under modern specifications is five or six times as strong, as concrete made under the old "hit and miss" methods.

Good forms are as necessary to good concrete as good aggregates and good mixing. Bad forms give ugly lines, honeycombed concrete, and are a disgrace to the engineer who allows their use. Forms must be water tight, have true face lines and square corners, and be adequately braced. It is better to have more than sufficient bracing, than not to have enough. Really good concrete inspectors are rare, and a man to make a good inspector must know when to say,"no".

Forms for concrete work should be built of clean, straight, sound lumber. For face walls only dressed lumber should be used and it should be two inch stock. For back wall forms, and unexposed surfaces, rough lumber may be used, but it should be straight so that tight joints may be obtained. One inch stock may be used here, but it must be well braced. For bracing, pieces two inches by four inches (two by fours) are generally used. Under slabs, and beam spans, larger pieces are necessary to prevent sagging.



Good alignment of handrails on bridge.

The forms must be built with tight joints, for otherwise the mortar will leak out and leave a "honeycombed" surface. Great care should be taken to secure straight lines on the forms, and good corners, as any small irregularity in the forms will show up much more glaring in the concrete. The dimensions of the forms must be carefully checked, and in building abutments for bridges, the bridge seat particularly.

The proportion of aggregates in mixing concrete differs considerably in different States. In Virginia the proportions for Class B concrete (mass concrete) are: one - three - six. This is a very poor mix and extremely hard to work properly in the forms; the ratio of coarse aggregate to fine, is too large. With sandstone, which crumbles in crushing and handling and therefore has considerable fine material, the results obtained are fairly good. On the other hand limestone, granite, and trap rocks give poor results, as there is not enough fine aggregate to fill the voids. Other States (West Virginia, North Carolina, etc.) use a one - three - five mix which is much better. For reinforced concrete construction Virginia uses what is called Class A mix; one - two - four. This is a very good mix, easily worked in the forms, and gives a surface that is easily finished.

The tendency is to use too much water in mixing

the concrete and this point must be carefully watched. A mix should be just wet enough to work well in the forms and not sloppy. For reinforced concrete work the mix must be fluid enough to completely cover the reinforcing. From recent experiments there has been evolved a test, known as the "slump test", which shows when the correct amount of water has been added. This has been incorporated in the Virginia specifications and is now used on all projects. It consists in filling a cone shaped form with a sample of the batch to be tested, and withdrawing the form. The resultant amount of slump in the mass of concrete determines whether there is an excess of water or not.

The greatest trouble experienced in concrete work is getting the men to work the concrete in the forms. It must be tamped until the mortar rises to the top, and then a spade must be punched down along the walls of the forms until the rock are worked back. This will give a dense concrete, and at the same time a surface, when the forms are removed, which can be easily finished. It requires constant watching to see that this "spading" is done, but it is cheaper to the contractor in the end. On a project at Gore, Virginia, the contractor would not spaed the concrete, and the result was a badly "honeycombed", rough surface. He spent one months time, and a hundred and fifty dollars, patching and rubbing one abutment, in order

Settlement of fill

at either end of bridge due to not tamping.

to get it in acceptable shape.

In warm weather, when the concrete will set quickly, the forms should be removed about twelve hours after the last concrete is placed. In cold weather two or three days should elapse, as the concrete will be slow in setting. After the forms are removed all honeycombed places are patched, and the exposed surfaces of the concrete rubbed with a wooden float, wet with clean water. This removes all board marks and leaves a rough finish. Some engineers accept this finish, but the best finish is obtained by rubbing the surface again, after the concrete has hardened, with an emery stone, or carborundum brick. This will leave a smooth surface, which is preferable to the rough, sandy finish. While not incorporated in the specifications, Virginia requires the smooth finish.

Connecting the grading, drainage, and surface is one very important point, much neglected. That is the tamping of the backfill to culverts, or bridges. The material placed here should be well tamped, or a better method is to "puddle" it. This consists in thoroughly wetting the material as placed. If this is done there will be very little, if any, future settlement. If this settlement is taken care of, the surface when laid will be smooth; otherwise a bump will result which will require patching for several years.

A stretch of road with good surface.

## IV Surface.

The work of laying a bituminous macadam surface, penetration method, consists of three distinct steps: (1) cutting and preparing the subgrade; (2) laying and bonding the base course; and (3) laying, penetrating, and sealing the top course. Each of these steps is distinct in itself, but each one is necessary to the others. Poor work in one is bound to show up in the others. For this reason great care must be taken in each step.

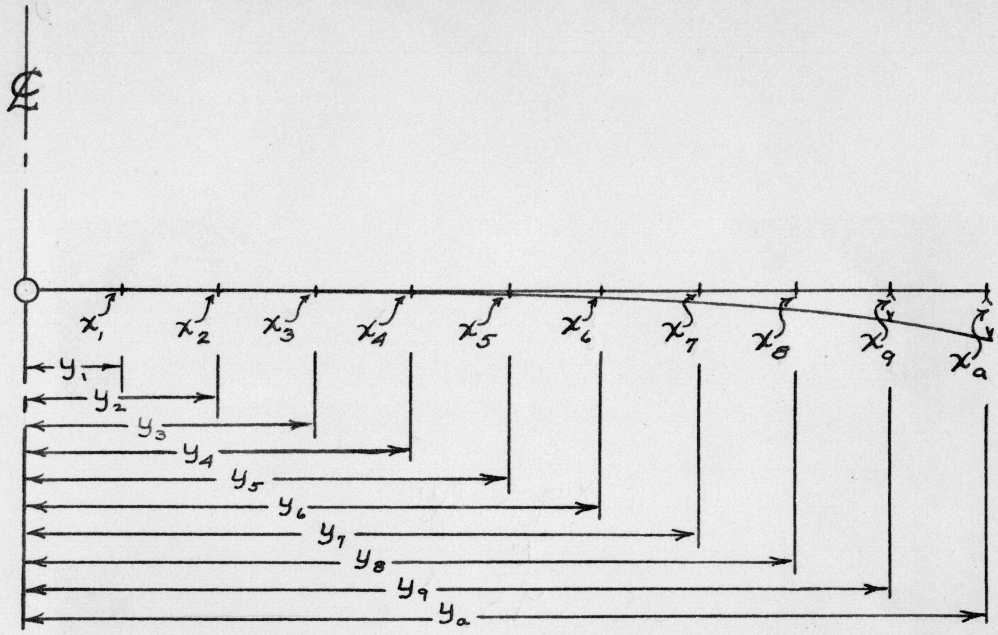
The macadam is the last step in the job; the end toward which the grading and drainage have been leading. If they have been handled sucessfully, the result should not be mared by a poor surface course. But good work here can only be obtained by constant watchfullness, and the use of good judgement and common sense.

In the preceding two divisions of the work, the engineer has had to deal with different problems, but in surfacing he will find that almost every day will present a new problem, or difficulty to be met met and solved. Here the old saying was never more truly spoken, "that a man's usefullness is over when he has nothing more to learn". For in penetration macadam the engineer is constantly finding something new, and learning new ways to do old tasks.

## IVa Subgrade.

The subgrade is the foundation of the surface, and, as in all work, the foundation must be good if the surface is to be good. Its perfection rests mainly on the work done in grading and draining. But still the subgrade must be cut to conform to the template of the desired cross section. This is sometimes known as "ditching". By template is meant the crown which the finished surface shall have. The Virginia standard for bituminous macadam is one half inch to the foot. In cutting the subgrade a wooden template with a level bubble set in the top is used. To cut this correctly the ordinates (vertical) are found by the formula shown in Figure 7. This is the formula for parabolas, and the crowned surface is a parabolic curve. The picture on page 40 shows one of the templates used for an eighteen foot macadam road.

There are two much used methods for cutting subgrade: by hand, and by using a road machine. The first is much slower than the second, but the result is better, except where the road machine operator is an unusually good one. To cut subgrade accurately, levels must be run and stakes set (either marked with the cut or fill, or the tops driven to subgrade). The subgrade is cut according to these stakes and crowned according to the template. This




$$y^2 = 2px \qquad x = \frac{y^2}{2p}$$

$x$ = desired vertical ordinate.
$y$ = horizontal distance from ℄.
$2p$ = width of macadam.

