Thesis

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Treatise on highway construction and Maintainance.

In this discussion I shall endeavor to discuss the problem of highway construction in a general way, but especially the construction of a modern highway in a country which has a natural deposit of gray limestone such as Rockbridge County abounds in. I shall also try to point out the value of a first class public road from an economic standpoint, and its value to the rapid development of the country, and also discuss the Technical side of the construction of a road.

Relation of highways to the economic development of a country.

The history of the development of modern civilization is almost directly traceable to the history of a countrys highways and its highway development.

Going back as far as the time of the old Roman Empire, history shows that its development was to a large extent due to its excellent system of highway construction and maintainance. In almost every case when Rome conquered a new territory the first thing she did was to introduce a system of roads & the art of road building. While the United States is far ahead of any other country in her system of railways she is behind almost all of the European countries in regard to highways.

Although the system of railways has made transportation of materials from one part of the country cheap there is a vast loss in the unnecessary cost of transporting materials over muddy & hilly roads to the railway and from it. It is almost impossible to estimate in dollars and cents the increase in value which good roads add to land, but we would

safe in saying that under ordinary circumstances that the value of the land would increase fifty percent. It is also impossible to estimate in actual money the value which is derived from good roads in the way of safety, convenience, the saving in vehicles and horses.

Since the discovery of the automobile a new field for highways is opened, and a quick transportation other than railways & plays an important part in the development of a country. Theoretically the track for an automobile should be perfectly smooth and free from ruts and loose stones, the delicate machinery and bearings of an automobile only last a short time when used on the rough & muddy roads which characterize a large part of our country.

The method for raising money for the construction of big highways which has proved the most successful is the taxation of the taxable

property of the county or district and if necessary the issuing of county bonds. However this problem should be left to competent men and should be determined in the most satisfactory way.

The first question which comes up in building a highway is where to locate it. This work should be in charge of a competent Engineer and he should make several preliminary surveys. The two main points which govern the location of a road are 1st those relating to the accomodation of traffic and second those relating to the cost of the construction.
In a thickly settled country the new road should be located so as to accommodate the largest number of people. The line should however be made as near straight as possible, and when curves occur they should be regular curves, and sharp bends should be avoided.

When the preliminary survey of the road is complete, and the grades located & determined of the various routes & ways, it is necessary to decide upon one of these.
The hardest proposition however which comes up is that of changing an old location. When the old roads were first used it was before the use of fast vehicles came into use & they usually followed the old bridle paths and paid very little attention to grades. Naturally the houses as the country grew, built up along the roads. To change the location of the old road would mean to have a lot of these houses off the main highway. In America the roads are governed by the county courts which have the entire jurisdiction over them. Although an Engineer may locate a road which will be cheaper to build & have better grades yet nine times out of ten he has instructions to stay in the

old road and make the best of it.

Of all the roads which have been tried in america & for that matter in all the civilized world, the broken stone road has proved the most durable. In many cases however it is impossible to build a broken stone or 'macadam' road and it becomes necessary to substitute some other kind of road. The roads which have proved the best excepting the macadam road are the Sand-Clay roads and the Burnt-Clay roads.

I shall treat these first two rather briefly here and pass on to a fuller discussion of a macadam road.

Sand-Clay-Roads. - Natural sand clay roads are sometimes found in localities where the soil contains the right proportions of sand and clay. The mixing of sand and clay as a form of road construction has received careful study and is of great value to a lot of the

southern states where sand and clay are the only available materials for road making.

It is a hard matter to specify the exact proportions of sand & clay to be used because the two materials vary so much in their composition and structure. Sand is the mineral quartz which has been disintegrated by the action of the elements. Sand is found in masses of fine grains. It is known that sand lacks binding power and on drying out becomes very loose.

Clay is formed by the decomposition of other minerals. The origin of all clay is the mineral feldspar, which under the action of water has gradually been soaked out and become clay. The particles of clay are much finer than those of ~~water~~ sand. Very often large deposits of feldspar have been disintegrated and form large banks of clay. Clays thus formed are called residual clays. It will be seen from this

that clays must vary in texture and composition. Some will be found to contain as much as 75 per cent sand, while others are almost entirely free from sand.

