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## GLADHEID VAN TEER- EN ASPHALTWEGEN.

T. H. S. BIBLIOTHEEK DELFT.

NIX-BANDOENG.

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## GLADHEID VAN TEER- EN ASPHALTWEGEN.

Met het oog op de bezwaren, welke het verkeer (vooral dat in physieke tractie) ondervindt van de gladheid van teer- en asphaltwegen, en de daartegen te nemen maatregelen, is door het Dag. Bestuur o. m. een onderzoek ingesteld naar de ervaringen ter zake, in het buitenland gedaan.

Tot nu toe zijn ten aanzien van een en ander mededeelingen ontvangen van:

1e de „Association Internationale Permanente des Congrès de la Route" uit Parijs;

2e het „Ministry of Transport" uit London;

3e het „Bureau of Public Roads" uit Washington; en

4e de „Asphalt Association" uit New-York.

Bedoelde mededeelingen vinden hierachter onverkort een plaats.

Het hieruit sprekende zeer in het kort weergegeven, wijst uit:

1/ dat in zekere mate ook in den vreemde bezwaren van de gladheid van teer- en asphaltwegen worden ondervonden, maar dat deze bezwaren niet van overwegend belang worden geacht;

2/ dat de gladheid eener wegverharding voornamelijk veroorzaakt en beheerscht wordt door het zich los op de slijtlaag bevindende vuil, en dat het dus aanbeveling verdient door geregeld schoonmaken de verkeersstrook zooveel mogelijk vrij van dit materiaal te houden;

3/ dat voor het autoverkeer, naast het blijven aandringen op voorzichtigheid bij de autobestuurders, de algemeene invoering van 4-wiel-remmen het middel tot vermindering van het slipgevaar op gladde wegen is; en

4/ dat in verschillende landen ter bestrijding van het bezwaar in kwestie voorgestaan en ook voorgeschreven wordt:

*a/* de verwerking in het bovenste gedeelte van teer- en asphaltslijtlagen van veel split, tot $12^1/_2$ kg/m² toe;

b/ de opbrenging van een (teer- of asphalt)huid op bestaande teer- of asphaltslijtlagen, in welke huid vóór de verharding zooveel mogelijk split van $^1/_2$ tot 1 cm. korrelgrootte wordt gewalst;

c/ het gebruik van steenslag met een maximum afmeting van 3 cm. inplaats van split als indekmateriaal;

d/ de weglating van de (veelal aangebrachte) asphalthuid op asphaltsteenslag-slijtlagen;

e/ de aanbrenging van smalle groeven in teer- en asphaltslijtlagen; en

f/ de vermindering der dwarshelling aan de oppervlakte der verharding.

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Association
Internationale Permanente
des
Congrès de la Route.
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Paris.

*Monsieur le Président,*

En réponse à votre lettre du 25 Novembre 1925, nous avons l'honneur de vous donner les renseignements ci-après :

La question du glissement sur les chaussées en asphalte comprimé des rues, comme sur les chaussées en béton bitumineux et asphaltique des routes, a effectivement préoccupé l'opinion publique durant l'été dernier, et j'ai trouvé le même souci chez nos voisins d'Angleterre.

Un certain glissement est inévitable sur toutes les chaussées lisses et unies ; il n'a généralement pas grande importance et n'offre guère d'inconvénient sauf losque certaines conditions climatériques se présentent, telles que brouillard se condensant ou légère pluie commençante. Alors, les voitures automobiles, si elles sont amenées à freiner, peuvent déraper et, si elles marchent vite, ce dérapage peut les exposer à des accidents. Ceux-ci sont d'ailleurs beaucoup plus rares lorsque les voitures comportent le freinage sur les 4 roues.

Quoi qu'il en soit, les inconvénients signalés ont retenu l'attention des pouvoirs publics car, même en prêchant la prudence aux conducteurs, il faut chercher les moyens de leur assurer une surface de roulement offrant le plus de sécurité possible.

Aux abords de Londres, on a pris le parti, l'été dernier, de badigeonner la surface de la chaussée avec une mixture de bitume et de goudron fluidifiée par la chaleur que l'on recouvre ensuite d'une bonne couche de menues pierres, et l'on fait passer le rouleau compresseur avant le refroidissement.

En France, nous étudions divers systèmes, soit pour incorporer des petits cailloux en plus grande quantité à la surface du béton bitumineux, soit pour strier la surface du revêtement asphaltique.

En définitive, des solutions techniques sont en cours d'expérimentation ; mais, en tout état de cause, il ne faut pas exagérer les inconvénients relatés, et il faut conseiller aux usagers de la route de ne pas oublier les précautions indispensables lorsqu'ils se trouvent sur une route de ce genre au moment où commence une pluie ou une condensation de brouillard.

Espérant que ces renseignements vous satisferont, et restant d'ailleurs à votre disposition, nous vous prions d'agréer, Monsieur le Président, l'assurance de nos sentiments les plus distingués.

Le Secrétaire Général

Ingenieur en Chef des Ponts et Chaussées :

P. Le GAVRIAN.

Ministry of Transport.
Roads Department.
—
London

*Sir,*

I am directed by the Minister of Transport to refer to your letter of 25th November, 1925 (No. 296 H/f R) concerning slippery road surfaces and requesting this Department to furnish you with information regarding its experience with such road surfaces in England and the precautions which are taken to render them more suitable for horse-drawn traffic.