Example:
To find vertical ordinate $x_6$ for 18' macadam. Then $y = 6'$ and $2p = 18$.
Substituting in formula:
$x_6 = \frac{(6)^2}{18} = \frac{36}{18} = 2''$.

Method of obtaining ordinates for Template.

Figure 7

Templates.

should be used every five feet at least, and the subgrade brought up exactly to it. In addition to the template, a straight edge (a board about fifteen feet long, with one perfectly straight edge) is used longitudinally.

Thus if the template and straight edge are used carefully, the finished subgrade will present a surface true to cross section and the grade of the road. This subgrade must be rolled with a ten ton roller until it is firm and solid, and will not cut up under a truck or wagon. Of course in very dry weather there will be some duston top, or in wet weather the wheels of a vehicle will make some impression, but the subgrade should never be in such condition that they will cut deep.

In very dry weather it is advisable to sprinkle the subgrade a little to lay the dust, and also to aid in making it easier to shape. Care must be taken however, not to get the subgrade too wet. During the spring and in the fall, the subgrade will be damp, particularly in the mornings. At these times care must be taken, that base stone is not laid when the subgrade is so damp that it will cut deep under truck or wagon.

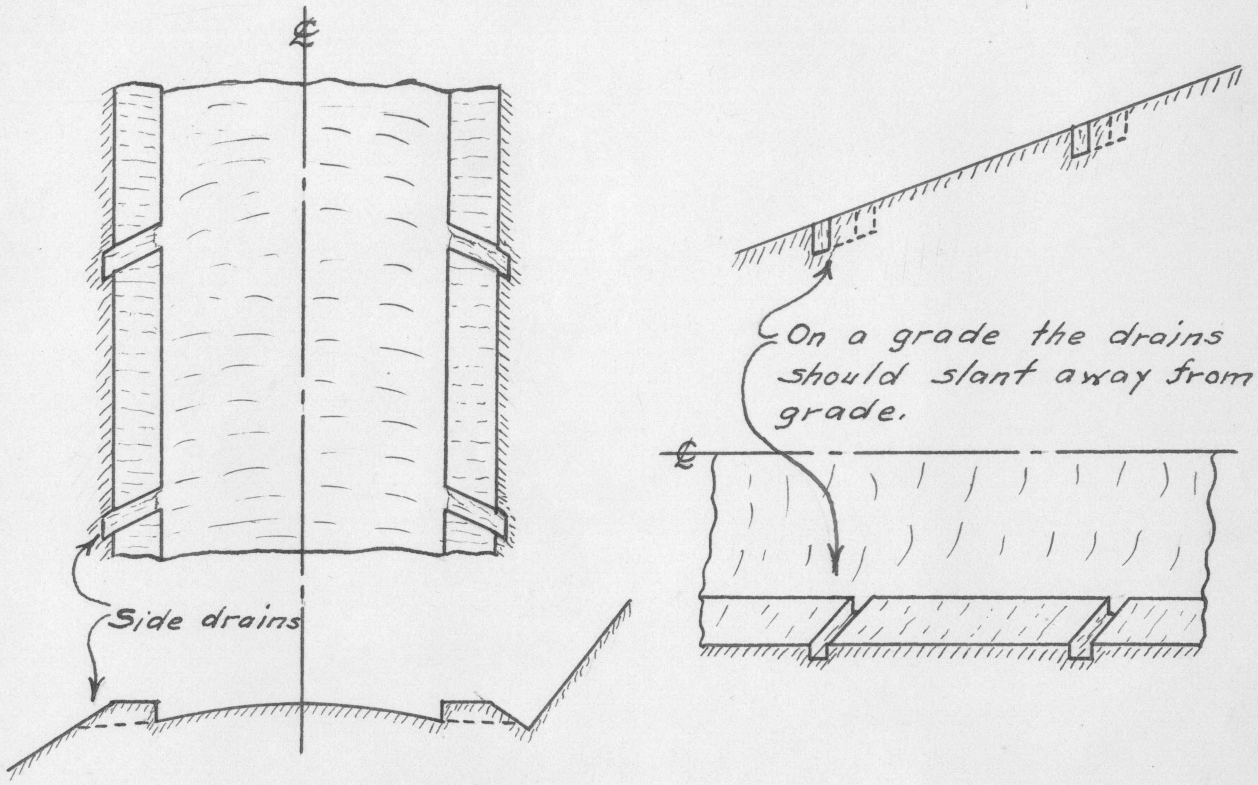
This matter of not having ruts in the subgrade, and of having a good crowned surface, is important, as it will have to stand exposed to the weather. If

it is not solid and crowned water will collect and stand on it, and a soggy place will result. These places are hard to deal with and frequently mean a weak place in the road.

Another point in preparing the subgrade is the cutting of side drains (Figure 8). These lead off through the shoulders on either side from the edge of the subgrade. On level or light grades these should be cut every fifty feet; on steep grades (5% or over) they should be cut every twenty or twenty-five feet. These drains serve to carry off the water shed by the crowned subgrade.

On a grade these drains must slant away from the grade. On sharp curves they should be cut close to-gether. When the base is laid these drains must be kept open or filled with large rock, so as to still drain. The danger of subgrade becoming soaked is not past until the seal coat is poured, as all other work will allow moisture to soak to the subgrade.

If the subgrade should become soaked and a spongy place develope, this material should be removed and dry material put in its place. Should this not be possible for any reason, some other treatment must be used. Several methods of dealing with this situation will be taken up later. The preparation of the sub-grade is too often neglected. The result is a rough surface on the macadam, or weak places in the road




Side drains in subgrade.

Figure 8

due to laying base on spongy material. "A chain being no stronger than it's weakest link"; if the subgrade is not right, the macadam will not be right.

At the south end of the town of Greenville, Virginia, it was necessary to lay a stretch of macadam on wet, spongy subgrade. This was not a case of negligence on the part of anyone, but was made necessary by the location and the time of year. It was in the late fall and this stretch had just been graded. A heavy rain soaked it thoroughly and there was no prospect of it drying out until spring. Being in the town it was necessary that traffic go over it during the winter, and unless it was surfaced this stretch of road would have become impassable. Surface was accordingly laid on it, but the picture on page 45 shows that it has been necessary to extensively patch it only one year after completion.

Surface laid on wet, spongy subgrade.

Hand broken base.

## IVb Base.

The second step in surfacing is the laying of the base. This may be one of two kinds: either of crushed stone, or of hand broken stone. It is easier to get a good surface with the first, but the second is cheaper. Where cheap labor is plentiful a hand broken base is generally used. On projects where convict labor is used this type of base is placed. In mountain sections, such as near Luray, Virginia, labor is plentiful and the hand broken base was used here. For either type base the stone must be first tested by the testing laboratory at Richmond, and must pass Grade B test.

In the crushed stone base course, the stone must be between two inches and three and a half inches in size. The pieces must be angular in shape, and all flat, slab-like pieces should be thrown out. These will not tie in with the other pieces of stone, but will shift about and make a weak spot in the base.

Stone is plentiful in the Shenandoah Valley, but it is not situated in such a way as to make quarrying cheap. The predominant rock is limestone, but it is hard to find ledges which will pass specifications for use in surfacing. The limestone does not lay in solid ledges, but is in knobs with large seams of clay all around it. This makes quarrying expensive, as it is often necessary to move twice as much dirt as the stone obtained. It was necessary to send eight samples

from one quarry site near Greenville, Virginia, before a ledge was found which would pass Grade A test. This quarry contained so much clay that stone could only be gotten out for two days at a time, and it was then necessary to close down the crusher and clean up the quarry site.

The hand broken base course is made up of stone which have been broken by hand, and the pieces shall not be larger than six inches. The large rocks, either field stone or stone from a quarry, are placed on the prepared subgrade and broken with napping hammers. Outside of the method of breaking the stone, the two kinds of base course are layed the same.

