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TREATMENT TO DECREASE OR
PREVENT SKIDDING ON PAVEMENTS

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
Edward Bergman
1942

THESIS

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Treatment to Decrease or Prevent
Skidding on Pavements

A Thesis Submitted to
The Faculty of
MICHIGAN STATE COLLEGE
of
AGRICULTURE AND APPLIED SCIENCE

By

Edward Bergman

Candidate for the Degree of
Bachelor of Science

June 1942

THESE

Chap. 2.

ACKNOWLEDGMENT

I wish to extend my thanks to all those who have aided me in preparing this paper. Most of all I thank Professor Allen, Professor Rothgery, and Mr. Cosens, all of the Civil Engineering department for their advice and assistance.

PREFACE

In the field of highway engineering there has been great development in technique and practice from the standpoint of both convenience and safety; but one phase of the safety side has been over-looked, that of skidding. It is the author's belief that this paper is the only work of its kind that covers some theory, method of testing, and prevention of skidding on pavements. So far as detail is concerned the paper lacks this quality; but in essence it outlines a survey of the problem.

Originally it was the author's intention to deal solely with treatment to decrease skidding on ice covered pavements, but this problem from a practical viewpoint was wholly a maintenance problem that did not offer any field for diversion. Instead a survey of skidding on pavements under all conditions was chosen and numerous scraps of material found in reference sources were accumulated and compiled under the title of this thesis. A lack of equipment did not enable the author to conduct any personal experiments but from the information obtained it is his belief that some worthy conclusions and results were obtained.

Edward Bergman

Michigan State College
June 1942

Treatment to Decrease or Prevent Skidding on Pavements

Introduction

Skidding is a thought that is not borne in mind by the designers of roads and pavements in states of a topographical nature like Michigan and other states where they do not have to contend with sharp curves, hills, and natural obstructions, but its importance is not to be overlooked because even here in Michigan treatment to prevent this hazard has proven very effective. In the winter of 1928-29 there was a reduction of 30% in traffic accidents in the state highway system due to ice control and sanding on straightaway as well as hills and curves. That there are many serious accidents caused by skidding is shown by the statistics of the Travelers Insurance Company of America. Their figures show that there are approximately 1,500 persons killed annually and 70,000 persons injured each year in the United States by accidents attributed, directly or indirectly, to skidding on road surfaces that were slippery. While some of these accidents were no doubt caused by motorists driving at excessive speeds, it is reasonable to assume that more drivers exercise extreme caution in winter and at times when the pavement is prone to be slippery. The psychological effect is an ever present source of discomfort and uneasiness to the motorist even though no accident occurs.

A rather curious problem arises when motorists are unduly cautious on curves with great super-elevation because if these curves are encountered at a speed less than that for which they were designed, the car may slide sideways down the elevation. This is not an impossible case as has been shown by records because many of the aforementioned accidents occurred on surfaces where there was practically no friction between the tire and pavement.

The qualities to be possessed by a road surface that allows travel in a safe and proper manner are few but essential. The surface should have sufficient roughness to provide friction enough between tires of the vehicle and the road to provide for safe starting, stopping, and steering of such vehicles. If a surface has these qualities there should be no skidding when the vehicle is properly operated.

Theoretical considerations.

Before tests were actually conducted on pavements to measure their ability to resist skidding some theoretical work had been done. Fortunately the theory was substantiated by the actual tests, so it might be well to mention the elements of theoretical consideration.

The amount of resistance offered by the surface is measured by its coefficient of friction which is the ratio between the force parallel to the road surface and the normal force of the tires on the road when skidding is impending or actually taking place. If the skidding is impending the coefficient is called the coefficient of static friction, while if the movement is actually taking place the coefficient is called the coefficient of kinetic friction. There is no relationship that exists between static and kinetic friction when applied to tires on pavement surfaces. This fact alone proves that nothing may be gained by experimentation using only static friction as has been reported by some investigators. This point is used in advertisements for some paving materials and offers good, true evidence but it shows nothing of a practical value.

