ROADS FOR MINES

BY GEORGE R. FANSETT

Transportation facilities, particularly with respect to wagon roads, play a greater part in the opening up and development of a mineralized district than practically any other single item and are usually one of the first matters taken into consideration by a consulting engineer while making an examination of a mineral property.

Many good properties have been turned down and many more have been worked at a loss owing to the roads and other means of transportation being in a poor condition than perhaps from any other single detail, and their condition can often be taken, for a working property, as a barometer of the management.

A few of the advantages derived from these when in good condition are cheapness of transportation, condition of goods shipped, ease of traveling, shortness of the time of delivery, and the advantage of having the time of delivery definitely known.

Cheapness of transportation is a very vital matter, and a few of the reasons why it is cheaper over a good road are that larger and heavier loads can be hauled over a good road in a shorter space of time, and that the wear and tear on the equipment is less. Improvement of one road in this State made it possible to haul six times as much in a load in a shorter time over the same distance with the same power than was possible before the road was improved. From this it is easily seen that for each ton of freight moved the cost per ton was greatly reduced.

The condition of the goods shipped, particularly machinery and other breakable and perishable goods, is an important factor. Machinery and other breakable supplies will arrive unbroken over a good road where it would be next to impossible to transport them satisfactorily over a poor road. Likewise, it is possible to transport large castings or machines assembled where otherwise this could not be attempted. Food stuffs, especially perishable products, such as eggs, vegetables and other supplies, can be brought in and used, where if the road is in a poor condition they would spoil en route, due not only to the roughness of the trip, but also to the time taken for the journey. This matter alone is very important, as it makes possible
better food and this better food may not cost as much as canned and other kinds of products.

The wear and tear on equipment, such as automobiles, wagons, horses and harness, over a road in good condition is much less than if the road is in poor shape.

When the time of delivery can be made in a short time and on schedule advantage can often be taken of a temporary high market price for the product. This happened with some companies in the last few years in connection with antimony, zinc, tungsten and other minerals.

The capital needed to run a mine which has good transportation facilities is much less than when the reverse is true, because it is not so necessary that repair parts and large stocks of supplies be kept on hand. This naturally reduces the interest on the investment.

When these facilities are in good order the management can plan the work to better advantage, thus accomplishing more in the same time with the same expenditure of money. Likewise, it is easier to get and to keep efficient help.

The above, a few of many good reasons, will serve to indicate why the roads and transportation facilities of a section should be in as good condition as the section can afford to maintain them and why everybody is dependent and affected by them and why everyone should cooperate to improve them and maintain them in as good condition as possible.

After it has been decided to build a new road or improve a part of one already existing, one of the first and most important matters to be settled is that all parts of the finished road will have the best possible location. This is very important because practically all roads which are now being built or improved will eventually form a part of the main system of roads of the country, and if any part of the road is poorly located this part may finally have to be abandoned.

The notion that a burro or cow trail between two places always is the best location for a road is one of the causes for the great number of badly located roads in this country. The ridiculousness of this notion is apparent and needs no explanation. Likewise, the notion that a “straight” road, running up and down over the hills and valleys, is always a good location for a road has long ago been discarded. This is due to several reasons, the main one being that a road built on this plan may not only be longer in actual length, but it also may include ascents and descents which are unnecessary, thus making the cost of hauling over it greater as well as increasing the cost of maintenance. Other disadvantages are that the cost of con-
struction is usually greater, there is greater damage from rains, greater wear and tear on the road from the traffic and on the equipment, as well as the rate of travel being slower.

From actual experience it has been found that roads can advantageously be increased in length to overcome these kinds of hill grades by about twenty to one. That is, to get around a hill 100 feet high it would be better to build 2,000 feet of road around a hill of this kind than to go directly over it in a straight line.

From the above it can be seen that straightness is often overrated, and the building of such a road may be more expensive with no compensating advantages.

The location of a road involves practically the same principles as the location of a railroad, and for that reason engineers who are experienced in that line of work are particularly well qualified to handle it.