The base stone is placed on the subgrade and spread to the required depth by the use of wood blocks. These blocks should be a perfect square on every face, so that no matter how placed they will be the correct size. There is a table furnished each inspector showing what size block should be used to get the desired depth of compacted base. For a six inch base course the block should be seven and seven-eighths inches. The specifications and plans in giving the depth of base course refer to the depth when compacted.

If the subgrade has been carefully prepared the blocks can be used to the greatest advantage. For then if the loose stone is brought up even to the tops of these blocks, the depth will be uniform across the

Bonding base.

roadway. One source of uneven surface is here; the subgrade is not smooth, the block rests on a high point or a low point, and the result is a hump or dip in the surface. Even with the blocks though care must be taken to get the surface of the base smooth.

After being spread to the required depth the base is thoroughly compacted by rolling with a ten ton roller. By thoroughly compacted is meant that the stone are keyed to-gether and do not shift under the roller. The voids between the stone are then filled with fine material; chips (quarter inch to an inch and a half) are spread over the base and it is rolled again. Then stone dust is spread on the surface and worked into the remaining voids with stiff brooms, after which the whole is rolled again. This process fills the voids between the keyed stones and the whole gives a firm foundation for the top course. The base course is now sprinkled and rolled until it is completely bonded.

Limestone gives the best results in bonding, due to its very good cementing qualties. Sandstone will bond very well, but crushes under the roller. Granite and trap are very hard to bond, as they are hard rocks and do not cement to-gether easily. Wherever possible limestone should be used for the base as it gives the best results.

It is sometimes necessary to alter the above

method of bonding the base. A small stretch of spongy subgrade will be encountered; not bad enough to require removing, but bad enough to make it impossible to bond the base by the regular method. Or it will be necessary to put the surface on a short stretch of recently graded road that has become wet, in order to allow traffic to get over it during the winter. A solid, unyielding base can not be laid in these places, but one with some elasticity is required.

The best solution has been found to be a penetrated base. That is the base stone are laid and compacted, but the voids are not filled. Where a crushed stone base is used no filler is required, but where a hand broken base is used some of the voids should be filled with two inch stone. The base stone are then covered with asphalt; about a gallon and a quarter to the square yard. This must be applied with pouring pots, by hand, as a distributor would rut the base. As this asphalt is not covered with chips, but the top course laid directly on it, the ruts could not be "ironed" out with the roller.

This method serves admirably, and often saves considerable expensive tearing up and replacement of base. The subgrade being yielding an elastic base will give with it, but will not be permanently distorted or broken. The top course is elastic also and hence the whole will give under a heavily loaded truck, but will

not crack or break, as would happen if you attempted to lay a bonded base.

By a "yielding subgrade" is meant one that will give under a roller; to an observer the appearance is that of a roller passing over a great mass of cotton. The ground forms in waves under, and after the roller, which is given the rising and falling motion of a ship. This soft ground must not be confused with mud or with muck. These two will not support the base at all and can only be removed and replaced. The picture on page 51 shows a section of road that was built with this "penetrated base". It was built three years ago on soft subgrade and only shows the ordinary amount of patching.

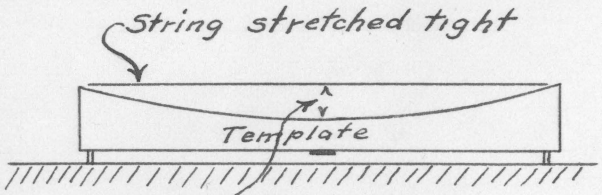
In dumping the crushed stone base, it should be done in either of two ways. Either dumped on a dumping board and placed on the subgrade from there with forks, or dumped directly on the subgrade slightly ahead of where needed, and forked into place. This procedure is necessary because in running from the crusher bin to the road, what dust was in the stone is jolted to the bottom of the truck or wagon, and comes out in a pile, covered by the large stone. If allowed to lie in place this fine material will not compact under the roller and will cause a hump in the base. Hence all "pockets" must be removed and scattered out over the top of the base.

Stretch of road built with "penetration base".

As the base is shaped up and bonded a template should be used to be sure the correct crown is retained. The straight edge should also be used to get a contionuous, even profile. Even with these aids, the inspector must depend on his eyes to detect humps and hollows, and must have these uneven places corrected. A smooth surface depends on a smooth subgrade and base, as much as on a smoothly spread top course. If these two are smooth, the chances are much greater of obtaining a smooth top.

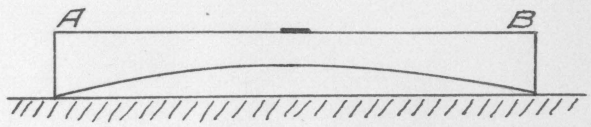
The template should be checked frequently, perhaps once a day, to be sure that it has not sagged in the middle and thus decreased the amount of crown. Also that the level bubble is set true in the board. Constant rough use will cause these errors if it is not watched and corrected. The first check is secured by stretching a string tightly from one point of the template to the other, and measuring the distance from the string to the template at the middle (Figure 9a). The bubble is checked by leveling the template in one place and turning it end for end (Figure 9b).

In laying the base the width should be carefully and frequently checked. Not alone the total width from edge to edge, but the width on either side with reference to the center line. The edge of a macadam road is the first place to break away, and care should be taken to see that the top course will have plenty

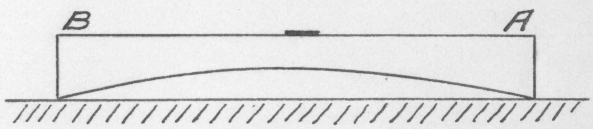



a.

Check against template sagging.




Level template then reverse ends to check bubble.




b.

To check template bubble.

To check template.

Figure 9.

of base to rest on. If a narrow place is discovered when the twos are laid, it means tearing them up in order to correctly bond the necessary additional width of base.

Number two stone ready to penetrate.

## IVc Surface.

The top, or wearing course, of the macadam is built of "number two" stone, ranging in size from one and a half inches to two inches. This stone is spread over the base in a three inch layer, which will compact to two inches when rolled. Blocks are used here in spreading the number two stone, as in the base. The same care must be taken to see that no dust pockets are formed in dumping the number two stone. Care must also be taken as to the size of the stone, and all pieces over two inches thrown out. It frequently happens that long slabs, only two dimensions two inches, will come through the screen, and these should be picked out.

Only clean stone should be used in this course. Dust, dirt, or other matter clinging to the stone will keep the asphalt from adhering to it, and the surface will "ravel" (tear up) soon after put down. For this reason only clean stone should be put down, and if it becomes dirty after being placed it should be removed. Some contractors will object to this, of course, as it means a loss to them, but it is absolutely necessary.

After spreading the twos they should be surfaced with the careful use of the template and straight edge. This is the last opportunity to get a true, smooth surface and great care should be taken. This

is the main fault now found with macadam roads, rough surface, and it is due to poor inspection. Few men can spread stone by eye so as to get a smooth surface, but with the careful use of the template and straight edge there should be no trouble.

An often neglected point is the edge of the macadam. This is true from two standpoints; first it is not built strong enough, and second it is not lined up so as to give a good appearance to the road. As stated before the edge is generally the first place the surface breaks. This is because cars run off of it in passing other vehicles, and horse drawn vehicles will almost invariably stay close to the edge.

To secure strength there should be the full depth of base under the edge, and in penetrating the top care should be taken to get the full amount of asphalt here. The full depth of base can be secured by using one of the spreading blocks at the edge, and by checking the width of the base; not only the total width, but also with reference to the center line. As to the asphalt, it should be applied so that there is a six inch strip of it over on the dirt shoulder. This should be done because the last six inch spray from a distributor is only half as much asphalt as is required.

The lining up of the edge of the macadam is not a hard thing to do and can be done in several ways. One is by the use of wooden forms along the edge while

spreading the twos, and another is by the use of a line. The former method secures the best results, as the line is usually used in a sloppy manner. The wooden forms consist of two inch boards, about four inches broad and about ten feet long. These have a hole in each end through the narrow edge, so that they may be held with the four inch side vertical. These forms are fastened down in place by steel pins, or long spikes. They are lined up either by measuring from stakes along the side of the road, or by eye. The earth shoulder is built up on the outside of these forms and the number two stone spread on the inside. When these two operations are completed the forms are removed and carried ahead; the dirt shoulder holding the stone in place.