The reason for variation between the two types is due to the fact that the total frictional resistance is the sum of the frictional resistance between the two surfaces plus the resistance offered by the interlocking of minute particles of rubber with equally small projections on the pavement surface. The more rigid particles on the surface tend

to shear the rubber in the tire. This actually occurs when a quick stop produces skid marks, which are ravaged particles of rubber sheared from the tire. The foregoing discussion is true when the pavement is dry but add water to the surface and important changes occur. On a wet surface this actually acts as a lubricant and unless it is squeezed or squeezed out from the surface it will separate the tire from the surface and skidding will result. If speeds over 25 or 30 miles per hour are used there will be no removal of the water and consequently no skid protection. When this water is trapped between the tire and the surface skidding resistance drops off sharply.

There are however many variables affecting skid resistance. The skid resistance, of course, varies from pavement to pavement and may also on the same pavement when conditions of load, moisture, and speed are varied. Professor Hoyer of Iowa State College, holds that there are eleven factors, other than the inherent properties of the surface itself, that affect the skid resistance. Of these factors, the type of skidding--straight skidding, side skidding, or impending skid--, the angle of inclination in side skidding, tire pressure, condition of tire, type of tire tread, and condition of brakes; also the temperature and moisture of the pavement surface; and the speed and load, are of prime importance.

Relative to the pavement surface it may be generally

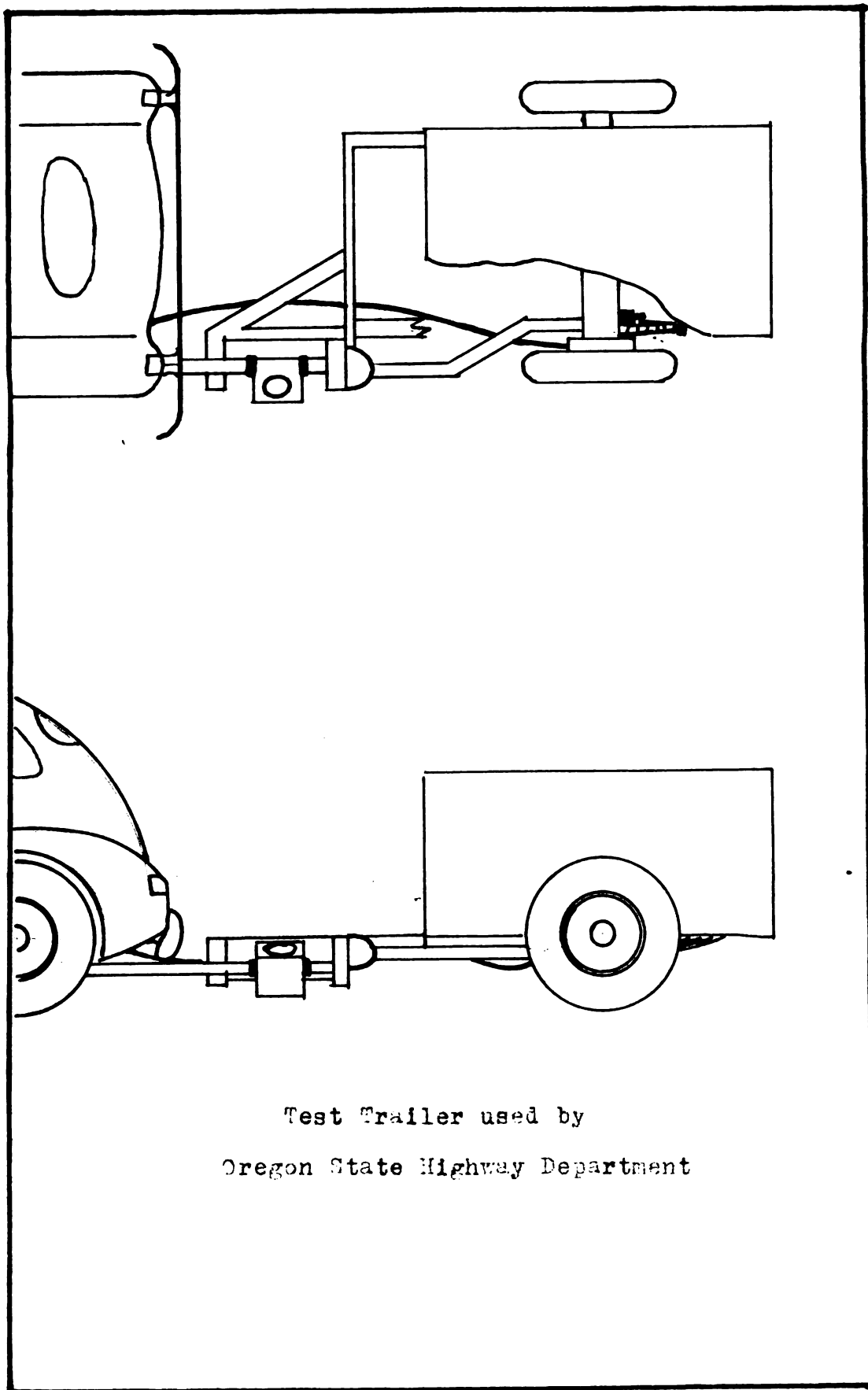
stated that the coefficients of friction are higher on fine or sandy textured surfaces than on the rougher surfaces when the surfaces are dry. On a smooth surface the tire tends to hug the pavement and to maintain almost constant contact. On rough pavements this constant contact is not so well maintained and the tire tends to clear the pavement between the individual projections. On wet pavements this contact is no longer maintained due to the lubricating film of water. Fine or sandy textured pavements have relatively high coefficients of friction when dry and relatively low coefficients when wet, while the coarser surfaces have coefficients intermediate in value and practically the same either wet or dry.