Some of the basic principles which help to determine the final selection of a route are the following:

1. To follow the route which affords the easiest grade.
2. To connect the places by the shortest and most direct route commensurate with easy grades.
3. To avoid all unnecessary ascents and descents.
4. To give the center line such a position with reference to the natural surface of the ground that the cost of construction shall be reduced to the smallest possible amount.
5. To cross all obstacles, where structures are necessary, as nearly at right angles as possible.
6. To cross ridges through the lowest pass which occurs.
7. To cross over or under railroads, and to avoid grade crossings.

A few other matters which have to be taken into consideration are first cost, maintenance, limiting grades to be used, drainage, topography and condition of the country over which the road is to be built.

The cost and money available for the improvement should not affect the kind of location made because it will cost practically the same to have a poor location made as to have this part of the work properly done.

Maintenance is the cost of keeping the road in good repair. If the road is well located and built this charge will be comparatively low, but if poorly done, as is the case with many of our roads, they may have to be practically rebuilt every time that they are put in shape, and in a short time after this rebuilding they may be in poor condition again. In such cases the maintenance charges are tremendous,
and the community and country suffer to that extent with no one getting any definite good from it.

The limiting grades used are very important, since the minimum or least grade used for any section of the road should allow for good drainage, and the maximum or highest grade used on any part of the road will determine the limiting load which can be hauled over that part of the road with the power available. By this is meant that if there is a steep ascent or hill in the road, the load which can be hauled over the road where this hill exists can not be more than can be hauled up that ascent unless extra power is available at that particular place, or unless part of the load is unloaded before making the climb.

The following table indicates the comparative loads, as found by experiment, which can be hauled by the same power up different grades:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Load Hauled</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00%</td>
<td>100% load hauled</td>
</tr>
<tr>
<td>1%</td>
<td>80% of total load</td>
</tr>
<tr>
<td>2%</td>
<td>66% of total load</td>
</tr>
<tr>
<td>3%</td>
<td>52% of total load</td>
</tr>
<tr>
<td>4%</td>
<td>47% of total load</td>
</tr>
<tr>
<td>5%</td>
<td>41% of total load</td>
</tr>
<tr>
<td>10%</td>
<td>26% of total load</td>
</tr>
<tr>
<td>15%</td>
<td>10% of total load</td>
</tr>
</tbody>
</table>

From this table it is seen that the size of load haulable by the same power rapidly diminishes as the grade is increased and that the lowest limiting grade possible should be used on all parts of a road. In practice it has been found that a 12 per cent grade (12 feet rise in each 100 feet of distance) is the maximum grade which can be used with safety, because when over this the wagons or vehicles are apt to slip and skid when descending.

In the location of roads it has been found that it is good practice to make the grade on the bottom of a long ascent a little steeper than at the top. The reason for this is that the horse or other power is usually stronger at the beginning of the climb.

The drainage of a road is one of the most important matters connected with a road, because if a road is not well drained it cannot stand up and give good service. Water is one of the worst enemies of a road and for that reason every precaution should be taken in the location for the disposal of it so that it will not wreck or damage the road.

The topography and condition of the section of country in which the road is to be built are two of the most important factors govern-
ing the final location. Owing to the great number of points which have to be settled from a study of these it is impossible to more than state here that practically every matter connected with the location of a road hinges more or less on these and the location greatly depends on the results of the proper study of them.

When in addition to these, there is a higher cost for the construction, higher cost for keeping it in good repair, or the higher cost and greater delays in hauling over it unless properly located, it is apparent that there is no part of the work on a road which is more important or where it pays better to have the work properly done by a thoroughly competent man than in the location.

The construction of a road can roughly be divided into the following parts:

1. Preparation of the earthworks.
2. Construction of the necessary structures.
3. Construction of the roadbed.

The earthwork, consisting of the embankments and cuts, is prepared in the same way as for a railroad, particular attention being given that the material from the cuts balances and is used for making the fills as nearly as it is advantageous to do so, that the best materials available are used so that the embankments will be as solid and as permanent as possible, and that sufficient time be given for the earthwork to settle in good shape before the roadbed is built on it. Where cuts are made in loose dirt the sides should be cut back to the natural slope of the dirt, which is 1½ to 1 or about 34° with the horizontal, so that it will not cave.

