"PUDDLE MACADAM," USING SOFT SANDSTONES

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There are approximately 3,000,000 miles of travelled roads in the United States Of this mileage less than ten per cent is included in all the state highway systems put together Except in a comparatively few states, only a part of the state highway systems are paved with so-called high types, and it is apparent that more and more reliance will have to be placed in the improvements of surfaces using local materials, and in many cases even materials that have not previously met standard specifications

The development of a state highway system is analogous to that of a railroad system, in that it is purely a means of providing a transportation service, and there is no reason why any section should be improved to a higher degree than necessary to carry the expected traffic. It must be always borne in mind that a highway is required to earn dividends on the investment, just as well as a railroad, and that the greater are these dividends, the greater are the funds available for development of the other parts of the system The gasoline tax has proven the most satisfactory means of obtaining money for highway construction and maintenance, and the amounts received reflect remarkably well the highway service rendered.

West Virginia has constructed and improved some 3000 miles of state roads during the past five years, all of which are being paid for from gasoline and motor vehicle taxation, including all fixed charges and retirement of bonds and all incidental expenses In 1925 the gas tax returned about $550,000 per penny of tax In 1927, by reason of connection of different parts of the system permitting greater range of travel, this return had increased to over $1,000,000 per penny of tax Much of this mileage is improved with medium types of surfacing, using local materials, which are not only entirely adequate and satisfactory to present traffic, but will permit of strengthening and widening at reasonable cost whenever additional traffic makes it necessary One of these types is modified bituminous macadam, a method of construction between water-bound and penetration macadam but possessing the good qualities of both

Modified bituminous macadam or "Puddle Macadam," as it is generally called in West Virginia, has been used in the construction of many miles of state highways during the past three years No claim is made for having discovered a new type, as it has probably

been used in many sections of the country in a similar form; in fact, our own idea for the type was gathered from the Maryland practise in widening and superelevating curves on macadam roads which had been originally constructed as water-bound macadam Some of these roads crossed the mountains at an elevation where water was distinctly scarce, and so, instead of thoroughly binding the surface with water, only a small amount was used, the surface then being swept, and after a few days of drying out under traffic, given an ordinary surface treatment. Later, the water was omitted entirely and the ordinary cold surface treatment material was applied directly to the surface after it had been bound up with dust and screenings

From observation of this work on repair and widening, the thought presented itself, why not construct a new road using the same methods, which would make it possible to carry on the work under traffic, and at the same time obtain the smooth surface which is possible with water-bound macadam To this end a specification was drawn up, which provided for the construction of a pavement in exactly the same manner as for water-bound macadam, up to the point where water is applied. Instead of binding and puddling the surface with water, it was swept free of surplus dust and screenings and cold tar applied at the rate of about 7 gallon per square yard The specification for this cold tar was as follows:

1	Water, not more than	2 00%
2	Specific Viscosity, Engler, 50 cc at 40° C	8.35
3	Distillation test on water-free material	
	0 to 170° C, Total Distillate, by weight, not more than	5 00%
	0 to 235° C, Total Distillation, by weight, not more than	20 00%
	0 to 300° C, Total Distillation, by weight, not more than	45 00%
	Residue, by weight, not less than	5 00%
4	Softening Point (R & B) on Residue from Distillation test not more than .. . .60° C	
5	Total Bitumen (Soluble in carbon disulphide) not less than	95 00%

Not earlier than twenty-four hours after the application of the cold tar a seal coat of cold asphalt was applied at the rate of about 6 gallon per square yard, making a total application of bituminous material of about 1.3 gallons.

Many miles of surface were constructed using this specification, but experience gradually showed that an increase in the first application was desirable, and that a longer period should elapse between the first application and the second in order to obtain a really smooth surface Accordingly the 1927 practise is as follows:

The subgrade is prepared, rolled and checked with a template to within ¼ of an inch prior to the placing of base course. This may be of either crushed or knapped stone but where the type is used for soft sandstone, the knapped base is preferable. This base course is again checked with a template to within ¼ of an inch and the top course of loose stone is spread with a spreader and templated off smooth and even to a depth of approximately four inches loose. This stone is then rolled and shaped, rolling from the edge to the center until a smooth and even surface is obtained. The first rolling should be about five or six times over the surface, just enough to shape and compact the loose stone and not enough to crush or break the stone particles. Stone screenings and dust are then thrown on the surface so as to have about ¼ of an inch over the top of the stone and this is rolled and further dust added until no movement is discernible under the roller. It is necessary to have this extra thickness of dust and screenings over the top of the stone as with a lesser amount, the fine particles will go to the bottom of the stone course and the coarser will ride to the surface As soon as the surface has become smooth and without movement, the surplus dust and screenings are swept to the side of the road, exposing the top particles of stone so that they present a mosaic appearance Cold tar is then applied at the rate of one gallon per square yard This is done either with a distributor or by hand. The latest practise is to prepare a section of such length as will take one distributor load, going down one side and coming back the other. Traffic uses the road at all times except for the few minutes when the bituminous material is being poured and cover coat is being applied This cover coat consists of ½-inch by 1¼-inch chips and when of soft sandstone usually crushes in two under the roller. Traffic immediately uses the surface and any uneven places are later brought to template and profile by the addition of fine material and bitumen.