Method of testing for friction coefficient.

A number of methods and types of equipment have been used to determine the coefficients. There has been some feeble attempt at standardization of means and method of making this test but with no success. A description of the equipment and method of test as used by the Oregon State Highway Department will be presented because it is relatively simple and very accurate. It is an adaptation of the equipment used at Iowa State and probably represents the best equipment of its kind.

On the following page is a drawing of the two wheeled test trailer as used in Oregon. It was built from the rear axle and a portion of the frame of a late model automobile. The spring and shock absorber assembly were intact. The torque tube was cut off near the differential and the right wheel brake removed. This allowed the right wheel to act as an idler. The towing hitch was placed in line with the left wheel and this allowed the towing and skidding forces to act in the same plane.

For towing a bolt with a ball and socket connection were used with a slight offset to prevent tracking in line with the wheel of the towing vehicle. Horizontal and vertical forces were absorbed by ball bearing rollers placed in these directions on one end of the tow bar. With this arrangement only the direct longitudinal force required to pull the trailer was transmitted through the dynamometer.



Test Trailer used by
Oregon State Highway Department

The integrating dynamometer is a device developed by Iowa State College and is a very accurate means of measuring a tensional force. It consists of a box containing an elliptical spring that changes shape when a pull is exerted upon it. Its short diameter is proportional to the force applied. By a means of rotating discs and revolution counters it is possible to get a ratio of the force applied and the resisting force.

The operation of the brake on the trailer was manipulated from a master cylinder within the car itself, its connection taking place through a flexible hydraulic hose. The tires were retreaded to a smooth finish, to represent the worst operating conditions. The box above the axle was divided into compartments with a dead load of 1,600 pounds. The compartments prevented shifting of the load, and assured a uniform wheel load of 800 pounds. The tires used were 5.50 by 17 inches and kept inflated at 32 pounds per square inch.

Professor Rothberg of Michigan State College designed a similar trailer but with the additional provision that allowed the wheels to be turned at right angles to the pavement for additional skidding tests.

After reviewing the various methods of making a test for friction using equipment as of above there are certain set rules for testing. Tests should be made at a number of different constant speeds, say 10, 20, 30, and 40 miles per hour. It has been shown by tests that at speeds greater than 40 miles per hour there is little appreciable

change in the coefficient. A great enough number of trials must be made at each speed to obtain a stabilized average. Of course it is imperative that the test be made over a representative stretch of the surface in order to get usable results. The test wheel of the trailer should track in line with one of the paths followed by vehicles travelling the road.

Operation of the brake and dynamometer have to be handled by an operator in the towing vehicle who, upon signal from the driver that the correct speed has been attained, will set the brake and start the dynamometer in use. A repeat trial over the same course should be run with the surface in a wet condition. In this way the temperature effect would be minimized.

Results of tests on various surfaces.

Although not a great deal of recorded material is available on the results of friction tests those that have been performed are complete enough to show how different surfaces behave and their characteristics. Those surfaces tested include portland cement concrete, bituminous, brick, and oil mat. A consideration of each type with statements of its characteristics will follow.

