

about. He was able to effect an agreement with the interurban companies and the waste was used in making their approach fills.

The pavement is a uniform 8 inch concrete slab with 2-inch crown, 20 feet wide on tangents and on the 3-degree curve. On curves over 3 degrees the pavement is widened from 20 feet at the ends to 28 feet at the middle and superelevated. On tangents and the 3-degree curves, the pavement was finished with a finishing machine and on curves over 3 degrees the entire width of the pavement was laid at one time, struck off with a heavy straight edge and finished by hand.

A 16 gauge, 7½-inch corrugated, metal strip with ½ inch round deformed tie bars was placed in the pavement on the center line. Throughout the entire job ¾ inch round deformed bars placed 6 inches from each edge and on the neutral axis of the slab were used.

A 1 inch preformed transverse expansion joint was used every 100 feet with ½ inch round deformed bars placed transversely in the center of the pavement on each side and 4 inches from the joint.

The curve intersections were laid one-half at a time, the two halves being tied together with ½ inch round, deformed bars.

The retaining wall is 680 feet long and ranges from 6 to 15 feet high. It is of reinforced concrete of the cantilever type design, constructed in 50-foot sections.

The contract for the county's part of this work was awarded to the Highways Improvement Company at a lump sum of \$69,860.79. The contractor at all times showed a desire to use the best materials and to do first class work and I believe as far as material and workmanship is concerned it is as good a piece of construction work as can be found.

## GRAVEL AS A ROAD SURFACING MATERIAL

By W. G. Parrett,  
Fountain County Surveyor.

The three principal, natural products used in the construction of our highways are gravel, stone and sand. Almost every type of highway which has been devised utilizes one or more of these materials for the greater portion of the pavement. But, the material must be brought to certain specific requirements for each of these various types of construction.

In many sections of the country, local gravel is the only available material suitable for road building and perhaps no other has so wide a range of uses in construction work.

Gravel may be defined as a mass of more or less rounded fragments of rock material which have been broken down, worn and shaped by the action of ice and water, collected and transported by the ice sheets and left in deposits known as glacial drifts.

The two great ice movements forming the gravel deposits in this state are known as the "Illinois Ice Sheet" and the "Wisconsin Ice Sheet." The former extended as far south as a line from Posey to Brown and from Brown to Clark counties and the latter, to a line from Vigo to Franklin counties. As the ice melted, rivers and streams were formed and these have continued to transport the materials further and to deposit it in bars. These deposits are commonly known as river gravel.

Gravel may be composed of almost any kind of rock material but the commonest pebbles are composed of quartz and the harder materials of fragmental rocks. When these rocks were broken down, their less stable ingredients were decomposed and the remainder having been subject to great wear by being transported over great distances, that part which remains in our gravel deposits contains the most durable parts of the rock formation.

Because of this wearing quality and because of the wide distribution of these deposits and the low cost of the material, it has become the most universally used ingredient in roadway construction and is used more than any other material for the plain surfacing of the roads.

In the earlier day when roads were nothing but mere trails, gravel was occasionally used, because of its proximity, to make the worst places passable, no attention being paid to the quality of the material or the method of placing it. As its value became recognized as a surfacing material it came into more general use and today, in this section of the country, no road is considered worth building unless it can, at least be surfaced with gravel.

With the almost complete change in modes of travel, and the intensive use of our more important highways, it became evident that the material in its natural state would not hold up, that a stronger binder was needed. Hence the removal of the natural and the addition of an artificial binder, such as Portland cement, asphalts and tars, which resulted in the development of our higher type pavements.

We should construct the higher type pavement on the main highways such as the federal, state and the more important county highways, leaving the less important county and community roads to be surfaced with gravel, thus obtaining as wide-spread distribution of reasonably satisfactory roads as possible within normal limits of finance and taxation.

The knowledge required for the proper design of a gravel surfaced road, where local materials are to be used, cannot be obtained altogether from books or papers on the subject, nor will any set of standard plans and specifications answer the purpose, as every road presents different problems in regard to the nature of the subsoil, drainage and the characteristics of the surfacing material. It is, nevertheless, necessary to keep in mind those methods that have been tried and found to be generally satisfactory.

### Quality of Gravel

One of the first things to be considered is the quality of the gravel in the locality, to determine whether it is, or can be made suitable for the purpose. As the quality of the gravel generally varies in the different deposits in the same locality and often in the same deposit, it is necessary that the person in charge of the selection, have a knowledge of the relation of the physical characteristics of the pebbles to the wearing qualities. Probably the best evidence is obtained by observation of the surface of a road on which similar material has been used.