If the earthwork of a road is properly located and built it should last indefinitely with very little, if any, repairs or attention being given to it, and if this part of the work is not properly done the roadbed on top of this earthwork can not stand up and give good service.

During the construction, provision should be made for the drainage by putting in drains or culverts before or while making the fills.

In Arizona, where the rainfall is often excessive for a short time, often amounting to a small cloudburst, special attention must be given for the protection of the road against this rain water by making the ditches, culverts, dips or other means of carrying it away or across the road, large enough to meet the worst possible conditions which may arise.

Culverts or dips should be built across roads as nearly at right angles to the roadbed as possible, special care being taken that they are well tied down to the bedrock if any can be reached. In cases where the bedrock can not be reached at convenient depth, the founda-
tion should be carried down well below where the action of the water can have any effect. When this is done the running water will not be able to reach the bottom of the foundation and undermine it, or the pressure of the running water be able to push it out of place.

This construction work should be under the supervision of a competent engineer, with practical construction foremen in charge of the work. There are few classes of work where inexperience is more costly and disastrous than in the management of road construction, and most of the money which has been wasted in this line of work can be laid to this score. Qualified and experienced men cost no more than poor men and these men can plan the work and take advantage of the local natural conditions so that a good road will not cost as much to build as a poor road built by an inexperienced management.

After the earthwork of a road has been properly located, graded and drainage provided, the next matter to be attended to is that of the roadbed. A few of the underlying principles governing the building of the roadbed are:

1. A good foundation, well drained.
2. A tight roof or covering, properly graded and crowned.
3. As small a percentage of voids as possible in the roadbed.

Since these points are more or less dependent upon the kind of material used in the roadbed and also that it has been found from experiment that the same power can draw twice as much over a gravel roadbed and four times as much over a good stone roadbed as over a dirt roadbed, and the maintenance charges for keeping up a good stone roadbed is much less than for a dirt road, it is important that the proper kind of material be used in this construction.

Some of the qualities governing the selection of stone for this work are hardness, toughness, uniformity of texture, and the property of re-cementing. In order to give good satisfaction a stone must have these qualities, and if certain stones have been selected as having them and are to be used, it is a good policy to send specimen or pieces of each to the office of Public Roads of the United States Department of Agriculture, Washington, D. C., where their value for road building purposes can be tested and advice as to their use can be obtained free of charge.

When the traffic, especially automobile, is so heavy that roads built of local material can not stand up and give good service, it is better to use one of the so-called permanent pavements, such as brick, stone or wood blocks, cement, asphalt, bitulithic or steel track. These are far more expensive in first cost, but will be found to be far more
Economical in the long run if the cost of maintaining a road of local material is excessive, due to the heaviness of the traffic.

Earth roads, built of natural soil, such as loam or clay, without a crust or other covering are by far the most common class of road found in the valleys of the outlying districts of this country, mainly due to the cheapness of their first cost. If kept in good condition by grading and rolling they give fair satisfaction, but the main objection is that the cost of keeping them in good repair is usually excessive, especially where the traffic is heavy.

They are usually built by scraping or shoveling the dirt from along the sides or side ditches onto the roadbed, and this is levelled, graded, harrowed, sprinkled and rolled to a smooth surface, by using road-machines, graders and rollers. In this work the grade should not be brought up in layers over 9" deep at one time, and each layer should have the same crown as the finished road is to have, particular care being taken that each layer is well rolled and packed before the layer on top is spread. In all road building care must be taken that no wood or other perishable material is used in the filling.

The sketch above illustrates the proper cross-section for a dirt roadbed, the crown having a grade of about 1" per foot. This gives sufficient grade for the water to run off easily without cutting into the surface of the roadbed if the road is kept well rolled and in good shape. The ditches along the sides should be large enough to handle all the water at any time and should have a grade of about 1 foot in 100 feet. In wet and swampy sections the roadbed should be well underdrained so that the surface will not get soft and become rutty from the traffic passing over it.

