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by

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# HIGHWAY MAINTENANCE

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## HIGHWAY MAINTENANCE

### INTRODUCTION

The systematic maintenance of county roads only has been discussed, however the general principles and methods outlined are applicable to city streets in many respects.

The discussion has been outlined and classified so that the methods peculiar to each type of surface are separated. The problems of maintenance, however, are often similar in which cases references have been made to other sections of the subject.

The testing of materials used has not been discussed at length as this phase of Highway Engineering is more closely allied to construction work. In maintenance the materials used are those that are most easily obtained locally together with certain standardized manufactured products.

Preliminary to the discussion of maintenance of the various types of surfaces a short description of the method of construction has been given. This has been done to better bring out why certain maintenance operations are carried out and are necessary.

The cost of the various operations have not been gone into as this item is ever changing with labor conditions and material prices. Estimates of today would not hold for work of a like character the next year.



## I MAINTENANCE DEFINED

The maintenance of highways is generally looked upon as the upkeep of the travelled surface of the roadway. It should include the general care that is necessary to keep in condition the ditches, drains and other details that go to make the complete highway.

As soon as a road is constructed and subjected to traffic it begins to wear away from the action of elements and the terrific impacts delivered by rapidly moving wheels. Maintenance alone cannot hold indefinitely the surface against these influences but by systematic work the life of the road can be prolonged and the full usefulness of the original investment realized. The important feature of the work is to keep at all times the surface in a smooth travelable condition.

Pavements of every type require maintenance. In many cases, if a crack or small break is patched in time no further repairs may be needed for a considerable period, while, if patching is neglected it may lead to the disintegration of the whole pavement.

A haphazard way of patching and treating highways is more expensive in the long run than a method of systematic upkeep. "Eternal maintenance is the price of good roads." A permanent road is an ideal that will never be attained, but a road may be so well maintained that it will give a long and useful service.

#### 1 - ORGANIZATION

To properly execute maintenance work there must be an organization that is flexible enough to meet any condition that may arise from natural causes, such as heavy rain or snow storms. Also traffic conditions change very rapidly at times and will cause unusual damages. On the other hand the organization should be so well defined and limited that the responsibility for any neglect of duty will fall directly on the person responsible.

For a State System of Roads, a Maintenance Engineer, reporting to a Chief Engineer and Highway Commission, should be made responsible for the development of the work in the field. The State should be divided into districts in which a District Engineer has charge of the details of the work and the organi-



zation necessary to accomplish it.

#### A - Patrol Maintenance

The ideal system of maintaining highways would be to have them divided into sections of such length that one person could look after and keep his section in repair. This is known as "Patrol Maintenance" and is extensively and successfully used throughout the United States. The patrolman in charge of a section must be supplied with the necessary materials and tools. On hard surfaced roads the patch materials must be stocked at convenient intervals along the road. The work and duties of the patrolman will be discussed under the various types of surfaces that are maintained by this method.

#### B - Gang Maintenance

There is often work on highways that is too heavy for a patrolman to handle. Under such circumstances gangs are organized to put the road once more in shape to be taken care of by the patrol method. Such work is usually known as resurfacing or reconditioning and is usually of short duration. A gang usually consists of a capable foreman and enough men

and equipment to do the work efficiently and rapidly. The foreman is responsible to his superiors for the way in which and the amount of work accomplished. The equipment methods and materials used by the gangs will be discussed further on in the subject.

#### C - Centralized Maintenance

Conditions are often such that a considerable mileage of hard surfaced highways radiate in different directions from a village or city. In such cases it is often economical to operate a small well equipped gang to work out over several highways ten (10) miles or more. The method, in reality, combines patrol and gang maintenance and has advantages in economy, however, the defects and breaks do not receive attention as promptly as by the patrol system. Larger failures in the pavements can be repaired where they could not be replaced by a patrolman working alone. For ordinary repairs it is not necessary to stock materials along the highways as they can be hauled out from headquarters on the same truck that conveys the equipment and laborers to the work. Equipment that enables the work to be done more efficiently, and that saves labor costs,



can be supplied where it would be impossible to furnish patrolmen with such tools. The laborers can be kept continually at work even in bad weather by repairing the equipment and mixing materials for patch work. The laborers receive closer supervision than if they worked on sections of the road alone as on the patrol system.

## II CLASSIFICATION AND MAINTENANCE

To better discuss the various operations of maintenance the roads will be classified as follows: Earth, broken stone, bituminous, concrete, cobble stone, brick, and bridges. The various types of surfaces under these heads will be discussed separately where the maintenance operations required to keep them in condition are not similar.

### 1 - EARTH ROADS

There is a greater mileage of earth roads in the United States than all other types combined. They may be classified as follows: Unimproved earth, sand-clay, soil, gravel and shale. Their maintenance and upkeep is a puzzling problem and rather unsatis-

factory at times because in favorable weather they are easily put in excellent condition and carry traffic more comfortably than the hard surfaced types, while in bad weather they become soft and often entirely impassable. However, there are certain improvements that can be made after which by systematic maintenance traffic can be assured a longer and more dependable service throughout the year. Water is the most destructive agency that must be combatted, therefore, the first and most important item to be taken care of is proper drainage. Drainage really has more to do with the stability of the earth road surface than the character of the materials used in it. The smoothness of the surface is the quality that is most appreciated by the public and is also very important. The majority of the people are not inclined to care how or of what a road is constructed. To them an ideal road is one that will allow the load, whatever it may be, to be carried rapidly and smoothly. The idea that an earth road can be kept smooth and in condition for modern traffic by the "once a year" gang method alone is out of the question and being



repair work will not be discussed. This may suffice for local roads and trails but it cannot be relied upon for highways carrying heavy traffic. Main highways after having been put in condition are best maintained by the patrol system or a combination of gang and patrol.

Efficient maintenance of any type of earth road requires a well balanced organization that functions well under any condition that may exist. The duties of each individual should be defined so that they will be directly responsible for a given section of road or a special phase of the work.

The patrolman should not be given more mileage than can be covered with the proper equipment twice in a single working day when necessary. Under ordinary weather and earth conditions a patrolman with a two horse team and road grader can easily cover an eight (8) to ten (10) mile section, depending somewhat on the traffic, keeping the surface smooth and the drainage in good shape. He should have available besides a small road machine, a road drag, either steel or wood, a wagon and small tools



such as shovels, hoes, rakes, axes, etc. When holes wear in the surface they should be immediately filled so that water will not stand. Holes that retain water soon become larger as the material softens which when churned about under traffic creates a condition that soon breaks down any type of earth road. When the weather is such that the surface does not need smoothing new selected materials should be hauled to places that have become badly worn or that give trouble when wet, brush should be cut and other details looked after. In this way the road receives continuous attention and the patrolman can be employed by the month or year.