Portland cement concrete surfaces: This type of surfacing is probably the most existant type of pavement in use today in the United States. Its standard of quality is very uniform and it is being more widely used and more standardized than any other surfacing. From tests conducted on portland cement concrete relative to its skidding properties it was found that when wet it only had a skid resistance equal to that of certain bituminous surfaces; but it did have the most consistent properties when tested in both the wet and dry state. The method of finishing is an important factor in determine the amount of skid protection. If the surface is finished to a smooth top the cement paste drawn to the surface forms a smooth, hard layer that allows slipping to take place. The finish should bring the sharp sand grains to the surface in order that a gritty pavement top will result. This may be accomplished by using a canvas belt, operated laterally across the pavement at the time of initial set of the concrete. This also breaks

up the coating of cement paste that might form on the surface. If this paste is allowed to stay on top of the pavement it not only is moderately smooth to begin with, but is polished to a fine finish by the action of traffic.

If, at the time of finishing, excessive manipulation, vibrating, or floating is permitted this results in a slippery surface and should be avoided. Proper handling of equipment and only a reasonable amount correct brooming and belting will make for a very non-skid surface.

The coefficients of friction of concrete surfaces range from .4 to .9 for straight skidding and from .5 to .8 for sidewise skidding. The coefficients of dry, rough textured portland cement concrete pavements range from .8 to 1.0 for straight skidding and from .9 to 1.0 for sidewise skidding.

A comparison of friction coefficients when the pavement is slightly wet and when it is dry show a greater variation as to range on the dry pavement than on the wet. This effect of moisture on the pavement as previously stated is substantiated by the tests. It shows that the friction coefficients arranged themselves directly as the coarseness of the surface texture; an inverse relationship existed when dry.

Bituminous pavements: These pavements exhibited a more wide range of coefficients than any other surface tested. Where the coefficients were low they were very much so. This state of condition is very bad because once the motorist is

subject to this slippery surface he is prone to believe that all such surfaces are just as bad. This is especially true when bituminous pavements are wet. That this contention is not altogether false was substantiated by test, as some of the pavements tested were dangerously slippery when wet. But in another respect this contention carries no truth because on some of the surfaces tested the coefficients of friction on wet pavement were substantially higher than on any other type of pavement tested. Professor Moyer as well and many other engineers believe that it is possible to build a bituminous road that would be as skid proof as any road in use today. Of our latest bituminous surfaces built in the United States most of them are relatively skid proof.

The reason for skidding on these surfaces is that a layer of excess bituminous material had been present on the surface. This may have been caused by the use of too much material or a too slow curing asphalt. Those pavements tested that had the greatest resistance to skidding were the ones that were covered with sharp, hard sand or finely crushed rock that was bonded in place by the bituminous material acting as a cement. This sandpaper like finish offered high resistance to skidding.

The friction coefficients for high type surfaces of an asphaltic nature when in a wet condition were higher than that obtained on any other surface tested. Very low coefficients were encountered on penetration macadam when wet, especially if a soft seal coat was used in its top.

From data collected on the surfaces tested it was shown that there was a higher coefficient on those surfaces that had a greater hardness than those that were soft.

Brick pavements: Tests on brick pavements were carried on exclusively by Professor Moyer and the test results showed that brick has a coefficient (as a whole) slightly less than that of portland cement concrete. The modern paving brick of today is quite skid resistant. This is due to new manufacturing methods. De-aired, vertical fiber, and lugged bricks have a finish that will stand up and is very gritty in nature. With these properties and proper installation using a hard filler the resultant pavement will be very safe.

Oil mat surfaces: These surfaces are different from bituminous macadam in thickness only. In the oil mat surface the heavy surface and base is omitted. The friction coefficients of these surfaces are approximately the same as those of bituminous macadam except that they are more prone to bleeding and consequently are more slippery as they grow old.

Treatment to prevent or decrease skidding:

It is not probable that the roads in the United States today will be replaced by new roads that are of a skid resistant nature; but that many of the dangerous ones can be improved by treatment or maintenance is something that can be anticipated. Professor R.A. Moyer of the Iowa Engineering Experiment station performed tests on various pavements and proved that any surface can be made virtually skid resistant with treatment. He showed too that by proper maintenance the effects of snow, ice, and mud can be controlled to make for safe driving. The speed factor is a thing however that must be controlled by driver education. This has far flung effects because on wet surfaces at 40 miles per hour the friction available is only $1/4$ to $1/5$ as great as at 10 miles per hour. These surfaces might be no more safe than if ice covered roads if they offer little resistance when wet.