Earth roads require constant and continuous attention by men whose sole duty it is to look after and make the necessary repairs as they are needed. The method commonly followed in this country of repairing the roads once or twice a year in a more or less slipshod manner is not only more expensive than to keep men on the job doing this work all the time, but the roads repaired in this way are usually always in bad shape, even after the overhauling.
Experienced men with the proper tools, such as rakes, scrapers, drags, road-machines, rollers, etc., if kept on the job and made responsible for the condition of the road will do the work much better and far more economically than with the prevailing method.

The split-log drag, a picture of which is shown above (Fig. 2) has been found to be a very valuable tool in the maintenance of earth roads if used intelligently. To get good results the road must be well drained and crowned, and the best time to use the drag is after a rain when the road is still damp. A stick of timber or a piece of railroad rail can also be used to advantage as a drag.

If the traffic becomes so heavy that the cost of maintenance of an earth road becomes excessive it is then better to substitute a hard surfaced, permanent roadbed for the earth roadbed, and when this condition prevails the community which has had its roads scientifically located and built will find it very easy and comparatively cheap to make the necessary changes and improvements.

When clay is the only material used in the construction of the road, the crown should be built high and steeper than for a dirt road, and the side ditches should be extra wide so as to give the best drainage possible. Unless this is taken care of the road will not stand up long and the result will be a sticky and slippery mass.
Clay alone does not make a very good surfacing material, but if mixed with the proper proportion of clean, coarse, sharp sand the mixture will give good results where the traffic is not very heavy, and if the road is properly built and maintained.

The mixture of sand and clay which gives the best results is one where the sand has been added to just, and not over, the point of saturation and this mixture has been thoroughly mixed to a homogeneous mass. By this is meant that enough sand is added to the wet clay so that all the voids or spaces between the grains of sand, which should touch each other on all sides, are filled with clay and this mixture should be mixed so that it is all of the same composition. The mixing is best done by using a clay mixing machine such as is used in brick yards for doing this work.

The selection of the proper kind of clay and sand is important as some clays are practically useless and fine rounded sand is worse than valueless. Clays containing a high percentage of iron are usually good and only use coarse, hard, sharp sand for this purpose.

When this mixture has been prepared and spread, it is rolled as soon as it dries out on top, enough sharp sand having been spread on the top of it so that the clay will not stick to the rolls of the roller and the clay which oozes out during the rolling will be taken care of.

This class of road, in sections where the climate is favorable, has given fairly good satisfaction for light traffic but must have constant attention if kept in good shape.

**Sand Roads.** The above remarks on the plan of construction do not all apply to sand roads, since sand has no binding qualities and if kept wet is more compact and firmer than if allowed to dry out. For this reason a sand road should be built flat, with no crown, depressed somewhat in the center, and covered with straw, shavings or some similar material which will help retain the moisture and give a solid surface.

**Gravel Roads.** Gravel, when not rounded or water-worn, makes a good substitute for crushed stone in the construction of roads where the traffic is not very heavy.

The same methods of construction should be used for a gravel road as for a crushed stone road; that is, the subgrade, after being shaped to the proper crown by a shaper or grader, should be well rolled before any gravel is spread on it.

If the gravel runs uniform in size it can be used as taken from the pit, but when this is not the case it is better to screen it through a 1½" screen, the oversize to be used in a lower course or layer to a depth of about 6" and the balance in the top layer to a depth of about
4", using no gravel which is over 5" in diameter. Each course should have the same crown as the subgrade and should be well sprinkled and rolled separately after enough clay has been added to fill up the voids or spaces between the gravel. The final rolling should be done by the heaviest roller available.

Broken stone roads, often called macadam, are much used and are very well adapted for main country roads where the traffic is moderate. When built properly of good material they usually give better service than a gravel road and are often substituted for them when these fail.

This class of road, when used in the country districts, usually consists of from 12 to 15 feet of broken stone surfacing in the center of the road and well made shoulders which extend out from 3 to 5 feet on each side so as to confine the surfacing material.