Small tractor patrol outfits are coming into favor and prove very efficient. A tractor patrol can cover a section from fifteen (15) to twenty (20) miles. The tractor should be equipped with either rubber tires or a track layer attachment, depending on the road type, so that the surface will not be broken loose under the tractive forces. A road machine blade attachment or small road grader





ONE MAN PATROL GRADER MACHINE



should be part of the equipment as well as a trailer and three-way drag and the necessary small tools. It has so far proved more efficient to have two men with an outfit of this character, however, with more modern equipment this is not always necessary. The duties are the same as with the horse equipped patrol.

In addition to patrol maintenance it is often necessary to use gangs for resurfacing, scarifying and reshaping the roads. Under heavy traffic some earth roads wear away at the rate of two (2) to four (4) inches in a year. The traffic loosens the material and the wind and rains carry it off the roadway. There has been no surface binder manufactured to prevent this wear except for gravel surfaces. This will be discussed later.

A well organized and equipped gang should have an experienced foreman, twenty (20) to thirty (30) men, a camping outfit, a five (5) or ten (10) ton track layer tractor and large scarifier road grader, a small tractor and small grader, six (6) to twelve (12) two(2) ton trucks for hauling ma-



terial long distances, and several teams with wagons. Before new material is applied the old surface should be broken up and the road-bed flattened. This gives the new material a chance to adhere to the old surface and produce a more uniform piece of work. Great care should be taken not to have too much crown. A curved crown with a drop of three-quarters ( $3/4$ ) or an inch to the foot has proved most satisfactory. Higher crowns than this force traffic to follow the same tracks thereby making travel disagreeable and causes the road to wear unevenly. Nothing but the best grade of surfacing material should be used even though it has to be hauled for long distances. The foreman should have good judgment in the selection of materials and then be able to line up his forces so that it can be handled to the best advantage. Trucks or teams should be timed and spaced properly so that they will not bunch on the road or at the loading point. The loading is usually done by hand labor, however, improved loading devices have come on the market that should greatly reduce the cost provided there is enough work



to keep them continuously in use. The material is dumped in the center of the roadway and spread by hand or by road graders. It is then kept well machined or dragged until it settles and becomes firm. After the first rain new material will cut through but when put back in condition seldom gives further trouble.

When an earth road becomes rough but still has a fair amount of surfacing material on it the riding qualities can often be improved by ripping it up or by scarifying and reshaping it. Some material becomes sandy and dead on top which if scarified and mixed with other materials already in the roads give considerable service often better than new material. Work of this nature can best be carried on with a large track layer tractor and scarifier road grader followed by a small tractor and grader to reshape the surface. Only a few laborers besides the machine operators are necessary.

Snow removal is a very important phase of maintenance and should under no conditions be neglected. Two objects are obtained by removing snow in





SNOW PLOW ATTACHMENT ON CRAWLER TRACTOR



that traffic is allowed to proceed and the roadway is cleared of a very destructive agency. This work requires other help besides the regular maintenance organization and should be well outlined and systematized before the winter season. Patrolmen and regular employees should be given authority to hire additional labor, teams and such equipment that is not already in their possession.

The A framed plow with an opening of twelve (12) to fourteen (14) feet and sides twelve (12) to eighteen (18) inches high should be started as soon as the snow has fallen to a depth of two (2) inches. This will allow traffic to proceed and the snow will not become packed. As soon as the snow stops falling and before it has time to freeze it should be pushed entirely off the roadway into the ditches by road machines. The plow can be pulled by horses or pushed by tractors or trucks. Other improved equipment built over the same principle as the above described plow is often used but snows not over a foot deep can be very easily handled by



home made plows.

The same method of snow removal may be employed on all types and classes of highways.

#### A - Unimproved earth roads

Unimproved earth roads or trails that have been allowed to exist for years without maintenance demand a special treatment before they can be effectively maintained. This special treatment is properly called "conditioning" because it is not real grading work nor can it be correctly termed as maintenance. The aim in conditioning an earth road is to widen it and provide suitable drainage after which it can be maintained and kept smooth by the patrol system. It is attempted to move only enough material longitudinally to cover up cross-drains that are installed as the work progresses. Naturally a conditioned road does not present finished rolling grades and regular curves but by the proper manipulation of the equipment the alignment and grade can be put in a





MOUNTAIN TRAIL



PART OF SAME TRAIL AFTER A LARGE OUTFIT HAD  
PUT IT IN CONDITION FOR PATROL MAINTENANCE.



fair shape allowing traffic to proceed with considerable ease and safety. The roadway from back of ditches should be twenty two to twenty six feet wide. The ditches should not be deeper than one foot to eighteen inches below the center of the road. The roadbed should have a curved crown of not more than one inch to the foot. When completed the work should present an uniform appearance.

The equipment necessary for such work should be a large track layer tractor and blade grader, a smaller tractor and blade grader, plows, wagons, a supply truck and a camping outfit with enough small tools to supply as many laborers as are necessary to give the work good progress. A small air compressor outfit for drilling rocks is also very essential. For efficient work it is important that the above equipment be kept busy and well lined up at all times. If there are obstructions such as rocks and large stumps they should be removed well ahead of the large tractor and machine. The large road machine is guided into the banks with the blade set at an acute longitudinal angle with the end next to the bank slightly elevated.





LARGE ROAD GRADER WIDENING ROADWAY

JAVIS  
HONORE, VA



In this way the old ditch, if any, is filled and the material is worked to the center of the roadway. Enough cuts are made to get the proper width. By working back under the banks the material is caved off and shifted into position. Small trees are undermined by the machine and thrown aside. By the time the proper width is obtained the cross-section of the road is usually flat. Several cuts are then made to form the ditches after which the big machines are moved to another section. Sections about two (2) miles in length are worked to prevent loss of time in turning.

The rough and heavy work having been done by the large machines the small tractor and machine follows up to shape up the material and give it the proper cross-section. This outfit is kept busy going over the road filling up depressions and cutting off high places for a week or two after the large outfit has passed. The road is then in condition for patrol maintenance provided there is no local surfacing material available. However, if there is such material as soil, sand, gravel, shale or slag available the





SMOOTHING UP MATERIAL THAT HAS BEEN PULLED LOOSE  
BY LARGE TRACTOR OUTFITS.



cross-section is left nearly flat and the crown is built up out of the surfacing. The surfacing is done as soon after as possible in the same manner as resurfacing work that has been previously described.

There are many miles of roads, however, that cannot be surfaced because of the lack of a better material locally. Where the natural material is sand the road if kept rather flat will remain in better condition than if rounded up. The material if shifted slightly, causing traffic ruts or lanes to change position, sometimes help to make travel easier. A very small amount of clay added to a sand road will make it much firmer. The clay should be thoroughly mixed with the sand by harrowing. Sand roads usually give better service in the winter than during the dry summer months. Clay roads that cannot be surfaced will naturally become slick after rains and are apt to break down under traffic in the winter. If they can be kept perfectly smooth and well drained they will stand considerable abuse from traffic. Both sand and clay roads without surfacing materials should be dragged as often as necessary to keep them smooth.



