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Comparison of various types of road surfacing

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COMPARISON OF VARIOUS TYPES OF ROAD SURFACING

by

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LIST OF ILLUSTRATIONS

NOTE: All of the above mentioned pictures were taken during construction of Route 21 between DeSoto and Potosi Missouri, in 1934.

COMPARISON OF VARIOUS TYPES OF ROAD SURFACING

INTRODUCTION

It is the intention of this thesis to compare the more common types of road surfacing by establishing both the good and poor qualities of each type of pavement. All of the subject matter that follows is based on the theory that each approved type of pavement has its use and the most economical pavement to construct is the one that gives the greatest service to the traveling public per dollar, invested over a period of years.

To make a direct comparison between gravel and concrete surfacing would mean very little, for gravel is a much cheaper type of pavement, hence the service and desirability is much less. By that is meant that even though gravel costs only one tenth as much as concrete, it would not be one hundredth as good on heavy traveled roads because of its undersirable features or lack of proper service.

Since the item of service is to play such an important part in this thesis, it might be well if the writer gave his definition, as applied to road building. It is that quality that creates the ease, safety, and comfort of the user. The service on a gravel road carrying only two hundred cars a day would be satisfactory because the dust interference would not be great but the service on a gravel road carrying two thousand cars a day would be very unsatisfactory.

There are only four major types of road surfacing, namely; concrete, asphalt, brick and gravel that are now being constructed in most states and I will endeavor to touch on the service, approximate cost, construction procedure, new developments and adaptability of each type in the order named.

A table has been prepared showing the maintenance cost per mile for all of the above mentioned types of pavement. These figures represent actual expenditures of the Missouri State Highway Department for the years of 1930, 1931 and 1932. A similar table could have been prepared showing the comparative first costs but it would have been of practically no value for the location of the project in relation to the source of material used would make a wide difference and the comparisons would have been misleading. This table, which you will find on the next page, shows the total maintenance cost per mile subdivided into such headings as surface, roadbed, structures, replacements and snow removal in order to show the expensive features of maintaining the various types of road.

AVERAGE COST PER MILE FOR MAINTENANCE

Cost of Maintaining an Average Mile of Concrete Pavement

Distribution of Cost Per Mile

YEAR	MILES	SURFACE	ROADBED	STRUCTURES	REPLACEMENT	SNOW REMOVAL	TOTAL COST PER MILE
1930	2235.5	$104.47	$152.59	$ 14.04	$ 16.47	$ 18.85	$306.42
1931	2687.3	103.71	144.86	9.48	105.43	11.09	374.57
1932	3046.8	107.61	154.68	11.60	21.52	14.99	310.40

Cost of Maintaining an Average Mile of Bituminous Pavement

YEAR	MILES	SURFACE	ROADBED	STRUCTURES	REPLACEMENT	SNOW REMOVAL	TOTAL COST PER MILE
1930	199.7	$216.44	$110.42	$ 5.47	$ 86.36	$ 13.87	$432.56
1931	229.4	125.85	92.45	6.03	48.97	6.16	279.46
1932	260.3	106.52	85.65	5.18	216.41	5.74	419.50

Cost of Maintaining an Average Mile of Brick Pavement

YEAR	MILES	SURFACE	ROADBED	STRUCTURES	REPLACEMENT	SNOW REMOVAL	TOTAL COST PER MILE
1930	18.7	$112.55	$ 43.01	$ 10.56	$ 38.22	$ 12.70	$217.04
1931	18.7	134.84	92.26	7.29	0.00	5.99	240.38
1932	18.7	52.75	121.06	5.31	0.00	15.02	194.14

Cost of Maintaining an Average Mile of Gravel Pavement

YEAR	MILES	SURFACE	ROADBED	STRUCTURES	REPLACEMENT	SNOW REMOVAL	TOTAL COST PER MILE
1930	2756.8	$264.33	$ 53.90	$ 12.43	$211.98	$ 12.10	$554.74
1931	3227.3	238.63	53.87	7.43	169.22	6.77	475.92
1932	3695.6	216.58	52.27	10.85	207.36	7.09	494.15

See Reference No. 1

PORTLAND CEMENT CONCRETE PAVEMENT

This type of pavement some few years ago was purely a matter of experimenting as far as most states were concerned, but now it is the result of a series of carefully conducted tests and a product of accurate design.