The two properties which are the most important in road making about clays, are, first, plasticity, second its power of shaking when it is first uncovered. A clay is said to be plastic which becomes sticky like dough when it is mixed with a certain amount of water, and can be moulded into any shape, and it will retain this shape even after it has become dry. There are clays however which will fall to pieces just as a piece of quicklime. It is seen from this that the physical properties of the clay plays a very important part in the kind of road which it will make.

another physical property of clay from the standpoint of the road which it makes. Some clays

shrink when they are dried, which causes the cracking of their surface. This shrinkage renders the composition of sand and clay unstable. If the clay would stay in the same position after shrinkage it would do no harm. When the water is natural which is removed from the absorptive, it causes an expansion which causes the grains of sand to be separated. This property however cannot be overcome altogether but it can be remedied by adding more sand to the clay. By adding more sand the road is weakened, but sufficient testing will show what proportion of sand and clay should be used.

Before attempting the construction of a sand clay road, it is best to test the material in the neighborhood in order to secure a clay having the least possible shrinkage. The best way to do this is to examine the highways which are the most traveled. In almost

very community there are short sections of natural sand clay roads which may be examined.

Mixing of Sand and Clay. The best sand-clay road is one in which the wearing surface is composed of grains of sand in contact in such a way that the voids in the sand are entirely filled with clay, which acts as a binder. Any excess of clay above the amount necessary to fill the voids is detrimental. Whenever the proper conditions exist between the sand and clay the road will bear heavy traffic for a long time even when the subsoil is sand or clay. Thorough mixing of the sand and clay is absolutely essential to good sand clay roads. The best way to mix the sand and clay is after a hard rain. The clay should have been spread before the rain and after the rain a few inches of sand should be spread on the clay and plowed and

harrowed thoroughly. This process is rather disagreeable as the mud sticks to the harrow, but it is the only method which has proved satisfactory in very repeat. Many experiments have been tried with the dry mixing of the sand and clay but all of them have proved more or less unsatisfactory.

Method for Calculating the proper Amounts of Sand & Clay to be used. It has already been shown that the best mixture for sand clay construction is one in which there is just enough clay to fill the voids in the sand, thus securing the proper cementing in the road. No rule can be laid down for calculating in advance the best mixture. The relation of weight and volume vary very much according to the amount of water that is in the material. Some clays will hold as much as 20 per cent of water, which is held in the structure of the material

and is known as water of combination. An easy method for making a rough approximate estimate of the volume of the clay filler required for any unit quantity of a given sand is as follows: Two ordinary glass tumblers are filled to the brim, one with dry sand to be tested and the other with water. The water is then poured carefully from the one glass into the sand in the other until it reaches the point of overflowing. The volume of water taken from the one glass which was originally full can be taken as an approximate measure of the voids in the unit volume of sand contained in the glass. A simple calculation will reduce these volumes to percentage. The tendency usually is to calculate too little volume of sand and often it is necessary to apply it the second time. Clay tends to work to the top of the road.

Constructing a Sand-Clay Road. There are two distinct methods of constructing a

sand-clay road. In the first case the road may have a sandy subsoil. In the secnd case it may have a clay subsoil. Each of these methods will be treated under a diffrent head.

Drainage. In all forms of road construction the most important consideration is that of drainage. If natural drainage does not exist artifical methods must be employed. The best natural drainage is usually found upon a loose gravel or sandy soil especially when the grade of the road is above that of the surrounding country. If the land is porous nothing is needed except to keep the crown of the road well up and the side ditches open & wide enough to carry the water which comes from the heaviest rains.

Sandy Subsoil. Here is given a section showing the clay top upon the sandy subsoil. It has been found best to put the clay

on the part of the road meant the
scource of the clay so that the
carts can run over it. After
spreading the clay it should be
covered with a layer of sand. When
the road has been opened to traffic a
sufficient amount of sand should be
added from time to time to keep the
surface smooth and prevent the formation
of mud. After the layers of clay and
sand are put on it is often necessary
to plow & harrow them as already
described. If the materials are
especially adapted to the purpose it
is possible to construct good sand
clay roads without the use of plow
and harrow. The mixing can be
left to traffic.