Should the surface dry out before it is smoothed up the blade grader is the best equipment to put it back into condition, however, if it can be worked on before it is dry the drag is better as it has more of a puddling action and has a tendency to make the surface water proof. Snow removal is very important and should under no conditions be neglected.

#### B- Sand-clay roads

Sand-clay roads as the name implies are constructed by mixing sand and clay together. The correct proportion of the two materials is rather indefinite and depends largely on the character of the materials used but it is generally accepted that about one-third ( $1/3$ ) the quantity of clay to two-thirds ( $2/3$ ) sand makes the best mixture. It is very important that the two materials be thoroughly mixed. The surface when first constructed is usually about ten (10) inches thick and if kept properly dragged and machined remains smooth. When it becomes worn so that the surface is not smooth and shows signs of breaking up, scarifying, remixing and shaping are often very helpful. When small sections break through they can be



patched up by adding the material that is lacking in the mixture. Care should be exercised in selecting materials. Sharp coarse sand and pure clay give the best results. Patrol maintenance is generally satisfactory on this type of road but care must be used in using the blade grader because too much material may be pulled loose. The clay from the loose mixture soon leaches out leaving a surplus of sand on the surface. This sand if allowed to remain holds moisture in wet weather and is apt to soften the mixture beneath, besides making travel disagreeable in dry weather. The drag is more fool proof in the hands of the average patrolman, however, at times blade work is necessary. Dragging does most good when the surface is still quite wet.

When the surface in long sections becomes so thin and weak that it breaks down under traffic resurfacing is necessary. In resurfacing it is always best to break up the old surface and mix it with the new material added. When new material is added a turn plow should be used to bring up material from the roadbed to form the new mixture. Thorough mixing





DAVIS  
ROANOKE, VA.

SCARIFYING AND RESHAPING OLD ROUGH SAND CLAY ROAD





USING TURN PLOW TO BRING UP NEW MATERIAL  
INTO THE SURFACE OF A SAND-CLAY ROAD.



is very necessary and while the surface is bonding under traffic it should be closely watched to keep it in proper shape. The bonding may be rather slow in dry weather but the moisture collected by capillary attraction and from the atmosphere is usually enough to cause the mixture to become firm. The correct time to resurface is in the early spring because traffic is usually less interfered with then than any other time during the year.

Snow removal is extremely important because the excess moisture combined with frost action has a very softening effect on sand-clay.

#### C - Soil roads

Soil roads are so named because of the fact that the surfacing material is usually taken from the surface of adjoining lands. Soil, if it contains small particles of stone, has a wearing quality that makes it particularly desirable as a road surface, in that it bonds together and does not become plastic unless the weather is unusually severe. Soil suitable for road surfacing is usually found in sections where there is granite and was undoubtedly formed by the process



of disintegration through exposure to air and water which carried away the clay and left only the granular particles which still retain enough bonding materials to cause them to adhere to each other under traffic. Other soils with coarse particles of sand, chert or flint are at times found but are not as abundant as the ones found on the Piedmont and Coastal Plains.

On hill sides where considerable erosion has taken place the soil is usually scarce.

Roads surfaced with this material are not maintained unlike sand-clay except in replacing worn out materials, the original material that is in the roadbed is not mixed with the new. Soil unlike sand or clay does not occur in pits or pockets and being found on the surface is easily plowed and loaded on wagons or trucks. Only the best grade of soil should be used even if it is necessary to haul it a considerable distance. As long as there is a thickness of four (4) to six (6) inches on the roadway it can be kept smooth and in shape if properly dragged and machined when damp. At this thickness it is apt to go into pot holes under heavy traffic, however, and if



conditions are such that the road cannot be resurfaced, scarifying is often helpful but care should be taken not to bring up and mix in too much of the underlying material. Weak places that occur can be patched with new soil but care must be taken not to make the new patches too high. If too high, a hole at each end of the patch may form. Long continued dry weather is hard on soil roads and if the traffic is heavy and rapid rhythmic corrugations may form. These corrugations are probably due to the impact delivered from the rapidly moving wheels on the granulated material that shifts its position and forms a small ridge with a corresponding depression. There is no remedy for this in dry weather but the situation can be relieved when the road becomes damp by machining and dragging.

#### D - Gravel roads.

Gravel is usually defined as being a mixture of fragments of stone that have been deposited by water or glacial action. To be suitable for road surfacing purposes the particles should vary in size from sand to 1-1/2 inches and be in such proportions to form a uniform mixture. The fragments should be



hard and tough so that they will not be easily ground to dust under traffic.

Gravel occurs in banks or beds in the Coastal Plain near the eastern border of the Piedmont Plateau and in various other regions such as sections where there have been glaciers. Stream gravel is also very satisfactory for surfacing.

When the sub-base of a roadway is clay, sand gravel is preferable and while it takes it sometime to bond under traffic it finally becomes firm and tough. On a sand sub-base gravel with a small amount of clay is desirable. However, the ideal conditions are seldom met, but if the material is closely watched and mixed a good road surface is obtained.

The maintenance of the surface is handled very much the same as any other type of earth road. Machining and dragging is necessary and even then in dry weather the rhythmic corrugations occur. These are more pronounced in sand gravels than those that have a clay filler. Machining when damp helps to rid the surface of this roughness. Where available



if a thin course of small clean pea gravel, if left on the surface, is very helpful in preventing wear. This, however, does interfere somewhat with automobile traffic but in some States is much used.

Bituminous binders are extensively used and have proved fairly satisfactory, not only as a dust layer but when the proper materials are used the road will present a good smooth wearing surface. Once the surface is treated in this way it is necessary to handle the maintenance much in the same way that macadam is kept in condition. Care should be used in making successive bituminous treatments as too much of this material on the surface will push and roll under traffic. This is because the gravel base is granular and not absolutely stable yielding to traffic impacts. Should this occur it is necessary to rip up the surface and reshape it probably adding more bitumen and clean sand or gravel to cause it to bond together again.

Sulphite liquor, which is a by-product from paper mills, is used and gives relief from dust for one season. The surface has a tendency, however, to





APPLYING BITUMINOUS MATERIAL TO A GRAVEL ROAD





APPLYING CALCIUM CHLORIDE TO AN EARTH ROAD



break into small pot holes but after a rain these can be filled by dragging or machining, but will break out again with the next dry weather. It is claimed by the producers that successive treatments with this material will produce a surface that will give entire satisfaction.