Ten years ago the mix was proportioned by volume and neither expansion nor contraction were provided for during construction of the pavement. The theory used was to let the pavement crack, then fill the cracks with some plastic material, thereby forming a more or less natural expansion joint. This method of construction proved very unsatisfactory because the crack maintenance was very expensive and the surface soon became rough because the slab elongated and the increased length had to be absorbed by the slab sinking in the low places and pushing up in the high places. "Blow-outs" were very common due to this elongation and in some instances considerable damage was done.

In 1927 the Missouri State Highway Department adopted the policy of designing the mix or using what is now commonly known as "weight proportioning." The paragraphs that follow will give you the very latest method of weight proportioning in a brief manner.

It is absolutely necessary to have proper laboratory equipment and a field laboratory in order to intelligently control the mix. The following equipment should be supplied; one Harvard balance, several drying pans, one gas stove, one large set of scales, several fifty pound weights, and numerous small articles such as brushes, cloth, and measuring devices.

In order to correctly proportion the various materials, it is necessary to know the dry rodded weight, the total moisture, and the percent of absorption for both coarse and fine aggregate. The dry rodded weight is determined by drying the aggregates on a hot stove until all the moisture has been driven off, then weighing a known quantity that has previously been rodded with a five-eight inch bullet-pointed steel rod. The percent of total moisture is obtained by the following formula $\frac{W-D}{D}$ times 100 where W is the wet weight and D the dry weight of the same quantity of material. The percent of absorption is determined from a similar formula, $\frac{I-D}{D}$ times 100 where I is the weight after immersion and D the dry weight of an equal quantity of material.

The correct method for determining the amount of coarse and fine aggregate as well as the quantity of effective water in any given mix can best be shown by the following example:

Given: Mix of 1:2:3½ by volume
Six sack batch
One sack of cement weighs 94 pounds
per cubic foot.

Results from tests made as indicated in a previous paragraph provide the following figures:

Coarse aggregate, dry rodded weight.... 95 lbs. per cu.ft.

Fine aggregate, dry rodded weight......100 lbs. per cu.ft.

Coarse aggregate, total moisture....... 1.3%

Fine aggregate, total moisture......... 3.2%

Coarse aggregate, absorption........... 0.6%

Fine aggregate, absorption............. 0.5%

Calculations:

Coarse aggregate, effective moisture equals 1.3-0.6 or 0.7%

Fine aggregate, effective moisture equals 3.2-0.5 or 2.7%

Cement	Sand	Coarse Aggregate
1	2	3½
6 cu.ft.	12 cu.ft.	21 cu.ft.
6 sacks	1200 pounds	1995 pounds

Considering all the figures mentioned above, the weights of both coarse and fine aggregates in the mix should be as follows:

1200 times (100% + 3.2%) equals 1238 pounds of fine aggregate

1995 times (100% + 1.3%) equals 2021 pounds of coarse aggregate

The total amount of effective water in the batch can best be determined by the following formula:

$$Z \text{ equals } \frac{A\ (C-E) + B\ (D-F)}{8.33}$$

A equals Dry rodded weight of fine aggregate

B equals Dry rodded weight of coarse aggregate

C equals % of moisture in fine aggregate

D equals % of moisture in coarse aggregate

E equals % of absorption in fine aggregate

F equals % of absorption of coarse aggregate

Z equals Total effective water in batch in gallons

After the total amount of water in the batch is known, it is a simple matter to add an additional amount to get workability. By knowing the actual amount of water in each batch of concrete, it follows that each batch will naturally be of the same consistency for the amount added will be varied to make the total effective water the same for each batch. The advantages are evident, for when the mix is controlled by making each batch of concrete approximately the same, greater strength will be obtained. The mix will also be cheaper for more coarse and fine aggregate per sack of cement can be used and they are the

the two cheaper ingredients in concrete.

This method of controlling or designing the mix was probably the greatest development in concrete pavement over a considerable number of years. There is no doubt in the minds of engineers that the strength was greatly increased, but at the same time it did nothing to solve the much discussed subject of expansion and contraction of concrete pavement. The first step to render real aid to this phase of the work was the addition of mat reinforcement.

REINFORCEMENT FOR CONCRETE PAVEMENT

When a pavement slab contracts as the result of any physical or climatic influence, all cracks and joints will tend to open, due to a shortening of the unbroken section between the cracks. It is recognized that one of the functions of steel in pavement is to prevent the widening of contraction cracks, which means in effect, that the mat reinforcement must be of sufficient strength to drag a given slab unit on the subgrade so that the movement is controlled between expansion joints. This movement is often improved by the addition of tar paper on the subgrade.