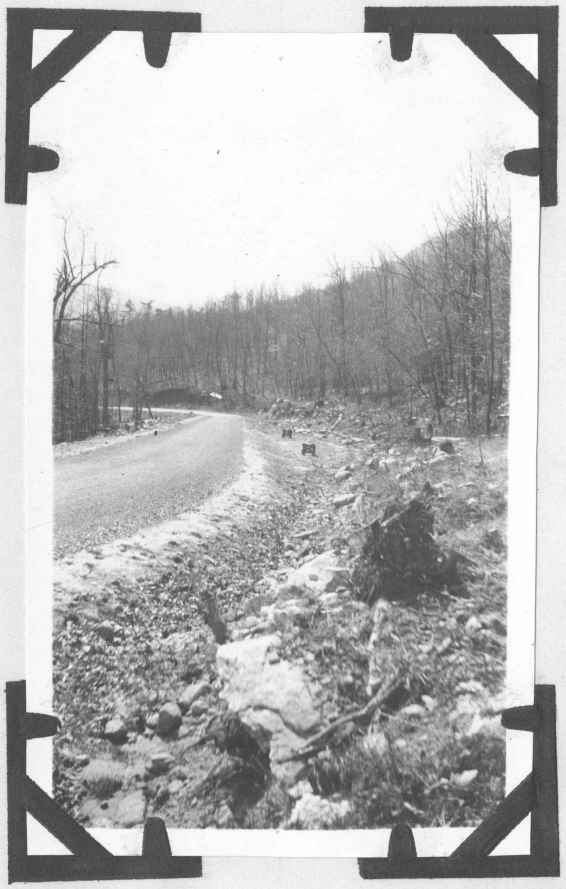
The method of using the line is somewhat similar, but the result obtained is usually a ragged edge. The line is stretched between pins driven along the edge at the right distance from the center line. The earth shoulder is then built up on the outside of the line, and the twos are spread directly against this dirt shoulder. Due to the dirt falling in on the base, trucks running over the shoulder, etc., the result is a ragged edge. By using the forms the edge of the macadam will be straight and will stand out distinct for a long time. With the line method the edge is irregular, and soon becomes indistinct. The illustrations on

pages 59 and 60 show this. The first is of a project completed three years ago, where the forms were used. The second is of a project completed one year ago where only a line was used.

In spreading the number two stone it is just as important to see that the stone are not too thick, as to be sure that they are not too thin. The asphalt will not penetrate through over three inches of rolled stone, and if the stone are thicker the additional depth will not be bonded. This will give a shifting mass under the surface, cause "rolling", and result in a break in the macadam. At first thought it would seem that the thicker the stone the better road, but for the above reason such is not the case.

After the twos are spread and "leveled up" they are rolled; once over with a ten ton roller. This is not an invariable practice however, as conditions may make it best not to roll the twos before penetrating. If sandstone, or similar rock, is used, it is best not to roll the twos as this stone crushes badly under a roller. Again if the number two stone runs small in size; that is one and a half inch stone predominates, then they should not be rolled, as the stone will key to-gether until the asphalt will be unable to penetrate.

The asphalt used is either one of two kinds; a natural asphalt known as NA-2, or a product of petro-



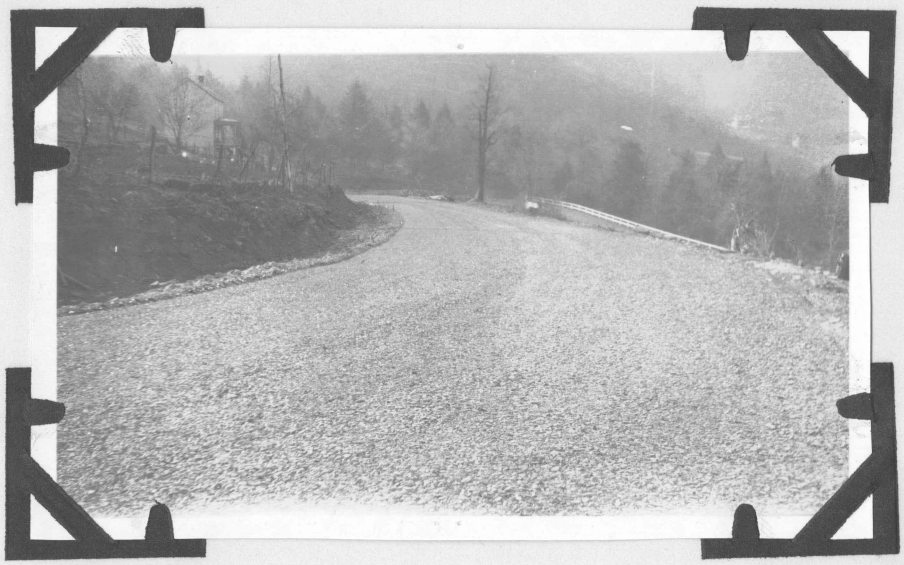
Distinct line at edge of macadam.

Indistinct line at edge of macadam.

leum known as OA-2. This material is applied in two coats, a penetration, and a seal coat. In the first coat one and three quarters gallons are applied to the square yard, and in the second coat one half gallon to the square yard. These are applied by either one of two methods; either by handpouring, or by a distributor.

The capacity of the pouring pots (if hand-poured), or the distributor (if machine applied), is known and a distance is staked off which will allow for the required number of gallons to the square yard. The asphalt must be heated to a temperature ranging from two hundred seventy-five degrees, to three hundred fifty degrees Fahrenheit. The best results are obtained when it is applied at a temperature of three hundred twenty degrees. It should not be heated above three hundred fifty, as to do so will burn the material and it will be useless.

The temperature of the atmosphere should not be less than sixty degrees, except in the early spring or the early fall when the asphalt may be applied at fifty. It should not be done then unless there is every indication that the thermometer will register sixty or above, later on in the day. Asphalt cools quickly, and when cold is as brittle as glass. Hence if it is applied when the thermometer is low, it will cool very rapidly when it strikes the cold stone, and

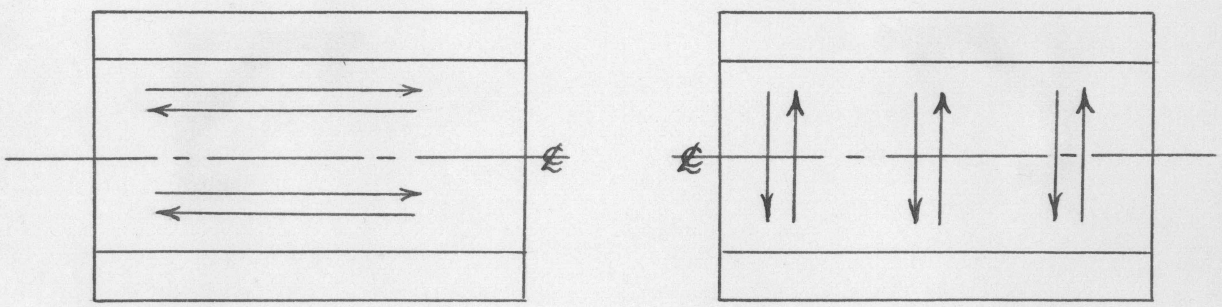


Penetration course.

will become brittle. The first vehicle over it will break the bond and the surface will ravel rapidly. If this occurs the only remedy (if it has not gone too far) is to apply a double heavy seal coat, and even this may not save it if the weather is very cold.

After the asphalt has been applied for the penetration course the surface is covered with chips and thoroughly rolled. The chips should be spread so as to cover the surface and fill the voids in the top of the penetration course. The surface is then thoroughly rolled until it is compacted, and any irregularities in the surface ironed out if possible. It may be necessary in extremely hot weather to grease the wheels of the roller to keep them from sticking to the asphalt, and also to wait a half hour or so to allow the asphalt to cool somewhat.