Calcium Chloride is used very successfully as a dust layer but it does not produce a bond in the surface except through moisture. The chemical will draw enough moisture from the atmosphere during the night to keep the surface damp during the day. About four (4) pounds to the square yard applied twice during the summer season prevents the very objectionable dust from rising from the roadway. Roads treated with this material must be kept smooth the same as if it had not been used.

#### E - Shale roads

Shale if it contains considerable grit or sand makes a fair surfacing for clay roads. However, to give the best service it must be hard and tough so that it will not break down when wet and form into dust under traffic. Shales in mountainous sections





SHAPING A SHALE ROAD

SAME ROAD AFTER IT HAS  
WORN SMOOTH UNDER TRAFFIC





usually occur in banks and if closely compacted must be drilled and shot out. Such treatment usually breaks it into particles small enough for putting on the surface where traffic will soon bond it together.

The surface is maintained by machining and dragging and by the addition of more shale in places that break down.

## 2 - Broken Stone Roads

Broken stone roads are those that are built by first putting down a base of large stone and a top of smaller stone to form the wearing surface. The surfaces may be classified as follows: Loose macadam, water bound macadam, tar bound macadam and bituminous macadam. The general term "macadam" is used to designate such types of surface and was named after John Loudon McAdam a famous Englishman who employed this method in England. The stone should be hard and tough being able to resist wear and should not disintegrate when exposed to the weather.

Traps, granites and limestones are the



most important road stone, however, flints, sandstones, and furnace slags are extensively used in the base course and at times for surfacing where no better material is obtainable.

A - Traffic bound macadam

Loose macadam is the term applied to the type of surface that is built by placing crushed stone on a graded roadbed very much in the same way that soil or gravel roads are built. The stone is usually placed in a six (6) to eight (8) inch course and depends on the action of traffic to bond it. Very often the larger stones are placed first and act as a base. The smaller stone and dust is placed on top and under traffic filter through the bed causing it to key together and bond. While the road is bonding it must be kept shaped by blade graders or other equipment. In time such roads, regardless of the kind of stone used, become hard but are usually very dusty when used by fast moving traffic.

The maintenance of such roads is very simple but expensive and consists of continuous



replacement of stone similar to that used in the construction. The cross-section can be kept true by shifting the loose material when it is wet. This is very important in that traffic is inclined to form ruts which will wash deeper on grades. Small depressions caused by the displacement of materials should be filled in the same manner. The surface must be kept smooth because once it becomes rough and bumpy the impact from the wheels cause it to break up very rapidly. Where there is an abundance of stone on the road and it becomes too rough it should be scarified the same as gravel roads are treated. Long dry seasons have a very detrimental effect when the traffic is heavy and the top material becomes quite loose at times and much of the bonding material is blown away.

The patrol method of maintenance is usually considered most satisfactory in that immediate attention can be given to any defects that occur. Under ordinary traffic a patrolman should be able to look after seven (7) to ten (10) miles of road. His equipment should consist of a team or small



rubber tired tractor with a wagon or trailer to haul materials, a blade road machine and small tools. He should have supply piles of crushed stone at convenient intervals. The drainage should be carefully looked after and the road kept smooth and properly crowned. When long sections become worn a gang should be used to put on a new surface.

Snow must be removed from such surfaces because too much water and slush churned about by traffic has a tendency to break up the surface and where the wheels cut through the snow to the stone, ruts are very often formed. Frost action is also bad when the road is wet. The patrolman can usually keep his section clear of snow if he starts with his blade machine as soon as the snow is several inches deep and works continually while it is falling. In case of very heavy snows he should have additional help and heavier equipment.

Calcium chloride is often used as a dust layer and works satisfactorily for one season. Application of about four (4) pounds to the square yard should be made early in the spring. This material



draws enough moisture from the air during the night to keep the road damp during the day and besides keeping the dust from flying will cause the stone to become cemented together. Application of this material is usually made by a farm lime spreader at a very low cost.

Light oils with an asphalt or tar content are often used to keep down the dust but have a tendency of floating off in heavy rains, unless the roads have been loose enough for them to penetrate deeply. Care must be taken not to use a material that is too heavy as it will form a mat that will push and break through causing the surface to become rough.

Often by careful maintenance and traffic it is possible to bond up a loose stone road so well that it will take a surface treatment of either tar or asphalt. This method of changing the surface type will be discussed under surface treatments on Water Bound Macadam.

Another method of changing the surface type will be discussed under Tar Bound Macadam.



Taken as a whole loose bound macadam is only satisfactory for moderately traveled highways. Where through motor traffic that moves rapidly and is heavy it is impossible to maintain such a surface without changing the type using the old macadam as a base.

#### B - Water bound macadam

Water bound macadam is that type of surface where broken stones two and one-half ( $2\frac{1}{2}$ ) inches to four (4) inches in size are used as a base course with smaller stone as a wearing surface. The method of construction is to cut a true subgrade over which the base stone is evenly spread and rolled with a ten ton roller which causes it to become keyed together and firmly fixed in place. Often stone dust and screenings are used to fill the crevices and water is applied to effect a bond but this is not always considered necessary.

After the base course has been well keyed or bonded the surface course is spread and rolled into shape while dry. The general practice has been to use stone ranging in size of one-half ( $\frac{1}{2}$ )



inch to two and one-half ( $2\frac{1}{2}$ ) inches, but recent developments show that larger stone in the surface gives good results and produces an excellent road at less cost but less screening and dust is produced when crushing which necessitates either importing this material or using sand as a filler. When the surface has been rolled and keyed together it is sprinkled, screenings applied and rolled again. This operation is continued until all the crevices are filled and the roads present a puddled appearance on top. It is then opened to traffic and closely watched to see that it does not ravel. Should it show signs of breaking apart it is sprinkled and rolled again. Care should be used in running a roller over a dry road as it will break the bond. Before the days of the automobile such roads gave good service without further treatment, in fact the action of steel wheels was an advantage in that the small particles worn off cemented the larger stones together.

The present day traffic is such that the surface of a water bound road must be treated with



a tar or asphalt to hold the particles together. this treatment constitutes about the first step towards maintenance. The character of bituminous materials used in such treatments varies widely in the different states and for this reason a general discussion of them will be omitted. Reference to the road specifications for any state will give this information in detail. The method of application, however, is almost universal and will be fully described.

After construction and the road has been thrown open to traffic it is allowed to season and dry out thoroughly for two weeks or longer. It is then swept by a rotatory horse or motor drawn broom. Accumulations that are not removed by this equipment are swept off by hand brooms. Motor driven blowers have also been used to good success in removing dust and have the advantage of blowing loose material away that could not be reached with the broom without disturbing the surface bond. The two pieces of equipment working together give excellent results and more than pay the extra expence in that on the



clean surface a much better bond and penetration of the bituminous material is secured. It is very essential that the road surface be perfectly clean and the stone exposed.