The correction of this problem of treating or resurfacing a pavement to make it skid resistant is one of a relatively simple but costly nature. If old pavements are to be resurfaced the prime requisite is to lay a covering that has a fine sharp texture. In concrete this may be accomplished by the finishing operation. In bituminous covering it is necessary to control the type of cement, the quality of the aggregate, and most of all the means of construction. The amount of tar, cut-back, or whatever might be used must be hard, of low penetration,

and so applied that it does not come to the surface due to wear or heat from the sun. A more complete description of the exact means of accomplishing this end will be discussed later.

Probably the most dangerous condition of a road is when it is covered with mud, snow, or ice. It makes no difference as to how the road may be constructed, these elements render it unsafe. Control of the menace caused by these factors is clearly a maintenance problem and methods of its treatment shall now be put forth.

The first rule in caring for a condition where ice or snow is to be removed is promptness. If ice is allowed to form, or sleet permitted to pile up the frictional resistance will only be about $1/5$ that provided by a concrete surface. If sand or cinders are applied at the time which freezing begins, which is near the freezing temperature, the frictional resistance may be raised 3 or 4 times that of the icy surface. When these abrasives are applied at a relatively low temperature they do not become embedded in the ice and the resultant action of wind and traffic may result in their removal from the surface. If temperatures drop suddenly, or sleet falls making it impossible to treat the pavement at high temperatures, the abrasives may be heated or mixed with calcium chloride to provide the same effect as application at a higher temperature. Direct application of rock salt or calcium chloride to the ice often times results in detrimental effects to the pavement surface

in that it will cause scaling of concrete or unravelling of a bituminous surface. It is claimed by the manufacturers of calcium chloride that the scaling of the concrete is not due to the salt but caused by the formation of small particles of ice in the porous surface, the ice expanding and breaking the concrete. But nevertheless it is recommended that instead of using any salt, either directly or mixed with sand or cinders, that the abrasives be mildly heated and applied in this manner. This is the suggestion given in reference only to portland cement concrete surfaces.

But that treatment of abrasives is effective was conclusively shown in tests conducted by the Iowa State Highway Department in tests made at Fort Dodge, Iowa. The report states that "all dry abrasives not treated with calcium chloride proved to be ineffective and were easily brushed off the road by the tires." As to the size of the abrasives there was no difference in their skid resistance when in the untreated state; but when treated with calcium chloride the coarse cinders were 42% more efficient than the untreated cinders, the same held true for sand except that the betterment was 31%.

The use of calcium chloride in connection with abrasives is for two purposes; to embed the sand or cinders in the ice, and to keep stock-piles of abrasive material in a condition where they will not freeze up. The use of stock-piles of abrasive material is an efficiency measure

to facilitate more rapid spreading of the material from sources not near any large supply of abrasives or sand. The use of calcium chloride is advised over the use of salt as a mixture for treatment preparations because of its "anti-freeze" properties. Calcium chloride may provide protection against freezing, at any temperature down to minus 53° F., while no protection is possible with sodium chloride below minus 6° F. Calcium chloride has the additional property that it is a much more rapid "melter" of ice than salt.

As to the type of abrasive to use there are many that have been used with success. The most commonly used abrasives are cinders, fine sand, slag, ore, washed cord, with all the fines taken out, crusher run stone and small run of bank gravel, even sawdust has been used with some results. The most practical aggregate is one which does not pulverize readily under traffic and which does not contain enough fines to roll up or bulk when saturated with moisture under traffic conditions. Neither can it contain particles large enough to be a danger to the traveling public. If cinders are used they should be free from any injurious chemicals which might affect the pavements, or any foreign substances which might injure the passing vehicles.

The presence of snow on a pavement is an important item included in the consideration of skidding. Although snow has from 2 to 3 times the skid resistance of ice, its treatment should be rapid in order to prevent its turning

to ice. Even though snow does offer this greater resistance to skidding the driver of an automobile under most conditions cannot be sure that ice is not present, or at any rate beneath the snow. The glazing effect of snow that makes it so difficult to distinguish from ice seems it necessary to apply sand and cinders at intersections, on hills, and on curves as soon as the snow becomes packed. The usual maintenance procedure of most of the highway departments of the United States is to start snow removal at the same time the storm starts and to continue it until the snowing has ceased.