After the surface has been sufficiently rolled, all excess, or loose chips, are swept off and the seal coat is applied. This is applied in the same manner as the penetration course, except when hand poured the pouring should be at right angles to the previous application (Figure 10). This coat is very light (really too light) and care must be taken to see that the surface is fully covered. This coat serves to exclude moisture from the road and if it is not complete moisture will soak in, soften the subgrade, and make a hole in the macadam. Illustrations on pages 64



a.

For penetration pouring should be longitudinal.

b.

For seal pouring should be transverse.

Directions in which pouring pots should be carried in applying asphalt by hand.

Figure 10

Hole in macadam due to bad seal coat.

Hole in macadam due to bad seal coat.

and 65 show examples of holes in the macadam from this cause.

After the asphalt is applied the surface is covered with chips. Just enough are spread over it to cover the surface, and only as many as will stick to the asphalt. Too many chips here will cause traffic to travel in ruts and not iron out the whole surface. This puts unequal strain on the macadam and is apt to cause it to break through. After chipping the surface is rolled thoroughly and is then complete.

One peculiarity of bituminous macadam is that it must be opened to traffic as soon as possible after being completed. It is an elastic type of surface and like rubber, if not used it soon loses it's elasticity. An example of this occured near Greenville, Virginia, where a stretch of completed macadam was kept closed to traffic on account of a bridge over the railroad being incomplete. This section was closed for six months and, when finally opened to traffic, had to be patched as the surface had lost it's elasticity. The patching was almost a surface treatment.

Guard rail and wide shoulder.

## V Guard Rail.

After the surface is completed the next steps are: the dressing up of the work, the erection of guard rail, and the setting of right of way monuments. None of these can be done until the macadam is finished, and they in turn must be carried out in the order named. The work must be dressed up; that is shoulders built and ditches cut. Until this is done the guard rail can not be built, as it is erected on the shoulders. The right of way monuments can be set before the other work is finished, but they are usually left until last.

After the macadam is completed the shoulders must be built to the full required width, and the banks in cuts must be pulled to an even, regular slope. The ideal cross section is shown in Figure 2, and the shoulders must be built and the ditches cut to conform to this. This is not an iron bound rule, but may be modified to suit conditions. Thus if a shoulder wider than four feet can be obtained uniformly on a fill, it is alright. The main thing is not to have less than a four foot shoulder, and to have an even, regular edge on that. The same applies to the shoulders in a cut section; they may not be less than three feet wide, but may be more if the

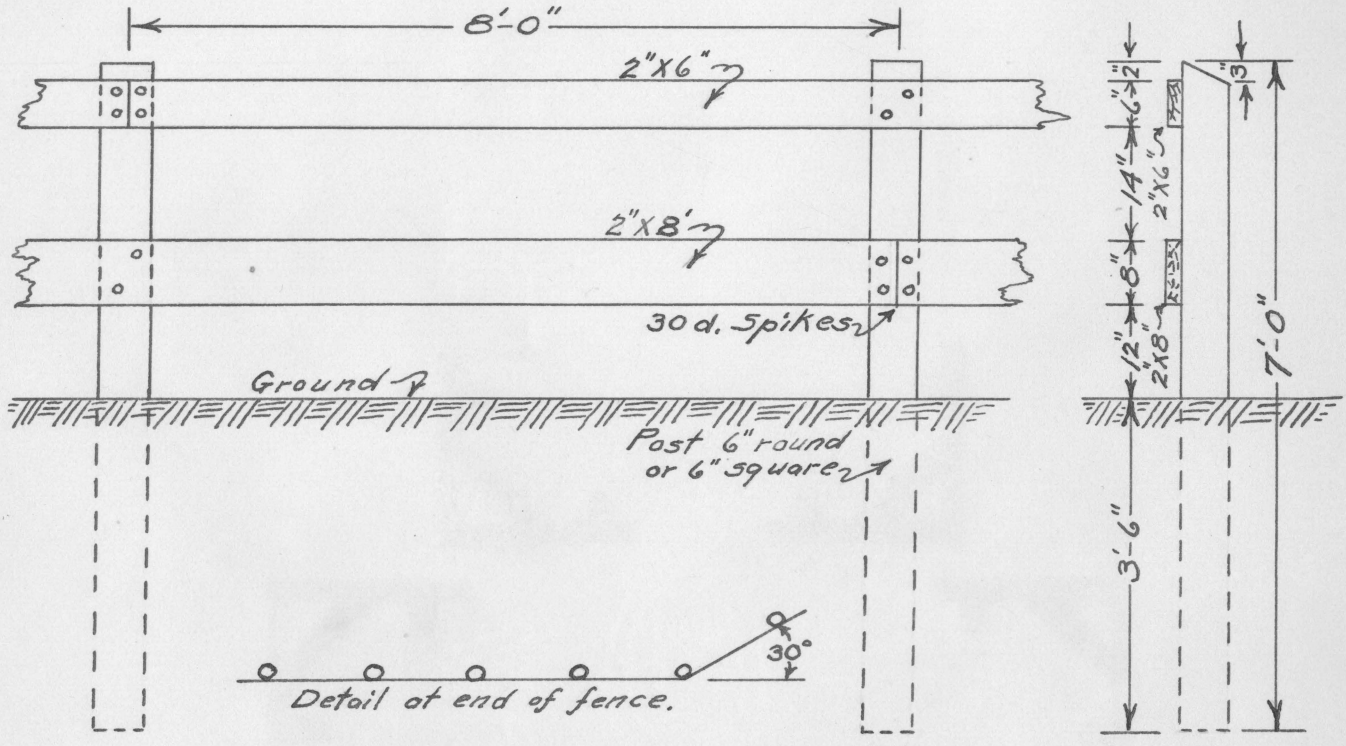
Shoulder more than four feet wide but of uniform width.

same width can be obtained for any distance.

The standard ditch in a cut section is known as "a road machine ditch". This from the fact that it can be easily cut with a road machine. This ditch is designed to serve a twofold purpose; primarily to carry the water from the road, and secondly to allow traffic to run into and out of it when necessary. Under ordinary conditions this ditch will carry all the water without any trouble, but occassionally it will be necessary to cut it deeper. This will only be where the surrounding country will not permit of leading the water away from the road. In such a case it is necessary to carry the water in the side ditch until a point is reached where it can be diverted away from the road.

The guard rail as erected in Virginia is either one of three types: wooden guard rail with wood posts, wooden with steel posts, or wire rope. The first and last types are in use in the Staunton District and attention will be confined to them. The sketches on pages 69 and 71 give the details of these two types, and are taken from the standard plans. As long as wooden posts can be secured these two types will be used, as the cost of the wooden guard rail with steel posts is very much greater.