Sand-Clay Roads on a Clay subsoil. After
proper drainage has been provided
for the road bed should be crowned
as nearly as possible to the shape
desired for in the finish. The
foundation having been prepared,
the surface should be plowed and

and harrowed to a depth of about 4 inches until it is pulverized as completely as possible. It is then covered with from 6 to 8 inches of good sand. The sand should be spread so that the layer is thickest at the center and gradually sloping off to the sides. The materials should be mixed while they are in a comparatively dry condition, then the wet mixing comes which was described on a previous page. Upon completion of the wet mixing the road should be shaped while it is still soft enough to be packed by a scraper.

Cost of Sand-Clay Roads. It is very hard to make any very definite estimates on sand-clay roads. The price of labor, length of haul, width of road etc vary so much in different localities. The figures which are available show that about the average cost of a first class sand-clay road is approximately $ 600 per mile.

Use of Sand-Clay roads:- The use of the sand clay road is not fully realized by the general public. When there is plenty of Sand and Clay in a country a good road can be built at about one sixth or less of the cost of a broken stone road. If when a road needs a little repair a few loads of gravel or Sand be hauled and put on it instead of brush a much better road will be the result. The study of the cementing properties of sand and clay is becoming more and more a study to the scientific world. And the use of this property in road making is coming into prominence each year.

Burnt Clay Roads. This is a kind of road which is used in sections where the clay is so sticky that it is almost impossible to get over it in a wet season. The Burnt clay road is of very little importance in our discussion of the roads in Rockbridge County. However it is interesting and relates somewhat to the properties of clay. In some

parts of Mississippi where this gumbo or stick y clay abounds, there have been experiments carried on of burning this clay until it clinkers and thus forming a hard surface. This burning is done right on the road. The road bed is plowed up and rounded into shape, then the wood is hauled along the road side. The cord wood is formed into cribs in which the lumps of clay are placed. Thus a sort of furnace is constructed along the roadside which makes a very easy way for burning the clay. This form of road has proved very successful. Although there has been very little burnt clay road built it has proved a success, & the cost of construction is such that it can be built in almost any country

Construction of a Macadam Road.

The purpose of this part of this article is to discuss the plain facts relating to the construction of a first class stone road in a County in the mountainous section of Virginia, where the pure gray limestone is abundant and the cost of labor is comparatively small.

Rockbridge County is situated on the North River that is north river runs through it from west to east and with its various tributaries forms the north fork of the James.

Rockbridge County is best adapted to agriculture and its staple products are wheat, corn, cattle, and sheep.

Owing to the natural hilly formation of a limestone county good roads lend very strongly to the minimum cost of delivering these products at the various railway stations.

Rockbridge County is cut by four railway systems, the Main line of the Chesapeake & Ohio which runs east & west through the northern part of the county, the Baltimore and Ohio runs almost

north and south terminals at Lexington the County seat. The Norfolk and Western runs along the eastern part of the County parallel to the blue ridge mountain. The James river division of the Cheaspake and Ohio also cuts the County and runs almost perpendicular to the Norfolk and Western. There is almost one hundred miles of railroad in the County, two iron furnaces and various other industries of a manufacturing nature which add very largly to the taxable property of the county and in that way affect the question of good roads.

Details of Construction. The term macadam relates to broken stone road, they are made of stone from 2 "to 2½". The stone for highway construction should be as hard & brittle as possible. a stone for road making should resist the effect of the atmosphere, many of the limestones are objectional on this account.

In Rockbridge County a gray metal limestone abounds which is very good for road making as has been proven by

expensive. While limestone is never as good material as Basalt or Syenite for road making, it makes a very durable road. Stone from a bye is usually better for road making than field stone because of its uniformity, but often good field stone is better than bad bye stone and the Engineer should use great care in the selection of the stone to be used. The width of the road should be from 12 to 15 feet with good solid shoulders on each side, 12 feet allows two vehicles to pass but 15 feet is about the right width an allows 3 feet between the Vehicles.