The conception of the function of reinforcement in concrete pavement has established what might be called "Subgrade Drag Theory", which is considered a rational basis for designing steel reinforcement. The amount of steel required on this basis of design involves assumption of a coefficient of subgrade friction and selection of an allowable unit tensile stress in the steel. It is common practice to select a coefficient of friction from 1.0 to 2.0; a value of 1.5 being usually used for average subgrade conditions. Allowable working tensile stress in the reinforcement will depend on the grade of steel used, ranging from 20,000 pounds per square inch for hot rolled bars to 25,000 pounds per square inch for cold drawn wire. The area of both transverse and longitudinal steel can be computed by the following formula;

$$\text{As equals } \frac{l\ w\ c}{2\ fs}$$

in which, As equals the effective cross-sectional area of steel in square inches per foot of length or width of section. It is well to note that the intended function of reinforcement is more efficiently performed by small members closely spaced than by large members widely spaced.

"l" equals the distance between transverse joints when computing logitudinal steel or the distance between longitudinal joints when computing transverse steel.

"w" equals the weight of concrete slab per square foot.

"c" equals the coefficient of friction on the subgrade.

"fs" equals allowable unit tensile stress in steel.

The reinforcement is usually placed aboutthreeinches below the top of the slab and it aids expansion materially because the sections between joints will move as a body. However, before the reinforcement can do any good, proper contraction and expansion joints must be installed.

EXPANSION AND CONTRACTION JOINTS

Probably next to weight proportioning, in considering the advancements that have been made in reinforced concrete pavements, should come proper expansion and contraction joints.

A careful study of the results obtained from numerous test sections indicates that approximately eighty feet apart is the correct spacing for expansion joints. Considering the elongation from about ten degrees below zero to one hundred and ten degrees above zero, one will find that an eighty foot slab will increase in length approximately three-quarters of an inch. Tests have also proven that each eighty foot slab should be separated into at least two forty foot slabs by the installation of contraction joints. Separating the slab into shorter units aids expansion considerably because it decreases subgrade friction and practically eliminates cracks.

There are two methods now in use for constructing the major part of the joint and numerous types of filler.

The joints are either constructed by placing one inch dowel bars at two foot intervals, leaving one end free to slide in a prepared slot, or by using what is known as a trans-load base. This latter method is now used entirely in Missouri and it is considered much more effective. The following sketch describes the joint and gives one an idea of its general appearance:

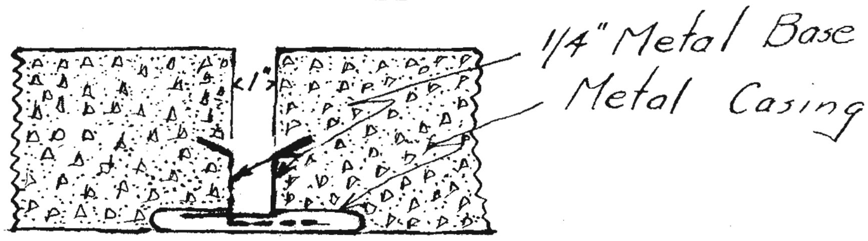

FIGURE "A"

The same type of joints used in expansion joints are also used in contraction joints, except that the one inch is not provided for expansion.

Numerous types of effective fillers are now on the market, such as Tarvia "X", Cut-back Asphalt, Zorbite, rubber and cork, but the one that is now proving the greatest success is an air joint encased with pure copper. On this type of joint, flanges extend from the copper chamber into each slab so that the joint will remain in tact during expansion or contraction. I much prefer the air joint because expansion and contraction are entirely free and the item of refilling the joints every year or two is entirely eliminated.

GENERAL - PORTLAND CEMENT CONCRETE PAVEMENT

Concrete pavement has reached such a high stage of development that there is now more miles of it constructed on heavier traveled roads than any other type of pavement.

The first cost is much less than it was and the maintenance costs,as shown in the table incorporated as a part of this thesis, are very nominal. It has many advantages over other types of pavement, such as smoothness, resistance to wear and ease of riding at night due to the fact that it is white in color.

It is the opinion of the writer that on practically all roads, except those covered in this thesis as being particularily fitted for asphalt, concrete pavement should be constructed if the traffic consists of as much as two hundred and fifty cars and trucks a day.