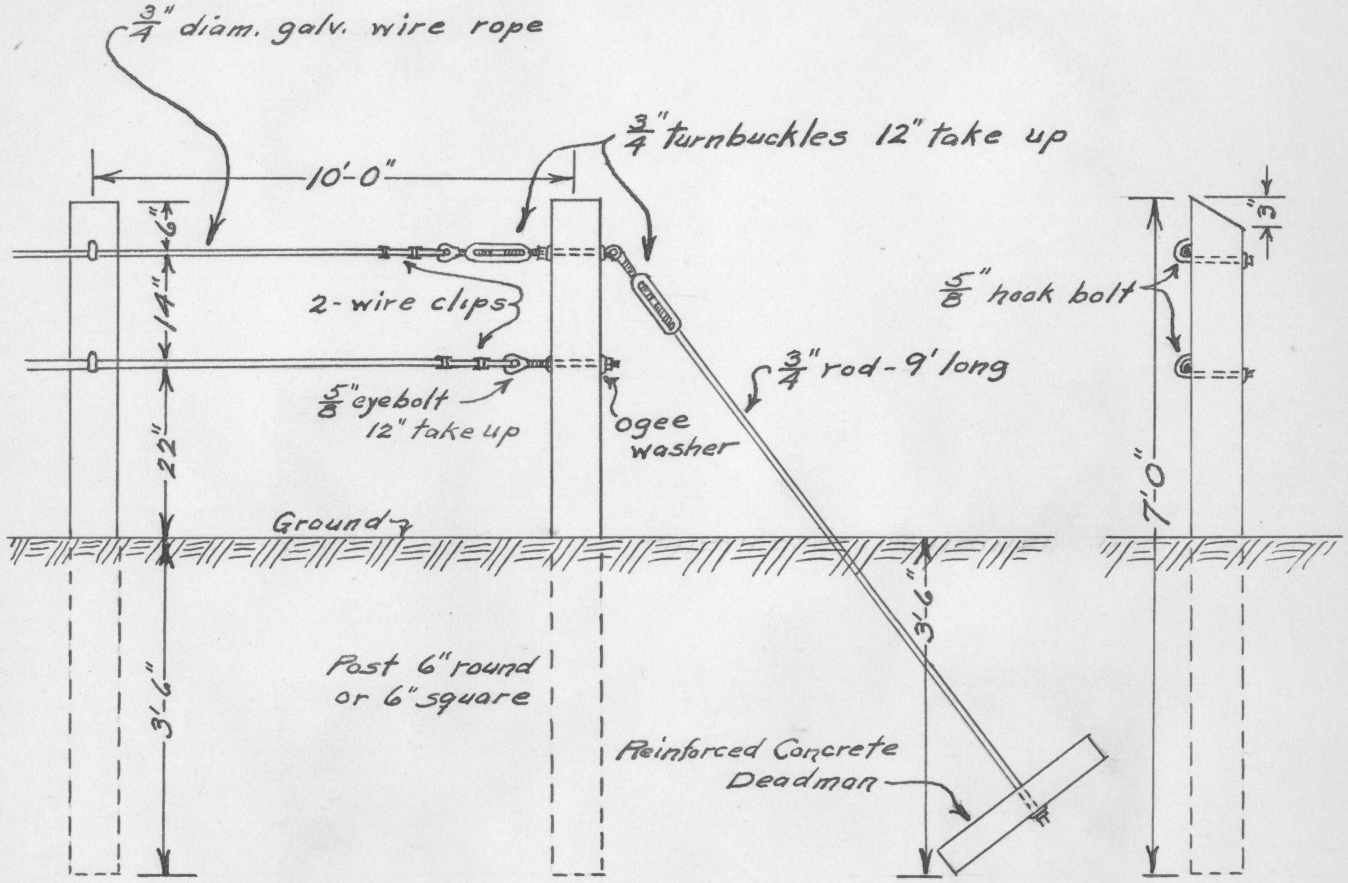
Guard rail serves a two fold purpose; it furnishes a physical protection against vehicles running over




Wood Guard Rail

Figure 11.

Completed wood guard rail.




Intermediate anchors are provided for sections of guard rail more than 500' in length.

Wire Rope Guard Rail with Wood Post.

Figure 12

Completed wire rope guard rail with wood posts.

high fills, and also gives a feeling of security to a driver which is purely mental. It might also be said to add to the appearance of a road, but this depends upon the manner in which it is erected. Carefully built it will add quite a bit to the looks of a highway; this is particularly true in the mountains. Guard rail is a rather new thing yet and will be considerably developed in the next five years.

In the erection of the wooden and the wire rope guard rail it will be seen from the sketches (pages 69 and 71) that the method of setting the posts is the same for both types. The specifications for the posts are the same, and they may be either square or round with a minimum diameter of six inches. They may be locust, mulberry, or chesnut and must be seven feet long. The posts on any one project must be all the same; either all round or all square, and of the same kind of wood.

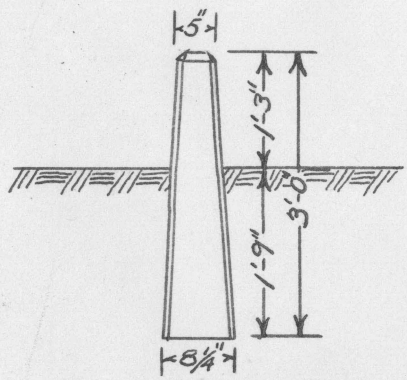
The posts are set at a distance of two feet from the edge of the macadam, and where two stretches are opposite each other the minimum clearance must be twenty-two feet. The posts must be set three and a half feet in the ground, and the earth firmly tamped around them. Care must be taken to see that they line up, for a slight irregularity will show up glaringly when the guard rail is painted. For the wooden guard rail square posts give the better appearance, while

for the wire rope guard rail round posts are to be prefered.

The rails of the wooden guard rail must be made to line up on top. This is rather hard to do, as vertical curves in the grade of the road must be transfered to the rails. It is important though as an uneven top rail will detract from the appearance of the whole stretch.

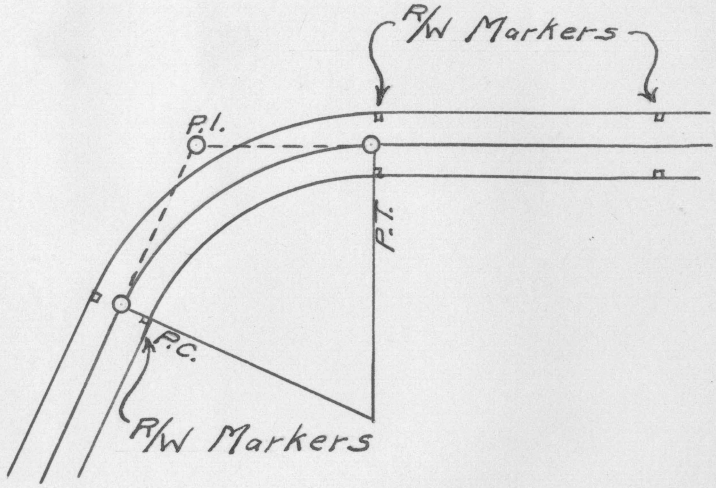
In erecting the wire rope guard rail the wire rope should not be stretched taut, but should have a very little sag. Not readily noticeable, as that much of a sag is very ugly, but just enough to allow for changes in length due to changes in temperature. This is supposing the guard rail to be erected in moderate weather. If erected in extremely hot weather, the cable should be allowed to sag to a noticeable extent. If erected in cold weather it should be drawn tight.

The right of way monuments are erected so that there can be no doubt at any time as to how much right of way the State acquired. At different times in the past roads have been improved, either by the State or counties, or by some private turnpike company. Right of way was then acquired, but not marked. Now in trying to reestablish this right of way, since turned over to the State, it has been found impossible to determine just where the boundaries are. Fences have been




Right of Way Monument

Virginia State Highway Commission




Right of Way monuments are placed at all P.C.s and P.T.s and at intervals on tangents, so as to be visible from each other, but not more than 2500' apart.

Method of setting Right of Way Monuments.

Figure 13.

G.D.F.

Right of way monuments in place.

erected as close to the road as possible and the real boundary line can not be determined.

The monuments are erected at the beginning and end of each curve, one on each side of the road, and on tangents so that they will be visible from each other, and not more than twenty-five hundred feet apart. They are set on the State's land, with the back face of the monument on the line. They are easily and quickly set, and look very well when in place. The erection of these monuments is the last step in the construction of a project.

In this thesis the phrases "should be closely watched", "must be carefully checked", etc. are frequently used. Not with the idea that contractors try to shy their work, for few will be found who intentionly do so, but to lay stress on the points which an inspector should see are correctly executed. Slips will occur due to inexperienced foremen or men, and it is these slips which the inspector must watch for and have corrected. Occasionally a contractor will try to do work that will not come up to specifications, but these cases are rare. Firm handling of such cases as do occur will minimize the occurence of others.

Completed stretch of macadam road.
Including grading, drainage, surface, dressed shoulders, guard rail, and right of way monuments.

# Part Two.

# List of Illustrations

## Accompanying Record of Professional Experience.

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Professional Experience

of

George Doniphan Felix

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The commencement exercises of Washington and Lee University were held on Wednesday, the fourteenth of June, in nineteen twenty-one. On this date I received the degree of Bachelor of Science in Civil Engineering. The next day I left Lexington for Staunton, Virginia, where I entered the employ of the Virginia State Highway Commission.