The ideal gravel should consist largely of pebbles which are hard and tough and will offer great resistance to abrasion. They should be well graded from the coarse to fine particles. There should be intermingled with the particles some material which will bond them into a compact mass. A careful examination of the gravel, with regard to these characteristics, will give this information.

The hardness and durability of a gravel is determined by the composition of its pebbles. With a knowledge of these ingredients, the relative hardness can be and usually is determined by visual inspection. It can also be determined to a fair degree by sorting out the pebbles from representative samples and testing them with a hammer. By means of weighing, the relative proportion in which the more durable materials are present, can be determined. The durability or resistance to abrasion may also be determined by use of the Deval machine. Pebbles of a certain size are weighed, placed in the steel cylinder, which is set at an angle of thirty degrees, together with a number of steel spheres, and the cylinder given about ten thousand revolutions at the rate of thirty-three revolutions per minute. The sample is then removed and passed over a No. 16 sieve. The material passing through is weighed and the per cent of loss determined.

### Grading of Gravel

In considering the grading of the gravel, it should be kept in mind that all that makes a gravel road better than an

earth road is the pebbles. In order to produce a surface of maximum density, these pebbles should be well graded from coarse to fine so that the minimum amount of binder, the weakest element, will be required. Natural deposits usually contain too large a percentage of the finer particles as well as particles of a larger size than desired. If the gravel in its natural state will make a surface that will support the traffic of the road under consideration, well and good; but if it will not, the excess material should be removed by screening, leaving a gravel containing the proper proportions of the different sized particles.

Authorities differ as to the maximum allowable size of the pebbles. Specifications range from one to three inches in diameter, the smaller sizes having the preference, probably due to the demand for a smoother riding surface. For maintenance material, the larger sizes should be screened out, for, if left on the surface, they will cause unequal wear and a rough surface. In the construction of a new road, the maximum size allowable should depend largely on the grading of the pebbles and the thickness of the surfacing material to be placed on the road. The larger pebbles placed in the bottom of a heavy course will not damage but will benefit the road.

In selecting a gravel that produces a hard, dense surface, the grading is just as important as that of aggregate for the higher types of roadway. The formula used in Montana for the grading of gravel for both road surfacing and concrete aggregates is:

$d = P^2M$  where  $d$  is the screen opening expressed in inches,  $P$  is the percentage passing a given size screen and  $M$  is the maximum allowable size stone. This is the formula of a parabola and the curve is known as Fuller's Density Curve. The screen test of a sample plotted and compared with this curve will show what is lacking in the gravel to make a surface of maximum density.

This curve shows that good surfacing gravel should contain from 45 to 50 per cent of pebbles passing a  $\frac{1}{2}$  inch screen and from 20 to 25 per cent of particles passing a number 8 screen.

It is generally considered that no gravel is desirable for surfacing if it contains a larger proportion of particles passing a number eight screen than from thirty-five to 40 per cent, and possibly that containing fifty per cent or more should not be called gravel.

### The Binder

No matter how durable the pebbles or how well graded, they cannot be successfully used for surfacing purposes unless they contain some substance which will bond them together so as to present a combined resistance to the disturbing action of traffic.

The principal cementing agent in most of our deposits is clay and this material generally occurs in excess of the required amount for binder. There seems to be the opinion among many that gravel which will pack in the shortest length of time, will make the best road. Gravel containing a clay binder will pack in less time but will give a poor wearing surface if the binder is present in excess of the required amount. When present in quantities of more than 10 per cent the surface will become slick and even muddy in prolonged wet spells. It is also more susceptible to the action of frost in the spring of the year.

Other good binders, though not so widely distributed, are silica, iron-oxide and calcium carbonate. Of these, the latter, or a combination of calcium carbonate and iron, makes the best natural binder.

The efficiency of the binder may be ascertained by observing the exposed bank of a gravel deposit. If the bank stands practically vertical and contains lumps composed of numerous pebbles cemented together, a good binder is present and the pebbles will cement in the roadway and produce a hard and compact surface. The bonding qualities of a gravel may also be obtained by the investigation of the surface of other roads on which the same gravel was used.

After the different gravels within reasonable distance of a proposed road have been examined, the screen test should be decided upon and incorporated in the specifications and the contractors, wishing to bid upon the work, advised of the source or sources of supply.