The advantages of this type of construction over penetration are as follows:

First, it permits the use of softer grades of stone than can be used for penetration, with satisfactory results.

Second, for sections of road far removed from commercial sources of stone, it permits the economical use of the complete run of the crusher, especially with soft material.

Third, it allows the traffic to use the road at all times, except for delays not exceeding fifteen minutes at a time when the bituminous material is being applied A 600 gallon distributor will cover 300

feet of 18 foot roadway, so that as a general thing this delay to traffic does not exceed one-half hour per day, as 600 feet of surface per day is a fair average.

Fourth, roads of exceptional smoothness can be obtained with this type of construction as it is possible to bring up depressions prior to the application of the bituminous material by adding small sized stone according to the amount of the depression Where the subgrade and base course are carefully checked, and as with the softer stone there is also tendency to pack down under the roller to an even and smooth surface, such addition is rarely needed.

Traffic uses the road so constructed during the following winter, and the seal coat is not applied until May of the following year The seal coat consists of ¼ to ⅜ gallon per square yard, usually either hot asphalt with ¾ by 1¼ chips, cold asphalt using ⅝-inch chips, or cold tar with ⅝-inch chips

Specifications for the hot asphalt are as follows.

1	Flash Point, not less than	175° C
2	Penetration at 25° C, 100 g, 5 sec	150-200
3	Ductility at 25° C not less than	30
4	Loss at 163° C, 5 hrs, not more than	3%
5	Penetration of residue at 25° C, not less than	90
6	Per cent of total bitumen soluble in carbon tetrachloride, not less than	99%

The specifications for cold asphalt are as follows

		Min	Max
1	Specific Gravity at 60° F	9400	9650
2	Flash Point (Cleveland Open Cup)		95° F
3	Specific Viscosity Engler (1st 50 cc at 50° C)	18	30
4	Asphalt Contents at 100 Penetration	68	
5	Evaporation Loss 20 Grs 5 Hrs at 212° F	25%	
6	Evaporation 50 Grs 5 Hrs at 325° F	27%	35%
7	Penetration at 77° F on Residue from 325° F Loss		200
8	Bitumen Soluble in CS_2	99 5%	
9	Per cent of Total Bitumen Insoluble in 86° Naphtha	15 0%	
10	Distillation A S T M		
	Per cent up to 150° C	5	10
	Per cent up to 200° C	24	29
	Per cent up to 205° C		32

Hot asphalt is used on heavy grades and where it is desired to obtain a non-skid surface The cost of such construction varies according to the location, but in general is about twenty per cent less than penetration macadam However, penetration macadam built under the same thickness of loose stone will have a final compacted thickness of about three inches, whereas the final compacted thickness of the

"puddle" macadam is about four inches Sections of the surface dug up after twelve months service, show that the initial gallon of bituminous material has practically penetrated to the bottom of the course and has produced a sort of bituminous concrete where the dust and screenings have been impregnated with the bitumen and act as a matrix surrounding and holding the coarser stone particles in place This type of construction will carry any traffic that can be carried by penetration and the methods and cost of maintenance after the first seal coat has been applied, are similar Traffic on different roads constructed in northeastern West Virginia during the past three years, varies from 500 to 3000 vehicles per day with an average daily traffic from 500 to 800

The following table shows the first cost, maintenance cost, and traffic on a number of widely separated roads of this type of construction

	State route	Miles length	Base course per cu yd	Top course per sq yd	Applied cost of tar per gal	Annual maint per sq yd	Vehicles per day traffic
No	1	6 0	$5 35 S	$ 75	$.20	$ 03	300-1000
	1	4 0	4 00 S	85	.25	03	300- 800
	1	5 0	4 50 S	70	18	03	300-2000
	45	3 0	4 15 S	75	21	03	300- 800
	45	4 7	5 00 S	75	18	03	300- 800
	47	4 0	4 60 L	68	18	03	300-1000
	9	1 0	5 00 L	70	18	03	500-1500
	58	5 0	5 25 L	.85	.22	04	500-1000
	47	8 0	4 25 L	70	.22	03	300-1200
Average by jobs			$4 68	$ 75	$.20	$ 03	300-2000

S—Sandstone L—Limestone

Average depth base compacted 5 inches, cost per mile	$7000
Top course compacted 3½ inches, cost per mile	7500
Bituminous binder 10,000 gallons, cost per mile	2000
Seal coat second year 2500 gal plus cover, cost per mile	500
Average cost per mile 8-inch gravel base	6000

All above figures based on 18 foot width. It requires nearly 2 tons of stone to make a cubic yard compacted base or top The table was made up from a number of widely separated jobs showing variations due to location and season Maintenance costs were based on ¼ gallon surface treatment every three years, which under a steadily increasing traffic has so far been adequate.