The bituminous material is usually shipped from the producer in tank cars. It is pumped into motor road distributors and applied to the cleaned surface at the rate of one-third ( $1/3$ ) to one-half ( $1/2$ ) gallon per square yard. A cold material that is liquid enough to flow freely in warm weather is usually used on the first treatment of a road. Better results are obtained by making two applications of one-quarter ( $1/4$ ) gallon each, one immediately following the other, on the first treatment. In this way the material will not flow off the road before it dries out and penetrates to the desired amount. The material gives better results if applied during the warm season as the volatile oils pass off more readily. In cool weather the material may be heated before application but the stone chills it and it will not penetrate into the surface so well.

After the bituminous material is applied





MOTOR DISTRIBUTOR MAKING APPLICATION OF BITUMINOUS MATERIAL  
ON MACADAM ROAD. (Insert) LOADING DISTRIBUTOR FROM TANK CAR





SWEEPING THE ROADWAY



CHIPS PILED ALONG ROADWAY



SPREADING CHIPS BY HAND





MODERN EQUIPMENT FOR LOADING STONE CHIPS  
AND COVERING BITUMINOUS TREATMENTS





SURFACE TREATMENT COMPLETED



clean stone chips proportioned in sizes from one-quarter ( $1/4$ ) to one and one-quarter ( $1-1/4$ ) inches are spread evenly over the surface at the rate of from thirty (30) to forty (40) pounds per square yard. Slag chips or washed gravel may also be used for the same purpose. The chips serve several purposes as they allow traffic to proceed at once and prevent the bituminous material from being picked off the road by the passing traffic. They also fill in depressions and form a mat over the roadway that acts as the wearing surface. After the chips have been spread they should be rolled by a light power roller to depress them in the roadway which prevents them from shifting over the surface.

A surface treatment as above described should be followed by a second cold treatment the following year of about one-quarter ( $1/4$ ) gallon and about one-half ( $1/2$ ) as many chips. The method of making the second treatment is in every way similar to the first. After the second surface treatment, a road under ordinary traffic will not need another treatment for from two (2) to four (4) years. Care must be



taken to avoid getting too much bitumen on the surface as it may push into ridges which are very hard to obliterate. It is advisable to use good hard chips and as large as will be held in place by the bitumen used. A quick drying cut back bituminous material, although more expensive, has been found to be better for cold treatment than the slow drying materials. The stone chips constitute about two-thirds ( $2/3$ ) of the cost of a treatment and must be held in place if the full benefit is to be derived.

After a road has become badly worn and full of small depressions a hot bituminous treatment may be used to good advantage as a last result before reconstruction. Such treatments, where large chips up to one and three-quarter ( $1-3/4$ ) inches are used, have given years of service. The bitumen is shipped in tank cars and being a semi-solid is heated by applying steam to coils in the car for that purpose. Application is made with a motor distributor while it is still hot and liquid. The surface is then covered with chips and rolled



after which traffic is allowed to proceed.

After a water bound macadam has received its bituminous surface it must be closely watched so that small breaks can be immediately patched before the holes become larger. This maintenance is best handled by having a patrolman on a section five (5) to eight (8) miles in length. Stone chips and suitable bituminous patching materials are placed at intervals along the road and the patrolman in charge hauls them to the point needed in a push cart or wheel barrow. The breaks are swept clean and painted with bitumen. Chips are then thrown in to slightly above the surface, more bitumen sprinkled on and the mixture tamped firmly in place. If proper care is taken a patch thus made is not unsightly and will stay in place. The bituminous material used for such patching must contain a highly volatile oil so the patch will set up quickly and become hard before traffic has a chance to displace it. Should, for reasons of neglect, the holes become large and deep a better patch is made by mixing the stone chips and bitumen together before placing them.





PATCHING MACADAM



FINISHED PATCHES





ARRANGEMENT FOR HEATING PATCH MATERIAL



SPREADING PATCH MATERIAL



For deep holes larger stone chips should be used so that the weight that comes on them will be transferred directly to the base of the road. When large chips are used the patch is not as easily displaced and will not push into ridges. A patch made with large chips should be topped off with smaller chips to fill the voids. A patrolman should have time to keep the earth shoulders up to the edge of the stone and the drainage in first class shape.

Water bound roads are more cheaply constructed but the maintenance cost runs higher, over a long period, than on surfaces of higher types. If strongly and well built they give excellent service where the traffic is not too severe.

#### C - Bituminous bound macadam

The base for tar bound macadam is constructed the same as that of water bound roads. The surface is also built in a similar manner except that cold liquid tar is used instead of water to effect a bond. From three-quarter ( $3/4$ ) to one (1) gallon of tar is used per square yard and is applied in several



applications. The surface is rolled while the tar is setting up and if possible traffic is prevented from using the road for several days. After traffic is allowed on the road the surface should be closely watched so that it will not rut or push out of shape. Should it do this all displaced material must be raked into place and the surface rerolled. This method of construction is used where water is scarce and has the advantage of being able to omit the first surface treatment that is necessary on a water bound surface. This cost is very little more as the chips used in the first treatment are omitted and the cost of applying the tar is no more expensive than by using water. The same method is very successfully used in putting a surface on old stone roads that are strong enough to act as a base. The old road should be slightly scarified, reshaped and bonded so that an even distribution of the new stone is received.

The maintenance of this type of road is identical with that of a water bound surface after it has been treated. The life and usefulness of this



type of surface is equally as good as water bound macadam and is as cheaply maintained. Successive treatments of about one-quarter ( $1/4$ ) gallon of cold bituminous materials at intervals of two (2) to four (4) years are necessary the same as for water bound macadam.

#### D - Bituminous macadam

The broken stone used in the construction of bituminous macadam is prepared the same as for water bound macadam and is of similar sizes. It is very essential that the base be well keyed together and bonded and that it shall not show any motion on the final rolling. The base is swept of all loose material and the stone well exposed before the surface course is spread. The surface course is evenly spread and rolled until it is well fixed in place. An application of hot bituminous material is then made at the rate of about one and three-quarter ( $1-3/4$ ) gallons to the square yard. Enough clean dry chips are then spread to fill the voids and the surface is rolled until it is thoroughly compacted. A second application of hot bituminous



material is then applied at the rate of about one-half (1/2) gallon to the square yard. A final application of chips is spread and rolled after which the road is ready for traffic.

A road built in the above manner, if heavy enough to carry the traffic that comes on it without internal friction, will develop very few breaks in the surface. Such breaks as do occur should be immediately repaired by the same methods used for patching the bituminous top of water bound and tar macadam. It may be necessary after the road has been subjected to traffic for four (4) years or longer that it will need a surface treatment of bituminous material and chips. On these re-treatments one-quarter (1/4) gallon bitumen to the square yard is usually sufficient. Care must be used not to have too much bitumen on the surface as it will push and become rough. Either a hot or cold patching material may be used to repair the breaks.