Concrete pavement has made rapid advancements in the past few years, but I believe even more rapid advancements will be made in the next two or three years. We can look for a much lower water-cement ratio because all concrete will be vibrated and this will mean cheaper, better concrete. More efficient curing agents will be developed and mixers so designed that a batch of concrete can be turned out every thirty seconds.

A disadvantage of concrete pavement is the high initial cost, and several types of modified pavement have been developed to combat this disadvantage. Chiefly among these modified types is what is known as "Cement Bound Macadam." This type of pavement consists of a layer of clean coarse aggregate laid upon a prepared sub-grade and bound together with a Portland Cement-sand grout of such consistency that, when applied to the surface, it flows into and fills the voids in the coarse aggregate. This type of pavement was first used in Scotland in 1872 and as early as the twentieth century in the United States, but its use was practially discontinued when mixed concrete was developed.

It is my opinion that cement bound macadam will never be used for anything but very lightly traveled roads or driveways, but no doubt the first cost is considerably less. The Portland Cement Association constructed a test road of this character at Elmhurst, Illinois, during the summer of 1933 and the tests so far have been very satisfactory, however.

ASPHALT PAVEMENTS

It is my intention to describe and comment on only the more common types of asphaltic concrete and cold and hot mixed asphaltic pavements because sheet asphalt, due to the fact that it gets very slick in wet or freezing weather, is no longer considered a desirable road surface.

Nearly all states in the United States, as well as several foreign countries, have done considerable experimenting with asphalt during the past few years, trying to produce a "non-skid" surface that has the proper resistance to both wear and weather.

Missouri, in particular, has done a lot of this kind of experimenting and most of the information that will follow was obtained by observing the experiments during active construction.

HOT MIXED ASPHALTIC CONCRETE SURFACE

There are only three major types of asphaltic concrete now in use and they vary only in kind and gradation of the aggregate incorporated in the mix. These three types are - asphaltic concrete with trap rock as the aggregate, asphaltic concrete with granite as the aggregate and asphaltic concrete with limestone or some other softer stone as the aggregate.

Trap rock is very hard and for that reason, it produces a very satisfactory and durable riding surface, but the quantity is very limited and the price considerably higher. There is only one quarry that produces this stone commercially in the state of Missouri and most states do not have a supply at all. Because of its rareness and the fact that the first cost is considerably higher, I do not believe much more will be used in the future.

Approximately the same can be said of granite that has been stated about trap rock for it is also very scarce and expensive to produce. It would therefore seem that much more limestone or other comparatively soft stones will be used as the aggregate in future asphaltic concrete surfaces.

CONSTRUCTION METHODS--REGARDLESS OF TYPE OF AGGREGATE

Proper gradation is very important to an asphaltic concrete surface and correct proportioning is even more important. It has been found that the best results can be obtained by using the following mixes in the surface course and the base course.

SURFACE COURSE

Aggregate	Passing	3/4 inch screen	100%
"	"	3/4 " " retained on 1/2 inch screen	0-5%
"	"	1/2 " screen retained on 1/4 inch screen	24-36%
"	"	1/4 " screen retained on #10 sieve	26-44%
"	"	#10 sieve retained on #40 sieve	12-22%
"	"	#40 sieve retained on #80 sieve	3-9 %
"	"	#80 sieve retained on #200 sieve	3-8 %
"	"	#200 sieve	3.5-8 %

Bitument...3.5-8 %

This course is generally constructed approximately one and one-half inches thick and thoroughly compacted at high temperatures as described in the paragraphs that follow.

BASE COURSE

Aggregate	passing	1-1/2 inch screen	100%
"	"	1-1/2 " " retained on 1 inch screen	14-22%
"	"	1 inch screen retained on 3/4 inch screen	7-15%
"	"	3/4 inch screen retained on 1/2 inch screen	9-17%
"	"	1/2 inch screen retained on	13-22%

Aggregate passing 1/4 inch screen retained on #10 Sieve		12-23%
" "	#10 sieve retained on #40 Sieve	5-16%
" "	#40 sieve retained on #80 Sieve	3-10%
" "	#80 sieve retained on #200 Sieve	2- 8%
" "	#200 sieve	2- 8%
Bitumen...		3.5- 6%

This course is generally laid at least two inches thick on a prepared subgrade and thoroughly compacted at high temperatures before the surface course is placed.