My actual experience began on Friday, the sixteenth of June, when I reported to Mr. A. C. Gilkeson, Project Engineer. The project to which I was assigned was six miles long and consisted of grading and drainage work. It was located in the mountains, twenty miles west of Staunton. My official title was that of axeman, though my duties were those of instrument man. This was because there was an instrument man on the project, whose place I was to take, but until he left I could only be carried on the payroll as an axeman. Owing to the fact that I was fresh from school and inexperienced, I was not given the title of instrument man at that time, but when the instrument man left I was designated as rodman.

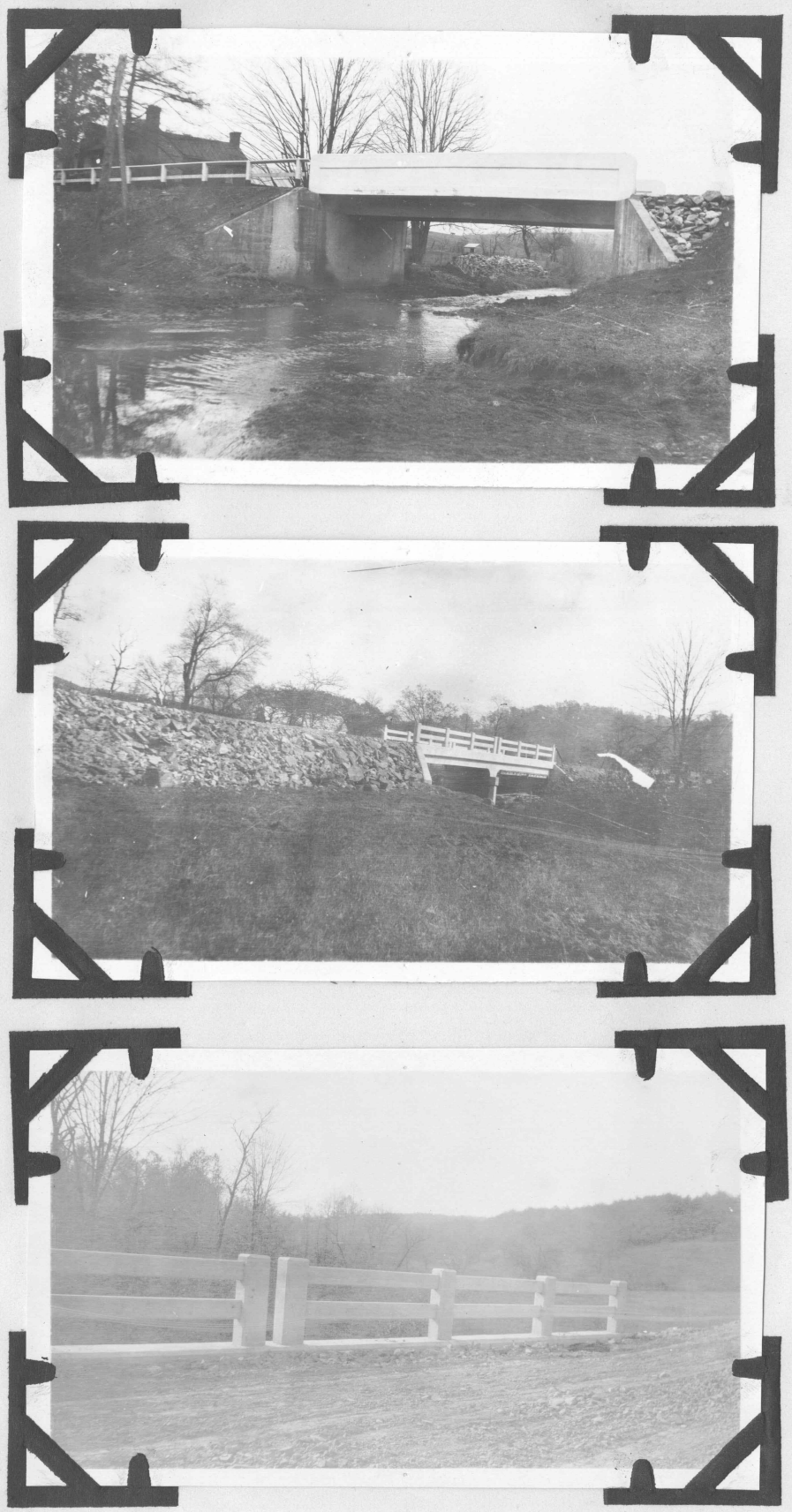
The work which I did however, was instrument

Completed road; the first project I was assigned to.

mans work. It consisted of rerunning the center line, taking cross sections and setting slope stakes, staking out pipe lines, box culverts, and bridges, and inspecting concrete. Also figuring the quantities under excavation and concrete. All this work was done under the direct supervision of the Project Engineer, and my authority and responsibility was only such as he desiginated to me.

After reporting on the project I early found out how little of practical working knowledge I had. One of the first duties assigned me was to cross section a borrow pit. Now I had done that on paper in the class room, and in the field during field work, but I was at a loss to know how to proceed, when told to do it under actual working conditions. I finally studied out the correct proceedure, but only took four sections that half day. It was a good lesson, for I found that I had a good deal to learn yet, and after that I had no trouble.

This project afforded me quite valuable experience, as the grade line laid on the plans was impractical and had to be entirely changed. The changes were made by the project engineer, but he explained them to me, and the experience has been of great value to me since. There were also two revisions in the alignment made by the project engineer, and I here got my first experience in locating work.

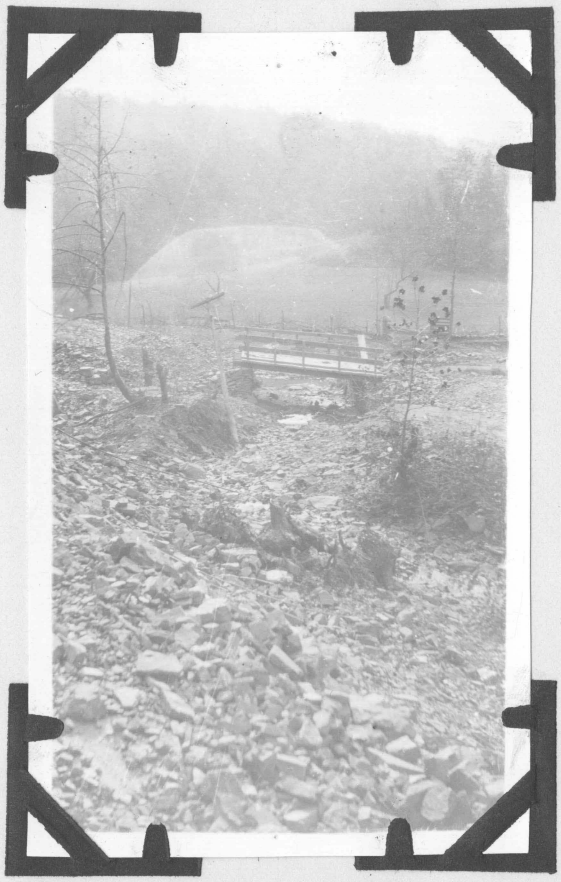


Concrete bridges; showing old and new type handrails.

The contract work was completed about the first of December, but the whole project had to be remeasured, which kept the project engineer and party there about a month longer. After the field work was completed, the notes had to be plotted, the quantities figured and checked, revised plan and profile made, and the final estimate made up. This kept us working until January fifteenth, nineteen twenty-two.

On this date I was transfered to a three and a half mile project in Albemarle County, about five miles from Charlottesville. This project consisted of grading, drainage, and bituminous macadam surface, but owing to the weather conditions work had been suspended. For about two months therefore, I worked in the office making up final cross sections, final plan and profile, figuring and checking excavation quantities, and making up final estimate. My title was still that of rodman.