#### E - Asphaltic concrete

Asphaltic concrete is a type of road that is extensively used on county highways. The method



of construction is to heat the stone and sand and transfer it to a concrete mixer where the correct amount of hot bitumen is added after which the two are mixed and placed on the prepared grade. Sufficient rolling is done to insure a dense surface.

The maintenance of this type of surface is not unlike that on other broken stone roads. Usually much less patching is necessary as the surface is more dense and is less liable to ravel. Drainage is very essential so that the subgrade will not become saturated. Surface treatments are rarely necessary but when needed the application is the same as for other broken stone roads.

#### Summary of The Maintenance of Broken Stone Roads

To carry any great amount of rubber tired traffic all broken stone roads must have a bituminous surface. The wearing course must be re-treated at intervals to renew the surface as in time it becomes brittle and will break down under traffic. Care must be used not to apply too much bitumen in these treatments as a mat will form on the surface and push into waves. Any breaks that occur must be immediately





SMALL GANG PATCHING. CENTRALIZED MAINTENANCE. NOTE EQUIPMENT.



repaired. Proper drainage must be provided at all times. Should the subgrade become saturated the road surface will certainly break down, especially if frost action takes place. Snow removal is necessary and should never be neglected. Constant care or continuous maintenance must at all times be given. The earth shoulders must be kept up to the macadam and if possible sod should be grown to improve the appearance as well as to hold the material in place. Care must be exercised that the shoulders are not too high so that water will not pond along the edges.

Centralized or gang patrol maintenance, where roads radiate from one point in several directions, is used to some extent but it is not always entirely efficient and economical. Broken stone surfaces, once a break occurs, should be immediately repaired as traffic soon ravel it into a large hole. A patrol can give such details closer attention and keep the surface in better condition.

### 3 - Asphalt Roads

Although asphalt is used very extensively



in the surface of most broken stone roads they are not generally classed as asphalt pavements. The term "asphalt pavement" is generally applied to surfaces that are composed of asphalt and small particles of stone or sand and laid in a sheet on a foundation course usually of some other material, such as broken stone or concrete. The three main types of pavements in this class are rock asphalt, sheet asphalt, and block asphalt.

#### A - Rock asphalt

Rock asphalt is a term that is used to designate a sand or limestone that is impregnated with asphalt and occurs naturally in many sections of the world. The proportions of mineral and asphalt in the natural rock often varies widely but when mixed and broken to proper sizes the finished product gives a uniform material that is well suited for certain pavement uses. After the material has been properly prepared it is shipped to the point of use in open cars and handled very much the same as sand or stone.

The base for a pavement of this type must



be rigid. The rock asphalt is evenly spread cold about one and three-quarter (1-3/4) inches thick over the the base and then lightly rolled. It is then opened to traffic. It is used very extensively in putting a smooth surface on cobble stone, brick, etc.

To repair a depression or hole the sides should be cut vertical and filled with rock asphalt and tamped smooth. Piles of the rock asphalt should be stored at convenient intervals along the road for repair work. The storage piles need not be protected from the weather as the elements have no serious effects upon it.

Rock asphalt has been successfully used in patching macadam and concrete pavements. It has no particular advantage, except ease of handling, over the prepared patch that has been previously described.

#### B - Sheet asphalt

A sheet or monolithic asphalt pavement consists primarily of stable base, either concrete or stone aggregate and asphalt cement, and a wear-

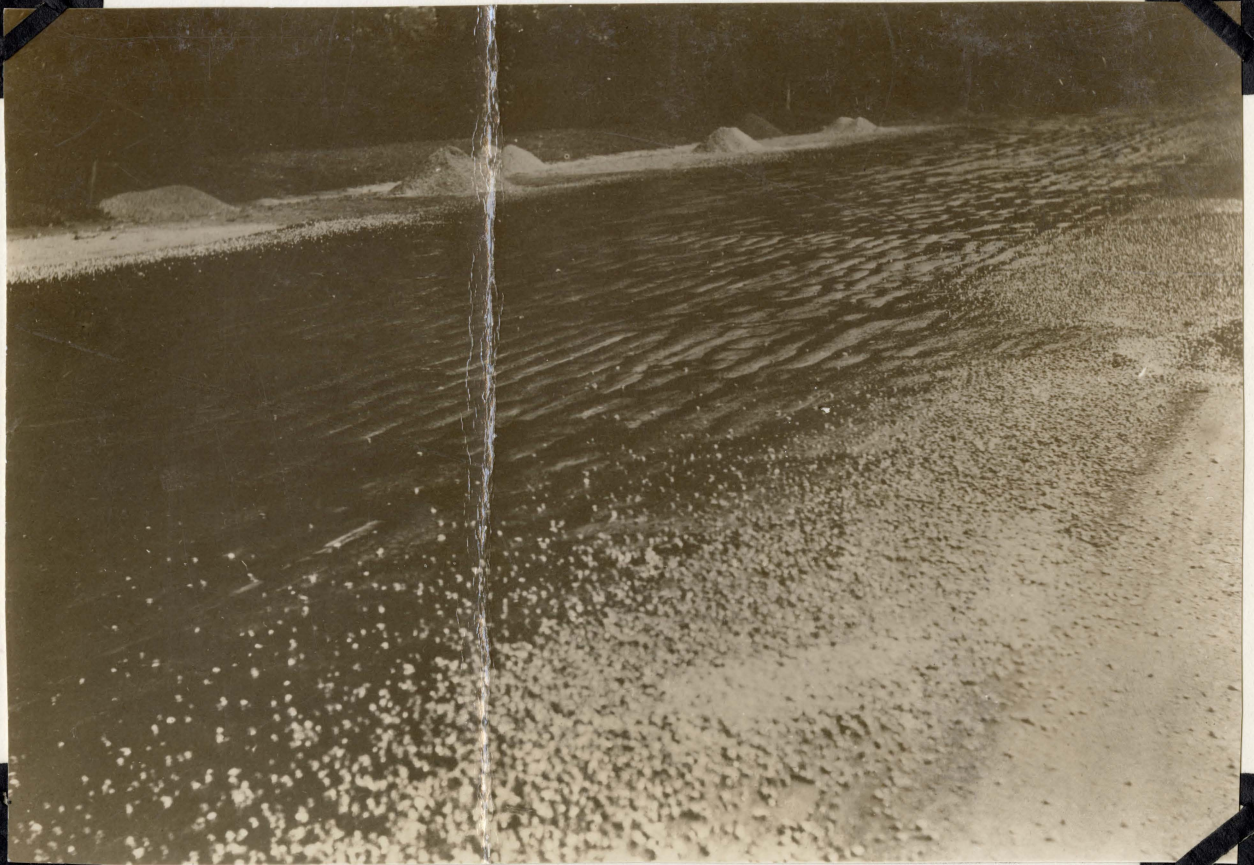


ing course composed a sand aggregate and an asphalt cement. The materials as in bituminous concrete are heated and mixed.