MIXING. All aggregate should be thoroughly dried and heated to at least 250 degrees Fahrenheit before they are placed in the mix. The asphalt plant should be so arranged that the various size aggregates can be separated and the rate of feeding the aggregates to the mixer so timed that the proper or specified amount gets into the mix at all times. Accurate scales to weigh the mineral aggregate are very necessary and the proper preparation of the asphaltic cement is highly essential. This material should be weighed on accurate scales, then heated to between 275 degrees Fahrenheit and 350 degrees Fahrenheit before it is added to the mix. During actual construction, the temperature of the mix should not be permitted to drop below 250 degrees Fahrenheit until the final rolling is completed.

Either the pug-mill or the rotary mixer can be used successfully with this type of pavement, provided the mixed material is left in the mixer sufficiently long to permit all the ingredients to combine. The operation of either type of mixer requires very close inspection if a uniform mix is secured.

COMPACTION. Two kinds of roller should be used continuously after the asphaltic concrete has been laid and while the temperature is still above 250 degrees Fahrenheit. Rolling should start longitudinally at the sides with a ten-ton three-wheel roller and rolling continued in the direction of the center line until the entire surface has been rolled. Due care should be exercised during rolling to make sure each rolling over-laps the previous rolling by at least one-half the width of the roller.

The pavement should then be rolled diagonally in both directions with a ten-ton tandem roller. It is also very desirable, when possible, to roll in a direction at right angles to the center line.

The roller wheels should be kept wet at all times and the speed should be limited to two hundred square yards per hour of rolling to insure the best results and to keep surface checking more under control.

SURFACE CHECKING: The worst enemy, without a doubt, to designers of non-skid asphaltic concrete pavements, is surface checking. This difficulty is very serious because when the surface checks or cracks, it leaves an opening for both surface and underground water that gets under the asphaltic concrete and causes raveling, blisters, and waves.

A number of different theories have been advanced, explaining the causes of these cracks, but most of them are based on the same principal when finally boiled down. This principal is that the difficulty in all cases is due to a soft, or yielding lower stratum, which compels the more rigid top crust to stretch out abnormally and finally shear loose during rolling operations.

Let us now see whether this principal can successfully explain the more common conditions that are known to encourage surface checking.

(1) Checking when a heavy roller is used. (The Dishing action under the roller causes abnormal stretching out-hence the cracks.)

(2) Checking when excessive diagonal or circular rolling is in progress. (It is equally clear that any unusual torsion on the crust will cause abnormal stretching.)

(3) Checking when a very hot mix is used for either course. (Hot mixes do not cause cracks, but if the base course is too hot,

it will be too soft, hence will yield abnormally, and if the surface course is too hot it will often penetrate into the base and soften it.)

(4) Checking when the base course is too open. (If base is too open the hot surface course will work into the voids and soften it considerably, then it yields.)

(5) Checking when the base is weak or dirty. (Here the trouble is the same as mentioned above because the base yields and puts undue stress in the top or surface course.)

Following are two pictures that show the kind of cracks I have been discussing. You will note the first picture (Figure 1) has a long crack next to the curb. It is evident that this crack was caused by a base failure due probably to excessive rolling on a weak base.

The second picture (Figure 2) shows numerous small checks, known as feather checks, which are probably caused in this case, by either too hot a mix or rolling when the temperature of the mix is too high.