The machinery for road building is expensive and great care should be exercised in the selection of this. A few years ago almost all the stone for road making was broken by hand, but in this day of high-paid labor and short working hours, the greater part of the work is done by machinery.
The stone crusher has come into use in the last twenty five years and is the main piece of machinery in

Machinery and Tools for Road building.

building roads. Large stationary stone crushers are used for city streets, but for country roads it is more economical to use a portable stone crusher. There are various kinds of crushers which can be moved from place to place on wheels ranging in price from $1,600 to $2500 the include the crusher, bins, screens, etc.

The output of stone crushers vary as does the work of all steam and electric machinery on account of the time lost in repair. A first class stone crusher may be expected to put out from 80 to 100 tons of stone per day if it is kept in good repair and handled by competent and experienced workmen.

In a country where the stone is shipped in it is easy to determine where to locate the crusher, but when the stone is to be obtained along the road careful consideration should be given to the location of the crusher.

The Engineer in charge of the construction should carefully go over the ground and determine where the best location for the crusher is. He should take into

Consideration first the value & quality of the stone and then combine these with the location & cost of blasting so as to obtain the maximum grade of stone at the minimum cost.
Another important factor which comes into the location of the crusher is the water supply, water is used both for generating steam and for sprinkling. The crusher should be located as near as possible to a stream or bay spring.

The steam Roller, has almost entirely supplanted the use of the old horse roller, and Experience has shown that it is better to thoroughly a stone road in the beginning than to depend on the vehicles to roll it after it is built. a 10-ton steam rollers is heavy enough for most roads and the average bridges and culverts will not carry a heavier one.
The cost of first class steam rollers varies from $2,500 to $3,500.
In addition to the crusher and roller the picks, shovels, wheelbarrows,

wheelbarrows, hammers & steel for blasting, carts etc. According to my estimation the first cost of a first class equipment for a highway construction would be approximately $7,000.

Haulage and labor. This part of the construction should be under the direction of a competent foreman. In the construction of a highway as in all other large undertakings the actual saving is in the small things, such as a few cents a day in hauling a ton of stone, and not in a few hundred dollars for buying a better stone crusher or roller.

Assuming that the haul of the broken stone is on an average 1 mile and that the crusher is set up at a ledge as would probably be the case in Rockbridge County the approximate cost of the stone would be as follows.

1. Engineer for the crusher and one for the roller these men take the entire charge of the machines and

keep them in repair. This cost can best be shown by detailed account. assuming that the output from the crusher is 100 tons per day.

1. Eng. for Crusher.		$3.50 per day
1. " " Rollers.		3.50 "
2. feeders for crusher.	@$1.25	2.50 "
2. Spreaders	@ 1.25	2.50 "
5. two horse teams	@ 3.00	15.00 "
1. " " with water cart		3.00 "
1. Engineer & Supt.		5.00 "
		35.00 total cost.
Incidentals (oil repair etc.)		15.00
		50.00 per 100 tons.

from the above estimates we see that the broken stone delivered & placed would cost approximately 50 cents per ton which is about the minimum cost of stone in any locality. In this county the location of the stone is about as good as can be found in any country & the cost of it should be the minimum. Care should be taken to employ capable mechanics to handle the crusher and roller because in handling machinery

it should be kept in the best possible repair so as to be able to do the greatest amount of work.

Grading a road. As in the construction of railroads a maximum grade should be determined and carried out. The usual maximum grade for roads in the United states is 5 % which should not be exceded on any permanent road. Very often in changing the alignment of an old road it is very hard to obtain a grade within the limit without going to a large expense, in a case like this it must be determined by common sense and good Engineering judgement. The grading should be laid out by the Engineer and the grade stakes set not more than 50 feet apart and the grad marked on them just as in railroad construction. In fixing grades care must be used to adjust the cuts and fills so that no material be wasted. This requires a minimum haul material in a fill shrinks in setting about 15 % this

Shrinkage is however reduced to a minimum by the use of the roller.

Foundation of Road. and road beds.

The essential requirements of a good road bed are that it shall be unyielding smooth on the surface and impervious to water.