The binder course, usually containing a larger mineral aggregate than the wearing course, is laid hot and rolled to a compacted thickness of one and one-half ( $1\frac{1}{2}$ ) inches. The wearing course of the same thickness is then laid.

While sheet asphalt is very durable under ordinary traffic it at times wears unevenly and the depressions collecting water will cause the materials, after a time, to break up and go into holes. Holes in the surface of sheet asphalt should be thoroughly cleaned out after having the edges cut vertical and filled with the same material of which the pavement was constructed. The bottom and sides should be lightly painted with asphaltic cement and after the new material is placed it should be tamped and ironed out by hot tamping irons. Patching the same as used on broken stone roads is also used but is not as satisfactory. Cracks that occur in the surface should be kept filled with asphaltic cement. Waving in the





SURFACE TREATING AN ASPHALT PAVEMENT TO  
FILL THE CORRUGATIONS FORMED BY THE SUR-  
FACE HAVING PUSHED UNDER TRAFFIC.



pavement is often due to a weakness in the base. When such weakness does occur the sections so affected must be taken out and rebuilt. Waving that occurs on the surface only, if the base is stable, may be remedied over small areas by heating the surface with an apparatus especially designed for this purpose. The burned material is removed and new hot material applied to the desired elevation and tamped or rolled in places. When the waves are slight but general the condition may be remedied by closing the road to traffic and giving it a hot surface treatment as has been previously described for broken stone roads. Stone chips are rolled into the surface and the road opened to traffic again after the bitumen is thoroughly set up and hardened.

#### C - Block asphalt

Asphalt blocks for pavements were first made in San Francisco in 1869 and have been rather extensively used throughout the United States since, however, in recent years it has developed that, on account of the difficult maintenance, they are not



economical for country roads. The blocks usually contain larger stone particles than are used in sheet asphalt and less bitumen. The ingredients are mixed hot and compressed into forms being cooled by passing through water. The blocks are then laid on a concrete or other rigid base.

The maintenance and repairs to the breaks apparently is a simple matter. The old worn blocks are removed and replaced by new ones. This, however, to get a good job, requires skilled labor which at times is impossible to secure. A better method of patching is to use rock asphalt or a patch made similar to that used for broken stone roads. Small depressions should be patched as soon as they occur as they rapidly develop into large holes. The pavement must be well drained because any slight movement in the base is reflected on the surface.

#### Summary of Asphalt Road Maintenance

The patrol method of maintenance on asphalt roads is not so successful on account of the large amount of equipment necessary to make the repairs. Centralized or gang patrol maintenance is more



efficient where the roads are so situated. The asphalt for large repairs is usually hauled from plants that operate intermittently in cities and where the amount of work justifies it small plants are operated at maintenance headquarters. Road equipment necessary is a truck for carrying laborers and supplies and a trailer for hauling a light roller and other equipment above described.

#### 4 - Concrete Roads

The term "concrete pavement" is usually defined as a surface of concrete that is laid in one course, thus forming a base and surface at one operation. Concrete is generally understood to mean a mixture of Portland cement and a graded mineral aggregate of gravel, broken stone or slag, sand and water. The proportions of this may vary according to the results desired, depending upon the thickness of pavement, the earth it is to be laid on and the traffic to which it is to be subjected. A proportion by volume, one (1) part cement, two (2) parts sand and four (4) parts stone makes a strong concrete and is extensively used for pavement work.



Within certain limits the strength and wearing quality of concrete depends upon the amount of cement it contains. The amount of water used in mixing cannot be definitely specified but better concrete is made by having the mixture comparatively dry. Too much water has a tendency to float the cement out.

The subgrade is cut and rolled to a true cross-section. The side forms are set to grade and the concrete poured. It is then stroked off and tamped. The tamping is often done by a machine especially designed for that purpose. After the initial set the surface is covered by soil or straw and kept moist for about fourteen (14) days and opened to traffic in not less than twenty one (21) days. Transverse expansion joints are often left about every fifty (50) feet, however, the present practice is to eliminate them except at the end of a days run. The joints are filled by a prepared asphalt or tar section or left open and poured with hot bitumen.

Concrete will crack at intervals due to temperature changes and the care of these cracks is one of the first maintenance operations. As soon as





CRACKS AND JOINTS OF CONCRETE  
PAVEMENT FILLED WITH BITUMEN



SURFACE TREATED CONCRETE PAVEMENT



they form the cracks should be cleaned and poured full of hot tough bituminous material and covered with sand. The transverse joints as they open should be treated in a like manner.

Due to excessive loads or a subgrade that settles the concrete may fail. Such failures if only small may be repaired by a patch of bitumen and stone the same as is used for broken stone work. Larger places that fail should be taken out and replaced by concrete. The edges of the pavement that remains in place should be cut vertical and the new concrete well tamped in place.

**Small** depressions are remedied by thorough cleaning followed by an application of small chips and bituminous material very much the same as is used for patching macadam. When the surface is worn to any great extent it may be surface treated as has previously been described for other types of pavements. Hot bituminous materials are almost universally used for surface treatments. Hard tough stone chips are preferable.

Constant maintenance of the earth shoulders



and side drains are very important and is usually more expensive than the upkeep of the surface. Traffic, in spite of the width of the pavement, will run off the edge and in wet weather rut it, especially where it joins the concrete. Ruts if allowed to remain will accumulate water that will eventually soak into the subgrade causing it to lose its bearing power with the result of a pavement failure. Wheel tracks that form at the edge of the pavement should be filled with stone if available. Thus filled traffic has a chance to climb back on to the pavement again where if they are filled with earth it will push out and the vertical edge of the pavement may cause the wheels to be guided for a considerable distance resulting in a long deep rut that is dangerous and expensive to repair. The shoulders should have sufficient slope from the pavement to drain well so that the water will not pond or wash along the edge of the pavement. Grass should be encouraged to grow but should be kept trimmed so that it will present a neat appearance. The side drains should be kept open and no water allowed to pond.



Concrete roads are best maintained by the patrol system. The patrol sections should not be over ten (10) miles in length so that the road may be given close attention. A patrolman should be equipped with a ten (10) gallon heating kettle for warming the joint and crack filler, a pouring pot with a narrow opening, shovels, grass cutting and other necessary small tools. Joint filler in barrels, sand and stone should be stored at intervals along the road. A tough hot bitumen that will adhere well to the concrete should be used.