The first part of the construction for this class of surfacing is the preparation of the subgrade, a sketch of the cross-section of this being shown above. This consists in the making of a trench the depth of which is the same as the finished surfacing material which is to fill it, and the cross-section of the bottom of which when finished will have the same crown as the surfacing is to have, care being taken that the shoulders on the sides are left from 2" to 3" higher than when they will be finished so as to allow for compressing by the roller.

This excavating is usually done by a grader and later smoothed and evened up with shovels and rakes to the proper crown, care being taken to discard all perishable material. It is then thoroughly rolled hard, usually starting at the lower sides and working gradually toward the top of the crown. After this has been completed, particu-
larly in damp climates, where the material in the foundation is not porous, it is advantageous to dig trenches about every 75 feet across the shoulders to the side ditches on both sides of the road to act as drains for the subgrade trench. These are filled with 3” stone at the time that the lower course of stone is spread on the subgrade.

The next step is the spreading of the lower course of broken stone to a depth of from 4” to 5” with the same crown as the subgrade. The stone used for this course should be from 2” to 3½” in diameter and should either be spread directly from an automatic spreading wagon or by shoveling directly from carts onto the subgrade. Never dump into a pile on the subgrade and spread from this pile as this gives poor results and the road soon will develop bumps or ruts.

After being evened up it is then well rolled, in the same manner as for the subgrade, until a firm, compact surface is produced. The usual practice is to spread and even up from 100 to 200 feet before starting the rolling and to keep about this distance between each section of the work.

The second course, made up of crushed stone from ½” to 1¼” is then spread over the completed first course to a depth of from 3” to 5” in the same manner as the first course was spread and is rolled in the same way, until a hard, compact surface is produced. After this has been finished the binder course, made up of stone dust, is spread to a depth of about ½” over all the surface. This is well rolled in, in order to force the binder down into the spaces between the stones, and after being well rolled it is then well sprinkled with a street sprinkler in order to wash as much of the dust down into the voids as possible. While doing this, if any bare spots should develop, more dust should be spread on them, and when this no longer happens, and the surface has a wave of water in front of the moving roller, it is considered wet enough. All depressions should be levelled up with crushed stone and not with the dust, and only sufficient binder should be used to fill up the voids, with just enough to cover the surface in a thin layer after the work is completed. The road is then allowed to stand for a day or so in order to give it time enough to dry out on top and harden, and is then ready for use.

The macadam class of road is particularly serviceable in mountainous districts, especially around hillsides, the only practical difference in the construction of such a road for hillsides being that it does not have a crown. The surface of such a road is built flat, the outer edge being higher than the inner edge, the fall being at least ½” to the foot so that the water runs off easily. Between the road and the hill should be built a ditch, large enough to handle easily all water from
the hill as well as from the road, and this is drained by dips across or culverts which run under and across the road, emptying so as not to undermine the foundation of the roadway. The following sketch illustrates the cross-section of such a road.

Owing to the increase of the use of the high speed automobile, whose wearing action and dust-producing action is much greater than any former class of vehicle, much research and experimenting has been made to find a cheap binder which will give better results than the water-bound classes of surfaces mentioned above.

Among those which have given some of the best results for the least cost on country roads are oils having a good asphaltic base, when properly applied. The selection of the proper oil and its application are big subjects in themselves and should be handled by an expert, or otherwise, if a poor oil is used or a good oil is improperly applied, the result may be worse than with no oil at all. If properly selected and applied the road will give much better service with much less dust and will last much longer.

The proper maintenance of a road is most important, since a road as soon as constructed and finished begins to go to pieces. For this reason a permanent organization for handling this work should be arranged for as soon as the road is finished, and should be made up of men skilled in this class of work who are held responsible for the condition of the road at all times, the same as is the practice on railroads with section gangs. The usual practice in this country of overhauling a road once or twice a year in a slipshod manner by unskilled labor is the most expensive and least satisfactory method possible and is to a great extent responsible for the poor roads and the high cost
of these, and not until the maintenance of a road is properly organized
can it be hoped to have good roads and cheap transportation over
them.