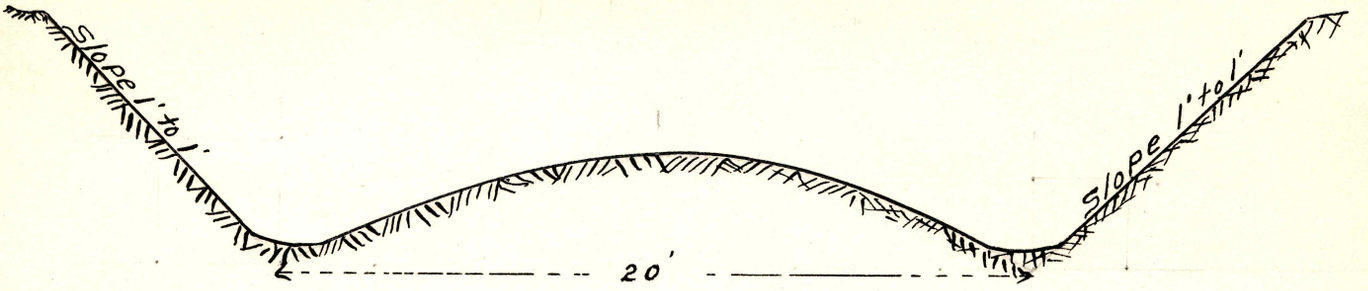
Unless a road is well drained there is practically little use in attempting to keep it in repair. The foundation of a road should be of clay or sand and clay mixed make a good foundation. The old method for road foundations was to build them out of heavy stone and place the lighter stone on top but this method has practically been done away with. In the modern construction a great of attention is given to the foundation of the road. It should be carefully prepared from porous earth & thoroughly hooked and rolled. The advantage of an earth foundation over a stone one is that it is porous & elastic. The

top mutal on a road with a stone foundation is more worn than the mutal on an earth foundation, the stone foundation is also harder on horses.

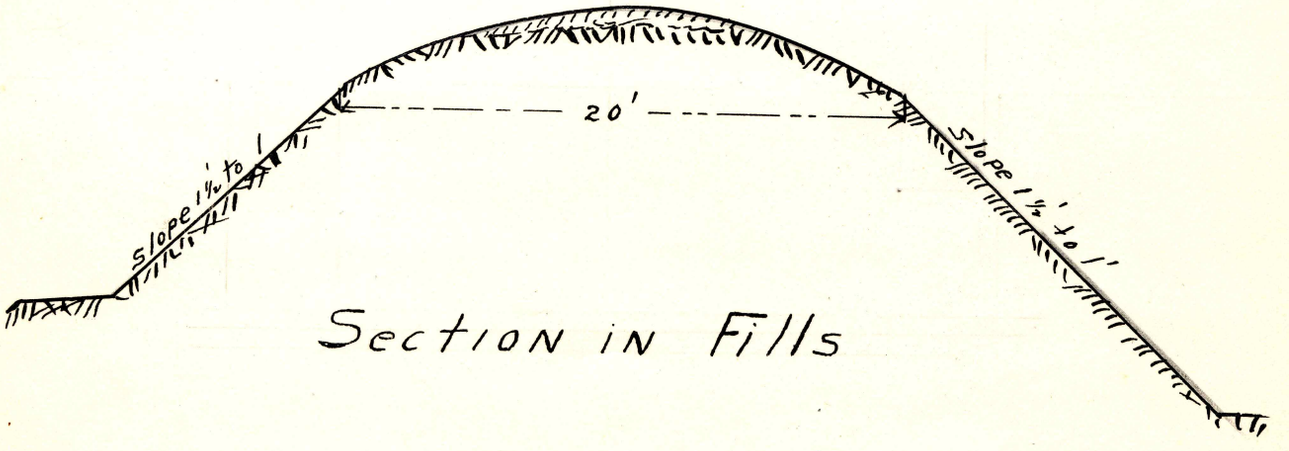
Surface. Drainage. It is necessary that all water which falls on the road be got rid of as soon as possible, and also all the water which flows on it from adjacent land. Culverts should be built at low points where outlet are available, and streams should always be used for outlets. The distance that water is carried in the side ditch should be as short as possible.
Very often when the quanity of water is small it can be carried across the road in tile pipes which must be buried deep enough so that the wheels will not break them.
For a large quanity of water concrete culverts are the best.
Good drainage is absolutely essential to good roads and in order to have good drainage the side ditches

Surface Drainage

(note) At this point is given two sketches showing the finished macadam road in a cut and one in a fill.