Centralized maintenance where the mileage of the surfacing radiates in several directions from headquarters is often efficient and economical. The outfit should consist of a small truck for carrying supplies, tools and laborers and a trailer on which to carry a heating apparatus. An outfit of this description and four (4) to five (5) men can maintain fifty (50) to sixty (60) miles of road. This method of maintenance can more easily handle large breaks and in cases of emergencies or where snow removal is necessary can better, on account of the unit





PREPARING COBBLE STONE FOR  
BITUMINOUS TREATMENT



TREATED COBBLE STONE



organization, take care of the situation. Each individual in the outfit can be kept continuously busy in making small repairs. Several should be kept ahead sweeping and cleaning cracks while the others follow with the hot bitumen filler and cover it with sand.

#### 5 - Cobble Stone Roads

Cobble stones are not extensively used at present for new pavements, however, their use in the past was very extensive for heavy traffic and many remain today to be maintained. Granite was the stone mostly used for such pavements on account of the ease with which it split in planes requiring very little dressing. Even then it was almost impossible to get a smooth surface and after considerable wear there was no way to maintain it without relaying the stones.

Many miles of such pavements have been taken up, the stone recut and relaid on a rigid base of concrete. The joints between the small blocks are poured full of bitumen and sand. This method of using the old blocks is very good but



expensive. Where the old block pavement is stable and in fair condition it is possible to cover the surface with sheet or rock asphalt. This has proved very satisfactory and is being extensively used. In such cases the new surface is maintained the same as has been previously discussed for such types.

#### 6 - Brick Roads

Brick pavements are extensively used in sections where there is no local material other than clay for road building purposes. Clays or shale, that have been subjected to great pressure by action of the earth's crust, make the best paving bricks. A paving brick must be hard and dense but not brittle to withstand the ravages of traffic. The pavement must be laid with bricks of uniform quality so that the wear will not be more on one section than another.

The brick should be laid on edge on a firm base of concrete or other stable material. Between the brick and base there must be a cushion layer of



sand to evenly distribute the bearing of the brick. Great care must be exercised in the construction as even small irregularities will cause the surface to wear rapidly. After the bricks have been laid and tamped or rolled firm the joints must be filled. Sand, tar, asphalt or Portland cement may be used for this purpose but in any case the work must be carefully done to prevent water from entering.

The maintenance of a brick pavement must start immediately after traffic has been allowed on it. Depressions that occur due to faulty foundation or to the use of defective bricks must be attended to at once. Should a break occur the adjacent bricks wear very rapidly. During construction sufficient bricks of the same quality of the pavement should be stored for maintenance purposes. With these it is possible to replace bricks that fail or make repairs that are barely noticeable. Bituminous patches, the same as are used for macadam and concrete pavements, are also extensively used and proved satisfactory but rather unsightly. Where excessive breaks have occurred it is possible to



prolong the life of the pavement by first patching it evenly and then giving it a surface treatment as in the case of a macadam or badly worn concrete road. Rock asphalt may be used for patching. Expansion cracks that occur may be filled with tar or asphalt. Should the cement filler break up over extended areas it should be cleaned out to a depth of one inch and new grout poured in. It is possible after the bricks have become badly pitted and worn to re-lay them turning the bottom side up.

#### 7 - Bridge Maintenance

Concrete highway bridges require little maintenance unless injured by being struck by a vehicle. However, the expansion joints should be kept filled with asphalt or tar and the weep or drainage holes from the pavement should be kept open.

Steel bridges require considerable attention and on account of the large investment and the importance to the traveling public should never be neglected. Where bolts are used they must be often



inspected and kept tight. Truss bars and bracing must be kept tight so that they will function as intended.

One of the vital points of a bridge and one that is mostly neglected, is the seat. The bridge seat must be kept clean of organic matter because if it is not chemical action and moisture that is held will soon cause rust. The expansion rollers must be kept clean and greased with a heavy oil so that they will function properly.

When the paint begins to crack and peel the bridge should be repainted. Before repainting all of the old loose paint and rust should be removed. Several methods for cleaning the steel are used. Wire hand brushes and scrapers are used on small jobs but where the amount of work will justify it the sand blast is much more effective. A sand blast apparatus which is operated by a large air compressor forces air and sand through a nozzle with terrific force against the object to be cleaned. In this way points that could not be cleaned by a wire brush are reached and the work



is much more rapid, one man being able to accomplish more than twelve with wire brushes.

The painting may be done by a paint gun that is operated on the principle of atomizer using the same compressor that was used with the sand blast. Hand painting, while often used, is not so good because it is practically impossible to force paint into places where it is most needed. One man using a gun can paint more than four with brushes.

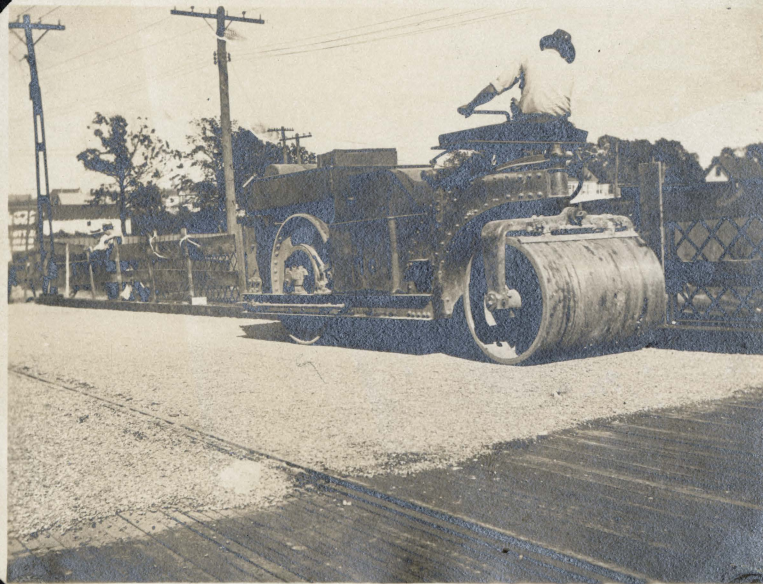
Bridges with wood flooring require close attention. Timbers that show weakness or decay must be immediately replaced. After the entire floor has become more or less decayed and worn it should be replaced. Before placing the new flooring the stringers should be well cleaned and painted. New flooring should be securely fastened in place. The floor boards should be fitted snug and smooth.

It is quite customary to surface treat bridge floors the same as macadam roads are treated. The floor must be tight so that the bituminous material will not flow through the cracks. Should there be cracks they must be well calked with oakum





SURFACE TREATING A BRIDGE FLOOR



ROLLING TREATMENT



or burlap. Small stone chips or coarse sand should be spread over the bitumen while it is still plastic and the bridge kept closed to traffic until it is dry so that the material will not be picked up on the wheels. When the surface treatment wears through in spots it must be patched and kept repaired the same as on macadam work.

Bridge maintenance is best carried out by an experienced crew and for that reason is often neglected by the regular road forces. Poor workmanship on a bridge is often very fatal and should be avoided if possible.