Figure 1 - Surface Cracks

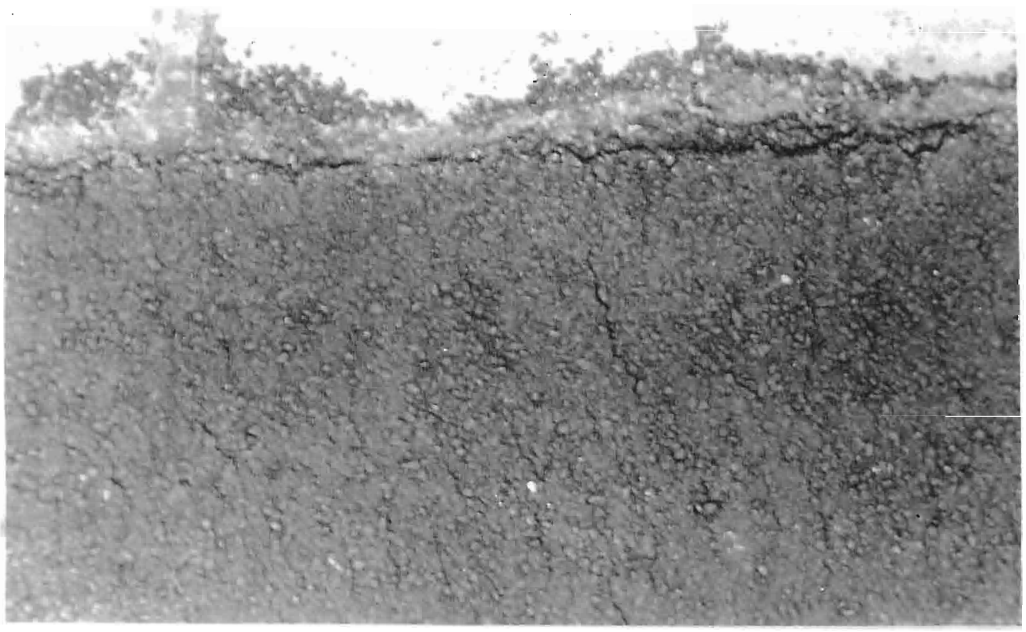

Figure 2 - Surface Cracks

Experience and experiments have shown that surface checking can be eliminated in practially all cases even though the conditions contributing to the cause might be different. Of course, the contributing factors should be corrected first but if they fail, as they often do, to eliminate checking, then the mixture should be allowed to cool a little longer before the initial rolling is done. Also, some times the weight of the roller will have to be reduced before checking is entirely eliminated.

The following pictures are good examples of how the pavement should look after surface checking has been eliminated. Figure 3 also shows the difference between a tight surface which becomes slick in wet weather and a non-skid surface. Figure 4 shows very good texture but due to the fact that too much hand raking was done, it is not as uniform as it could be. Figure 5 shows what is desired in a non-skid asphaltic concrete surface. All of these pictures were taken on the same project which is between Potosi and DeSoto, Missouri, on Route 21.

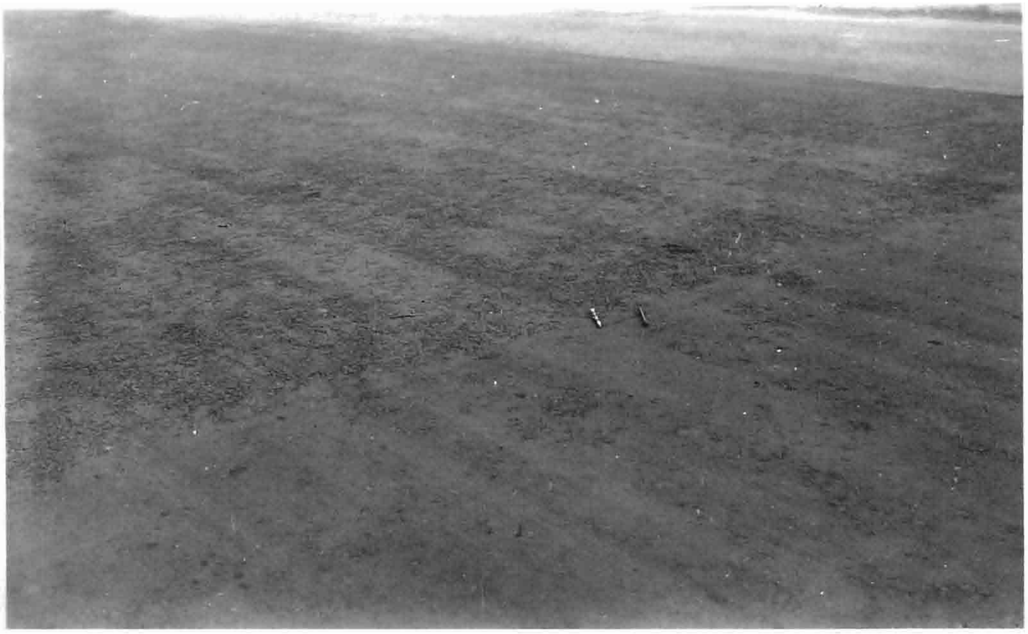

Figure 3 - Difference between mixes

Figure 4 - Very good texture

Figure 5 - Excellent non-skid surface

I realize that some will object to reducing the temperature of the mix or the weight of the roller as the last resort to stop surface checking for no doubt, this method will give you slightly less compaction or a little less strength. However, I believe it is much better to do that than to tear the inner structure of the pavement and leave cracks in the surface that will not heal. Traffic, in time, will render the desired compaction, but will never improve a cracked surface.