A skidding problem that is not rarely thought of is the one where mud acts as the slipping medium, but mud on a pavement constitutes a serious hazard in wet weather. The mud that becomes scattered on pavements usually comes from the shoulders of the road, from muddy side roads, farm drives, or field entrances. The treatment of this problem is simple and should be a normal procedure. If gravel coatings are applied to the muddy portions it will bind with the mud and hold it in place.

A brief summary of what several states do to control skidding in relation to the types of surfaces used now and their maintenance practices might be of interest. Kansas: A slightly different approach to the skidding problem has been taken by Kansas. They are investigating means of eliminating the oil streaks caused by drippings from cars at the quarter points of roads. It has been found that

these streaks are conducive to skidding. Also on curves the rigorous use of transition curves to eliminate centrifugal forces which often times induces a skid, is being used.

Wyoming: Highway construction practice in this state favors the use of hard surfaced bituminous types. To achieve this, rapid curing oils were used with a hard asphalt and sharp, clean sand used as a filler. Roads of old construction were constructed with a slow curing cut-back that had a tendency to soften in hot weather, allowing the aggregate to settle below the surface leaving a slippery film of bituminous material on top.

Their maintainance is limited to spreading sand, cinders, or coal slack on hills and curves during the winter as times almost their entire road system is ice covered.

Virginia: Experimentation by the Virginia Department of Highways has resulted in the development of a non-skid pavement that is meeting with much success. A special test section on U.S. Route 1 was constructed over the old concrete surface. The cover was sheet asphalt and was applied on a portion of the road that had proved to be somewhat slippery during rain and heavy fog.

The elements of the treatment and its means of construction are as follows: One quarter gallon of cut-back asphalt was heated to a temperature of 100° F. This binder was prepared from an asphalt having a penetration of 35-100 mixed with naphtha in the ratio of 2 parts of asphalt to 1 part naphtha. A covering of slag was immediately applied at a rate

of 20 to 22 pounds per square yard and no brooming was permitted. This top was then rolled lightly with a 5 ton roller and no traffic permitted to travel on the surface for 72 hours. The excellent results obtained seem to indicate that the time the traffic was kept off was well worth the trouble because this allowed the volatile materials in the asphalt binder to escape.

Winter maintainance in Virginia consists of spreading cinders, coarse stone dust, and sand with an admixture of calcium chloride or salt at a rate of about 75 to 100 pounds to the ton.

Texas: Because of the heavy rains in this state the presence of water on the surface of roads travelled at high speeds has been the source of a skidding menace that has been taken care of by the method of construction of their highways. When finishing concrete roads it is required that they be belted at the time of initial set in order that the sharp sand particles be brought to the surface and small lateral grooves be left in the concrete to facilitate rapid runoff of the water. This has produced a very highly non-skid surface.

Colorado: The State Highway Department of Colorado has achieved a non-skid surface in their bituminous road mix pavements. They attribute their success to control of the amount of asphalt used. By using only enough of this to the essential binding qualities needed, no bleeding will result. A seal coat is placed over this main course containing a cover

stone which provides a gritty surface that is very resistant to skidding.

From this slight review of what various states do to control it shows that there is some variation in the methods of constructing pavements; but there is quite consistent practice in maintenance.

Conclusions.

1. Sandy textured surfaces have a high coefficient of friction when dry; but a relatively low coefficient when wet. They are better than glazed surfaces in either case. In the wet condition however, they have a lower coefficient than the medium coarse pavements.
2. Glazed surfaces when wet have the lowest coefficients of any surface.
3. Lateral grooves in a surface provide for easy run-off of water and by so doing make for a surface that provides about the same skid resistance in either wet or dry weather.
4. An open-type asphaltic surface is more resistant to skidding because it allows water to drain off readily.
5. The coefficient of friction decreases with an increase in speed.
6. In maintenance to remove ice, it is better to treat the whole road rather than just the curves, hills, and intersections.
7. Public safety demands treatment or maintenance of slippery surfaces regardless of price or detriment to pavement.