Section in Cuts.



Section in Fills

must be suffuently large to carry the water and there must be enough slope to carry the water off. In cuts where the grade is in excess of 3 per cent it is sometimes necessary to pave the gutters with brick or paving stone. Usually a gutter 3 feet wide paved with brick is sufficient to carry the water.

Shaping the subgrade. It is not enough that the road way be graded. The surface upon which the broken stone is to be placed must be hard, smooth and carefully crowned. If the foundation is not hard and firm the stones will be pressed into it and worked by the roller, if it is not crowned an unnecessary amount of stone will be used. When the crown of the ~~road~~ finished road is of the same cross section as the crown of the subgrade the thickness of the macadam will be uniform. If the macadam is to be thicker at the center than at the sides, a part of the crown

will be in the macadam itself and the center of the subgrade should be raised enough to produce the contemplated surface crown when the stone is in place. In shaping the subgrade a road machine can be used to a great advantage. This is a machine which is used on almost all dirt roads & is a kind of combination plough and scraper.

Usually sufficient material is left on the sides to form the shoulders for the macadam. If the natural soil is not suitable for the shoulder material should be hauled as this is a very important factor, and great care should be used in making the shoulders strong enough to hold the stone. After the road bed is shaped to the approximate cross section, it should be rolled until it is hard firm and smooth.

This is a very essential point because if the surface of the

road bed is soft much of the broken stone will push into it.

Grades of stone. In nearly all crushers there are revolving screens which grade the crushed stone. The first or larger grade of stone is 2½ in diameter, this is about as large as stone should be for macadam roads. The next size is 1½ which is used as the second layer. This size together with the smaller pieces of stone form the top layer of the road.

Every finished road should be raised in the center and slope towards the ditches the slope of the shoulders should also be sufficiently large to allow the water to run off quickly.

For a road 15 ft. in width it will be found satisfactory to have the center 6½ inches higher than the sides, forming a crown of ¾ of an inch to the foot. On roads of greater width a rise of ½ of an inch to the foot is usually

sufficient.

Thickness of Stone. Since the wear on roads is greater on the center than at the sides some saving can be made by reducing the thickness on the Edges.
Most all roads which are being built now, are built in two layers. A layer of loose stone more than 6 inches deep cannot be compacted very easily by a roller. To secure smoothness and even wearing, the smaller sizes of stone should be placed in the upper course and the larger in the lower.
When a road is built with the sizes of stone mixed, unless the stone is very soft there inevitably results a rough surface in a very short time after the road is built.
When broken stone is spread loosely over a road the voids constitute about 40 per cent of the layer. After the roller is run over the loose material a large per cent

of the voids are eliminated. To secure a thickness of 6 inches it is necessary to to place on the road a layer of about 8 1/2 inches of stone. The "binder" or stone dust which passes through the 1/2 in holes in the screen is not counted as a course but fills up the cavities between the other larger stones.
Under ordinary conditions no other binder is necessary. In some instances known sand & loam or clay have been used with the first course as a binder but this is not necessary.

Placing the Stone. First the stone should never be dumped from the cart directly on the road. When broken stone or gravel is dumped from the ordinary cart it falls in a pile with the smaller fragments consolidated to a great extent in the center of the heap. When the pile is leveled the smaller fragments still remain in the center of the

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heap, and almost invariably an uneven road is the result. The most satisfactory way to spread stone is by the use of the automatic spreader. If this cannot be obtained the stone should be shoveled from the carts.
The depth of the stone should be frequently measured by stretching a string across from one grade stake to another or by means of stakes driven into the subgrade.
The first layer should be thoroughly rolled. Sometimes it is very hard to get a smooth surface on top of this. If holes develop additional material should be used until a comparatively smooth surface is obtained.
After the first course is prepared the second consisting of the stone varying from ½' to 1¼ inches is either spread or with the automatic spreader or shoveled on. This is thoroughly rolled until no depressions remain. Now the road is ready for the binder