SUMMARY - Asphaltic Concrete Surface (Hot Mix)

More asphalt is being used as a road building material each year. It was first used only as a resurfacing agent, but now three course asphaltic concrete pavements, six and seven inches thick are being constructed on earth base.

Asphaltic concrete should be so designed that the surface is pourous enough to prevent skidding, yet tight enough to shed surface water and offer resistance to wear. When this condition is obtained, there is no doubt but that the most desirable surface, possible to construct, has been obtained. The fact that the surface is black or dark grey in appearance is no doubt a disadvantage, but the fact that it offers a slight cushion effect for moving vehicles and thereby practically eliminates vibration, is an advantage that would overshadow any disadvantage. Also, it is noiseless, clean and particularily adapted to heavy traffic because repairs can be made without interrupting traffic.

Traffic should be great in volume and the desired service should be the greatest to warrant this high-type construction for an asphaltic concrete road will cost from ten to twenty-five percent more than concrete.

ASPHALTIC CONCRETE - (Cold Mix)

This type of pavement is practically the same as the hot mixed asphaltic concrete except that it is mixed in some large commercial asphalt plant and shipped to the job. Of course, a sufficient amount of liquifier has to be added to keep the mixture from hardening.

The construction method for this type of pavement is very similar to the hot mixed material but the formula for the mixture is materially different.

Following is the formula for the mixture now in use in most states which corresponds very closely to a number of commercial products that are on the market.

MATERIAL	BINDER COURSE	SURFACE COURSE	TOP DRESSING
Sand	------	-------	95 to 98%
Crushed Stone	80 to 90%	80 to 90%	--------
Liquifier	0 to 1%	0 to 1%	0.4 to 1%
Asphaltic Cement	3.5 to 6%	5 to 7%	Less than 8%
Hydrated Lime	0.5 to 1%	0.5 to 1%	0.5 to 1%
Mineral Filler	5 to 10%	5 to 15%	---------

The gradation of the coarse aggregate for the binder and surface course should be as follows:

BINDER COURSE		SURFACE COURSE	
Passing 1 inch screen	100%	Passing 5/8 inch screen	100%
" 3/4 " "	50 to 90%	" 1/2 " "	60 to 100%
" 1/2 " "	20 t6 45%	" 1/4 " "	5 to 25%
" 1/4 " "	0 to 10%	" No. 10 sieve	0 to 5%
" No. 10 Sieve	0 to 3%		

SUMMARY - - ASPHALTIC CONCRETE (Cold Mix)

This type of surfacing makes an excellent resurfacing material because it can be manufactured in the larger cities and shipped to all parts of the country in any amount desired. However, this material is very expensive due to the high cost of asphalt and the enormous amount of equipment involved in its manufacture.

The advantages and service rendered by this type of pavement are very much the same as for hot mixed asphaltic concrete, except the surface is usually not as smooth and the compaction or resistance to wear is not as great. However, the first cost is less and the maintenance cost is about the same.

ROCK ASPHALT

Rock asphalt should not be considered as a type of road, rather, as a type of surfacing for it must be supported by some kind of rigid base.

It consists of a natural mixture of mineral aggregate and bitumen. The mixture should be graded so that at least ninety-five percent will pass a three-quarter inch circular screen and not more than twenty percent should be retained on a one-quarter inch circular screen. The percent of bitumen should be between six and eight percent.

The actual construction method for this type of surfacing is very simple as it consists mainly of hauling the material to the road in tight trucks, dumping it in a spreader box, spreading with a self-propelled finishing machine to prevent segregation, then rolling until the surface is thoroughly compacted and smooth.

The advantages of this type of surfacing are that it is easily and cheaply constructed. It is very difficult to get a uniform surface with this type of material, however, and for that reason I do not believe it compares favorably with a cold mixed asphaltic concrete surface.

SUMMARY - - ALL TYPES OF ASPHALTIC PAVEMENTS

I have endeavored to cover all types of asphaltic pavements as well as rock asphalt in a complete manner, but any one that has had much experience with asphalt will certainly testify to the fact that there is still plenty of room for further advancement in all kinds of asphalt work.

An asphaltic road or surface that did not have much traffic on it, like one that had too much traffic, would soon deteriorate because there is a constant movement in all types of asphaltic materials that is directly affected by the volume of traffic. Therefore, the amount and type of traffic are very important factors to consider in the design of asphaltic pavements. Other similar items enter into the design also, which leads me to say that, theoretically, no two pavements should be designed exactly alike.