A PROPOSED METHOD FOR DETERMINING THE SKID- RESISTANT PROPERTIES OF A PAVEMENT SURFACE

It has probably been the desire of some individual or some group of individuals to know about the skid-resistant characteristics of a certain pavement surface at some particular time. Due to a lack of equipment or time it was not possible to be enlightened upon the subject, however. This has probably occurred many times to a county, or small town road commission but due to the expense it was not possible to obtain the information. The author shall now present a simple method for obtaining this information in hopes that it might offer a suggestion to someone to carry on the work.

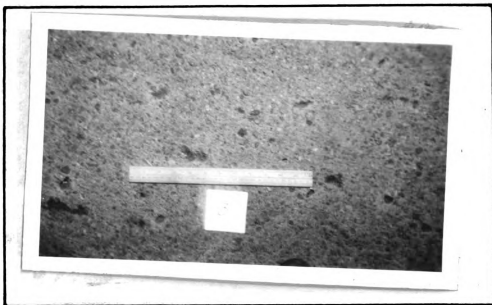
First the project should be placed in the hands of some research board such as the Bureau of Public Roads in order that it might be effectively handled. The duty of this organization would be to run test trials on the various surfaces with equipment as previously described. Having this information pertinent to the type of surface, its method of construction, constituents, finish, and coefficients of friction at various speeds on both wet and dry surfaces; it would then be required to photograph the surface by some standardized method. This could be best accomplished by taking a 5 by 7 photo of the pavement with a ruler lying on the surface and the full 12 inches extending over the whole length of the picture.

This picture with the information concerning the pavement would give a good idea of its exact surface qualities.

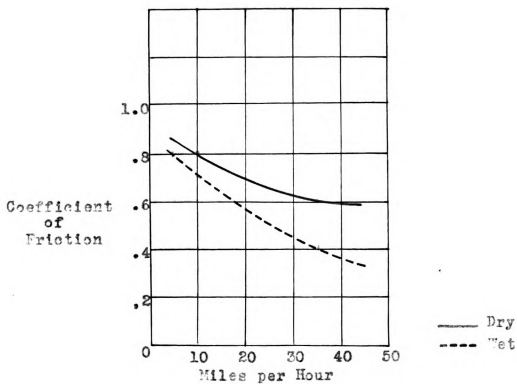
If a complete series of these pictures were taken and compiled in some orderly form and distributed to all road agencies or bodies they would have a means of comparing their pavements against some standard. All that would be required of them would be to take a photograph of their pavement in question, enlarge or reduce it to the required size, and compare it to one of the standard photographs.

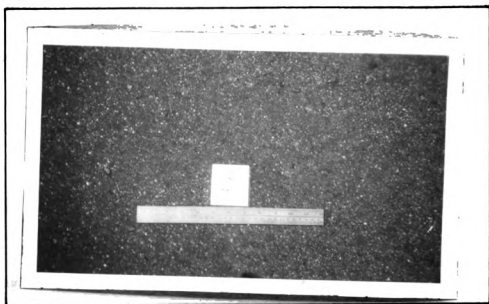
The method of comparison would be to first fit their pavement into the proper class, i.e. either concrete, bituminous, oil mat, etc. This being done then the photograph could be matched against all the pictures in this class and when the one most nearly the same is encountered it might be quite accurately assumed that the surface characteristics of the two would be the same.

On the following pages are some photographs taken by the author and compared as explained above to similar photographs taken by the Oregon State Highway Department, which are shown in their bulletin Skid-resistant Characteristics of Oregon Pavement Surfaces. Accompanying each photograph is a graph of the friction coefficients as they vary with speed, these being taken from the Oregon report.

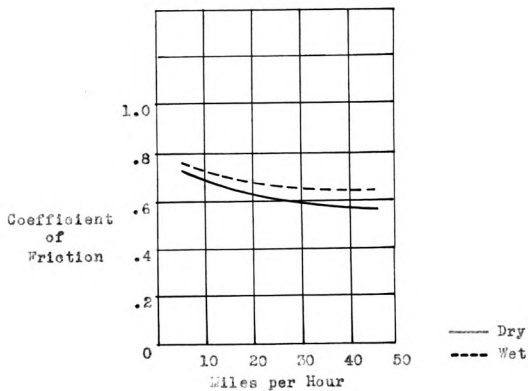


Photograph of Concrete on
College Drive on M.S.C.





Photograph of Penetration Macadam
on Bogus St., East Lansing, Mich.



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