About March first, nineteen twenty-two, I was promoted to instrument man and assigned to a locating party. The promotion consisted of an increase in salary and a change in title only, as I had been doing instrument mans work for the previous eight months. The locating party was making a location between Clifton Forge and Covington, a distance of about nine miles. The party consisted of a chief of party, instrument man, and two rodmen. I ran the transit and



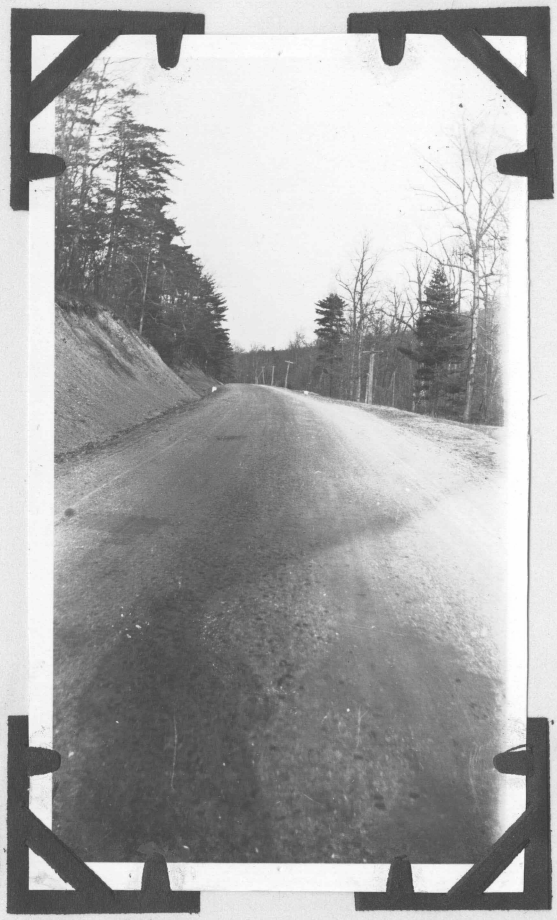
Wooden bridge on a grade;

connecting a county road with a new state road.

level, kept the notes, and plotted the plan and profile. This work was very interesting and gave me an insight into the way the plans I had previously been working by, were made.

The middle of April I was transfered back to the project at Ivy, Virginia, which I had left to go on location. Work had started again and I was used as an inspector of macadam. I inspected the placing and breaking of hand broken base, and the bonding of this course. Also looked after the spreading of the stone for the top course, and the application of the asphalt binder. This was my first experience with this type of work, but I was under a project engineer who saw that I did not make any mistakes. This project was completed on July twenty-ninth and the final estimate was turned in on July thirty-first. It would have been turned in on the thirtieth, but that fell on Sunday.

August first I was assigned to a two mile project outside of Lexington, which was being constructed with State forces. I was given charge of the engineering end of the work, and was directly under the District Engineer. My title was still that of instrument man. I ran the transit and level and staked out the work. This consisted of retracing the center line, taking cross sections and setting slope stakes, staking out pipe lines, box culverts, and bridges, and inspecting



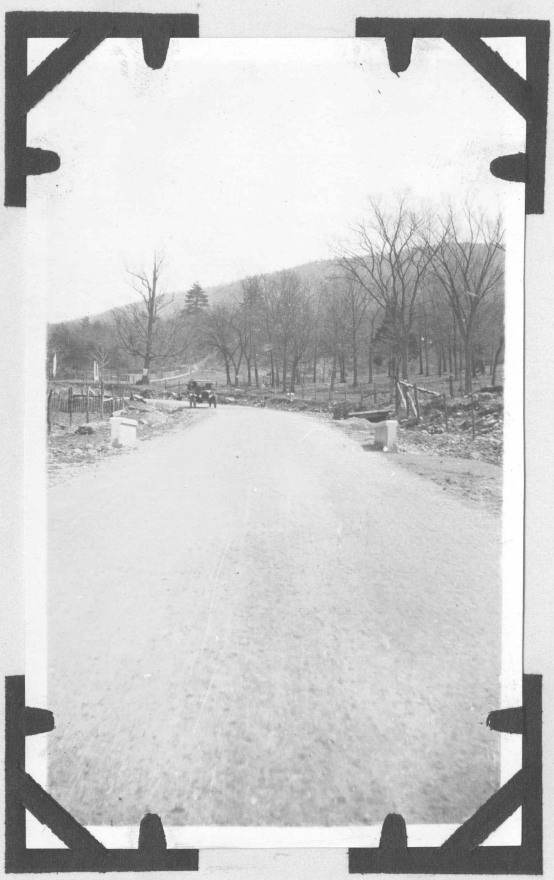
Macadamized mountain road.

the concrete work. When the work had been staked out, I was transfered to a project at Greenville.

This project was five miles in length and consisted of grading, drainage, and bituminous macadam surface. I was given the title of Inspector, which under a then recent reorganization took the place of Project Engineer, and placed in direct charge of all the work on the project. The first thing I had to do was reestablish the center line, and cross section the whole project. Pipe lines had to be staked out, and also culverts and bridges. After Xmas the work was closed down for about a month on account of the weather, and during this time I succeeded in getting the cross sections plotted, and the quantities figured and checked; I had two rodmen to help me.

When the work started up again in the spring, the two rodmen were transfered, and I had to handle the work from then on by myself. The work consisted of inspection only, so outside of the fact that the work was scattered over the whole five miles, one man could handle it easily. There was considerable concrete on this project, there being two bridges of over thirty foot span, four of ten foot span and over, and two box culverts. There was also a wooden bridge over the Baltimore and Ohio Railroad.

During the summer the grading was completed and all the drainage structures built, including headwalls



Box culvert handrails not conforming to grade.

to pipe. The macadam surface was completed on four miles of the project and the base laid on half of the remaining mile. During this summer and especially in the fall and early winter I gained some very valuable experience in regard to the application of asphalt. I found that it was very easy to get too many chips on the seal coat of the macadam, and that the excess was very harmful to the road, due to the tendency of traffic to follow in the same tracks. Also that bituminous macadam must be used shortly after being put down, or it will lose its elasticity and break up when finally opened to travel. Another point was that asphalt applied when the atmospheric temperature is under sixty, does not give a good job.

This project was "carried through" the winter and completed in the early spring. It would have been completed a month sooner than it was, but the extremely wet spring made it impossible to finish the surface. I completed all the plans, cross sections, and prepared the final estimate. All this work was done about a month before the date of actual completion of the job, and I was transfered about a week before the project was finished.

The project I was assigned to was about one third completed, and I relieved an inspector who had to go to the hospital. This contract was for grading and drainage only, and was four and a half miles long. It

Winding mountain road; old type wood guard rail.

was situated at Gore, Virginia, in the mountains. The grading ran about eighty per cent rock and the contractor made remarkable time with one steam shovel. Each month his estimate showed about twelve thousand cubic yards of excavation. This is small for railroad work, but I have not heard of any job in this section of the state where it has been equaled.

The drainage work consisted of sixty lines of pipe, eight box culverts, and one bridge of two twenty-five foot spans. This work was very interesting and the results obtained were very good. A different contractor had the drainage work, and he was not of a co-operative spirit. This caused some friction, but he finally fell in line and turned out a good class of work.

On this project wire rope guard rail was built; the first of that kind in the Staunton District. The contractor ( same one that had the drainage) co-operated to the fullest on this item of the contract and the result was a good piece of work. There was over a mile of this guard rail, and it was erected speedily and true to plans. I believe that this wire rope guard rail, using concrete posts instead of wooden ones, is the only kind that will be erected in the future. It is strong, durable, and pleasing to the eye, and economical to erect. Due to the diminishing supply of timber, a guard rail not requiring this item must be selected, and the wire rope type with concrete posts

Completed section of mountain road.

is the best I have seen.

From the Gore project I was assigned to the work I am now on at Luray. This project is three and a half miles long, and consists of grading, drainage, and bituminous macadam surface. It was half completed when I was placed here, and the work is mostly inspection. I have to remeasure the excavation over the entire project, and work up the final estimate. The work is the same that I have had on the other projects, and has not presented any new problems.