Therefore, the information I have assembled on this subject should be accepted as applying to an average asphaltic road or surfacing, that supports an average amount of traffic.

BRICK PAVEMENTS.

By brick pavement is meant a six inch concrete base, one inch sand cushion, four inch vitrified clay paving brick, and a bituminous filler, as that is the type of brick pavement that has been generally accepted as the most satisfactory.

This type of pavement does not require much detailed explanation, as the base is constructed in the same manner as concrete pavement and the method of laying the brick is a matter of personal preference.

Very little brick pavement is now being laid, due to the fact that it is more expensive than concrete pavement and very little, if any better. However, it does have several outstanding advantages that are worthy of consideration.

The one inch sand cushion under the brick acts as a "shock absorber" for traffic. It not only takes the shock of the passing load off of the base, but lessens the "rebound" action of the vehicle. However, under heavy traffic, the sand some times becomes displaced and destroys the smooth riding surface.

Due to the fact that the base is covered with one inch of sand and a four inch layer of brick, it is not subject to such extreme temperature changes, however, it is subject to some temperature changes and if proper expansion is not provided, "blow-ups"will occur and destroy several square yards of pavement.

Brick pavement makes an excellent surface for a road that carries heavy loads because of its construction and its resistance to wear. There will always be a few miles built each year in manufacturing districts where it is considered better than concrete for the kind of traffic it carries regardless of the fact that it is more expensive.

GRAVEL PAVEMENTS

There are quite a few more miles of gravel pavement constructed in the United States than all the other types of pavement combined for the reason that it is about the only cheap type of pavement that has been, generally speaking, successful. Shale, chats and oil would come under this same general statement but they are seldom used unless the material can be obtained locally.

Gravel pavements, although cheap to build, do not render good service and are expensive to maintain. They become very dusty when dry and considerable material is either blown or is pushed by traffic into the ditches. Also, they become slightly slick when wet and if proper drainage is not maintained at all times they will become soft in places where drainage is sluggish.

Gravel pavements were primarily constructed with the lone idea in mind to get traffic out of the mud, but in recent years considerable though has been given to various surface treatment with the desire to stabilize the surface and thereby produce a dustless, smooth riding surface. During the past two years, this desire has been successfully carried out by treating the surface with both calcium chloride and oil.

GRAVEL AND OIL MIXTURE

With this treatment the gravel is thoroughly mixed with an asphaltic base oil, either on the road or in a plant and spread uniformly over the surface. It soon packs and makes a very good road for light traffic.

This process improves the riding quality of the surface and, no doubt, saves considerable gravel for it binds all ingredients in the surface together and very little is lost by passing vehicles knocking the gravel into the ditches. During construction of this type of pavement, traffic is inconvenienced considerably, as it is much more economical to construct it under traffic than to have the expense of a detour. Also, maintenance is high although it is less than on an ordinary gravel road.

GRAVEL AND CALCIUM CHLORIDE MIXTURE

This type of pavement or surface treatment is being used extensively in some states, but has not reached that stage in Missouri. It consists mainly of adding fine clay to the gravel in a sufficient quantity to fill practically all of the voids in the gravel, then coating the mixture with approximately 0.6 of a pound of calcium.

chloride to the square yard. Water is than added and the entire mixture bladed to a smooth surface. The calcium chloride keeps the clay moist and the moist clay in turn binds the particles of gravel together which furnishes the proper metal to resist the wear of traffic.

As long as the clay remains moist, a very good surface can be realized, but when it dries out, more calcium chloride must be added to stabilize the surface. This process, in my opinion is a very good dust palliative, but not of much value otherwise.

CONCLUSION

The main advantages and disadvantages of four of the leading types of pavement have been outlined in this thesis without meaning to condemn any. Each type has its use and if the correct type is selected, the service will be the best; the maintenance costs will be reasonable and traffic will be supplied with the type of road best fitted for the number of cars involved.

BIBLIOGRAPHY

Reference No. One - Actual costs on file with Missouri State Highway Department.

Reference No. Two- 1931 edition - Modern Road Construction Trusion Steel Company.

Reference No.Three-Missouri State Highway Specifications.

Reference No.Four -Report by G. L. Oliensis - Chief Engineer Barber Asphalt Company, Madison, Illinois.

Reference No.Five- Better Roads. Edition - June 1934.

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