### Design and Construction

The design and construction of the roadbed, ditches and waterways should proceed in much the same manner for all types of roadway, although, in comparison, those of the gravel roads have not received as great care and attention as on the higher type roads.

The matter of drainage, is more important to the roadway having a gravel surface than to those of the more permanent type. Water is more damaging to the gravel surface than traffic. During wet spells the power of the binding material is weakened and the road is rutted. In the spring, if the surfacing is not heavy enough, it breaks through when the frost leaves. There is no reason to believe that the soil under the surface of the roadway contains less moisture than that of the adjacent fields and if it pays the farmer to drain the fields by the construction of drains at 40 foot intervals, why should it not pay to do likewise with the roads?

In the designing of a gravel surfaced road keep in mind the location or importance of the road as to the future use as well as the present, that the work done will not be wasted

should the road be rebuilt in the future. It is not always necessary to go to great expense in obtaining just the proper alignment or easy grades, as the gravel road is not what is called a permanent type, and small changes, both in grade and alignment, can be made at any time and at small expense. The shoulders should have just enough slope to drain the surface water and the subgrade be left flat or practically so.

Money is well spent in the rolling of the subgrade. On roads carrying considerable traffic and where the gravel is costly, the surface should also be rolled. Rolling brings out the weak spots and also prevents the gravel surface from being torn up by traffic until such time as required for the binder to function.

There are two methods of placing the gravel surfacing, the trench and the feather-edge methods. The former is probably the better where the gravel is very expensive. The latter is the more commonly used and is better adapted for our methods of maintenance.

The width to which the surfacing should be placed, depends on the amount of traffic which the road will carry. The depth, ranging from five to twelve inches, should depend on the nature of the subgrade, the amount of traffic and the quality of the surfacing material.

Every precaution should be taken in the placing of gravel to procure, when compacted, a smooth easy riding surface free from bumps and waves. Maintenance should commence at once and continue until this condition is satisfied. The better the condition and the smoother the surface, the less it will be affected by traffic. The traction necessary to propel the vehicle will consequently be less.

According to data compiled at the end of the year 1924, there were in the United States 467,905 miles of surfaced road, 52.2% of which are surfaced with untreated gravel. In our own state at the end of 1925, there was a total of 73,112 miles of road, 44.2% of which were gravel surfaced roads.

It is evident that we cannot replace all these gravel roads or construct all future roadways with permanent types of pavement and have the desired mileage. Therefore we must salvage what there is of value in them and reconstruct to enable them to carry the increased traffic. On many of our roads, gravel surfacing is giving satisfaction and as roads should not be built too far ahead of traffic requirements, the gravel surfaced road will be one of our principal types of roadway for years to come.

On account of the economic importance of this type of roadway the design and construction and the quality of the surfacing material should receive more attention and study than it has in the past few years. Many miles are yet to be constructed and much of the present mileage, which was built

without any regard to durability or suitability, will have to be reconstructed. Could we not, by no great increase in cost, so better construct this moderately priced road as to greatly increase its value as a road, thereby reducing the cost of maintenance and bringing the type to a closer approximation of the more costly pavements?

## HOW TO GET MORE EFFICIENT ROAD INSPECTION

By George Gault,  
Wayne County Surveyor.

The efficiency of any process depends upon the quality of the materials used, the fitness of the mechanical equipment used, and the skill of the workmen employed in the handling of the materials and equipment. No one will question the statement that the finest material can be applied to the work in such a manner that the finished product will be practically worthless, or that the finest workmanship can not produce the best finished product with poor materials or equipment.

We all have ideals we hope to reach some day. We are going to give you our idea of an ideal road inspection system. We realize that it will not be possible for us to use this system under existing conditions, but we feel that if we have some definite goal ahead we are more apt to make some progress in that direction. As conditions change we may have to change our goal to meet them, but if the angle of deflection is not too large, we have not wasted any of our efforts in the progress made up to that time.

As the efficiency of road inspection depends largely upon the efficiency of the inspector, let us first consider some of the characteristics of the ideal inspector.

First: He should be a man of such temperament that he can make any necessary suggestions or criticisms in such a way, that those actively engaged in performing the work will feel that he is acting entirely for the benefit of the work, and not to show his authority. He should be able to judge the temperament of those with whom he has to deal, and act accordingly. It will only be necessary to make a suggestion to one contractor, while with another it will be necessary to check up and see that the suggestion is followed out. We believe that this question of personality should be given serious consideration, as harmony is the strength and support of all institutions, and any lack of it between the inspector and the contractor, or between the inspector and the engineer can only result in detriment to the work.