Usually only about 1/10 of the screenings is required in 6 in work. The watering cart should be put on in advance of the roller and as much as possible of the dust washed into the crevices between the stone. The roadway should be wet and rolled until it puddles on the surface, showing that the voids are substantially filled. No more of the screenings should be used than is necessary to fill the voids and to leave a very thin coating over the larger stone. No matter how much macadam road may be rolled it does not acquire the metallic ring peculiar to the hard road for some days after it is completed, but gradually acquires it. It is a good plan not to allow the lower course to be spread too far in advance of the other, there is always a certain amount of travel over a road & too much of this is not good for the lower course of a macadam road.

There remains one more phase of a macadam road to be discussed, that is the question of Dust Prevention. Since the advent of motor vehicles this has been one of the most important problems which the highway engineer has had to deal with. The speed of the automobile has so weakened the roads and kept them in such an uneven condition that it is very alarming to road builders.

The macadam road has been developed with the object in view of withstanding the wear of iron-tired vehicles drawn by horses. It has met this condition satisfactorily. In the best road the rock should wear uniformly and the dust removed by wind and rain is replaced and a sufficient amount is worn off to bind together the stone. The powerful traction force exerted by the driving wheels of the automobile soon disintegrates the road surface. The fine dust which ordinarily acts as a cement

is thrown into the air is carried off by the wind or easily washed off by the rain. The result is that the stones composing the road become rounded, and water is allowed to make its way freely to the foundation of the road.

Before the coming of the automobile most of the dust found on roads was washed into the side drains by rain and thus gotten rid of. The heavy rubber tired automobile stirs up the dust and it is blown in every direction. It has been proven that dust carries disease and the amount of dust which automobiles put into the atmosphere is almost obliged to carry disease germs.

Many remedies for the prevention of dust have been tried and many theories have been advanced, but no satisfactory solution of the proposition has ever been discovered. Among the materials which have been tried as dust preventives

the mineral oils and coal tar have given the best results and have been found the most effective.

Oil as a dust preventive. Among the mineral oils, those which contain the greatest amount of asphaltic base give the best result. Those oils which contain paraffin should be avoided, and preference should be given to those which contain an asphaltic base, as this acts as a binder to the dust particles.

Oil for dust laying may either be applied in a crude state, or be partly refined. An oil which has been partly refined contains more of the base and is thus better for laying dust than the crude oil, however it is obtained at a greater cost.

Oil has been used to some extent on both dirt and macadam road and in both cases has given good results.

The crude oil in many cases can be applied to the road

through an ordinary sprinkling waggon.
When the oil is too heavy a spcial
device is employed for sprinkling it.
Often the oil is put on the road on
top of the dust. In many cases however
the road is swept clean and then
the oil applied so as to allow it to
penetrate as far as possible, in this
case usualy a thin coat of
screenings is applied on top of the
oil. When a soft road is treated
with oil it should be harrowed for
a few inches and the oil worked
in, and then a roller run
over the top.
The main objetion of oil as a dust
preventive, is that it does not last
long. The effect of oil is almost entirely
lost during a winter season,
another objetion to oil is that in
rainy weather it makes a mud which
is greasy and consequently very
damaging to clothes etc.

Coal Tar as a dust Preventive. Coal tar
has been used with considerable

sucess in a number of cases, and it is claimed by a number of engineers to be the best dust preventive. Coal tar is a by-product obtained from coal in the manufacture of gas. It contains a large quanity of 'tar' which is useful for binding together the particles of dust. Coal tar is applied in about the same way as oil except that it is never applied to the unswept surface.

In this discussion I have tried to point out the best methods for the building of roads of various different kinds. I have tried to discuss fully the construction of a macadam road which is undoubtedly the most economical road for Rockbridge County.

Respectfully submitted.

Robert Stuart Hutcheson.

Lexington
Virginia
June 3rd 1910