In reply I am to say that the question has for some time engaged the attention of officers of this Department and investigations have been made into various methods of overcoming the slippery nature of bituminous road surfaces, including experiments with surface dressings and different methods of road construction.

As to remedial measures for application to existing surfaces the attached circular letter, which was issued to all County Surveyors, gives the required information, and with regard to the modifications of method to be adopted in the case of new work, such clauses as the following are being inserted in specifications:

„Before final rolling the whole surface is to be evenly covered with dry clean granite chippings compressed into the surface while still hot, and before the final set has taken place, then finally dusted with Portland cement. Granite chippings as specified above to be spread at the rate of 1 ton to 100 yards super".

Another change of practise directed to the same end is the introduction of a larger mineral aggregate (broken granite, etc.) into the asphaltic or bituminous mixtures, so that the surface may have the character of a mosaic rather than the fine-grained finish which is common to many recently constructed carriageways.

I am, Sir,
Your obedient Servant,
. . . . . . .

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Ministry of Transport.
Roads Department.
—
London,

## ACCIDENTS ON HIGHWAYS.

You will have noticed, from reports appearing in the Press day after day that many serious accidents are occurring on the roads of the country, and that a very common cause assigned for these accidents is the skidding of the vehicle concerned owing to the slippery condition of the highway.

From numerous enquiries and inspections which have been made by officers of this Department, it has been ascertained that accidents mostly occur at or near road junctions, the inference being that the skidding of the motor vehicle is occasioned by the driver having unexpectedly to reduce speed in consequence of another vehicle crossing his line of route.

The large numbers of rubber-tyred vehicles now upon the highways have the effect of polishing *any* surface in a remarkable degree, and moreover every vehicle in its travel deposits a small quantity of oil on the road. When the surface is slightly wetted by a shower of rain or the deposit of heavy dew, this, in conjunction with the wide spread distribution of oil particles upon the polished roadway renders driving extremely difficult when it becomes necessary to check the speed of a vehicle by the sudden application of brakes.

If the roads of the country are to be maintained in a condition reasonably satisfactory for mechanically propelled traffic, they must continue to be made impervious to moisture, but it is quite possible to so maintain them and at the same time to give a roughened surface and thus greater wheel friction.

May I venture to express the hope that, to obviate the risk of skidding on all roads under your supervision, you will see that the surfaces (whether composed of asphalte, bitumen, tarmac, tarmacadam, or grouted or tar-painted aggregates) are treated with a suitable heated liquid dressing, incorporating into this the largest possible quantity of clean sharp crushed gravel or granite chippings. Experiments which have been made go to prove that the best results are obtained by the use of 1/4″ to 3/8″ material, and it will doubtless lead to economy and efficiency if a roller be used immediately spreading operations are complete.

This procedure should apply to existing surfaces and to all road works that may be undertaken in future, provision being made for such surface dressing in all subsequent specifications, no matter what the material used in the resurfacing may be.

Whilst this requirement will have the effect of somewhat adding to the cost of road works, it may reasonably be expected that additional durability will result therefrom, but in any case you will agree that in our endeavours to secure the best possible system of highway maintenance our first aim must be to protect the travelling public from injury, by doing everything in our power to minimise the possibility of accedent.

It may well be that you do not experience any difficulty in travelling over your roads with your own car under almost any weather conditions, but this is by no means a safe criterion from which to draw conclusions. It must be remembered that the number of motorists is being added to by upwards of 1.000 per week, many of whom are quite inexperienced and are often in charge of vehicles of which they have little knowledge, and when something unexpected occurs which causes them suddenly to apply their brakes the results may be disastrous to themselves, and not infrequently also to occupants of other cars which may be closely following.

It is of so much importance that everything possible should be done at once, that I hope you will immediately examine every road under your charge and take such action as I have had the honour to suggest.

Yours faithfully,

(sd.) HENRY P. MAYBURY.

Director-General of Roads.

U. S. Department of
Agriculture.
Bureau of Public Roads.

Washington D. C.

*Dear Sir.*

We have received your letter of November 25 in reference to the slipperiness of bituminous highways for horse-drawn traffic.

In the early years of the use of bituminous materials in the surface treatment or construction of highways in this country there was considerable criticism on account of the slipperiness to horse-drawn traffic. However, this did not become a serious matter and it is possible that as horses became accustomed to traveling over such highways they adapted themselves to the smoother texture of the surface, reducing the danger of falling. Under present conditions, of course, our traffic is largely that of motor-driven vehicles and there are some instances where users of such vehicles find the surface slippery to a dangerous extent.

This condition sometimes arises where a heavy seal coat of bituminous material has been applied on a bituminous macadam or bituminous concrete surface which, under continued traffic, develops an extremely smooth surface.

There has been a tendency to reduce the crown of bituminous highways so that now it is common practice to construct bituminous macadam roads with a crown of 3/8 to 1/2 inch per foot, bituminous concrete from 1/4 to 1/2 inch, whereas waterbound macadam and gravel roads which are not treated have a crown of 3/4 to 1 inch per foot. Frequently the seal coat customarily applied to bituminous macadam is omitted for the purpose providing a coarsely granular surface and less danger to traffic. In the surface treatment of highways the use of harder broken stone and slag and larger sizes is preferred for covering material when undue slipperiness is anticipated. In such cases the covering material may range as high as 1 1/4 inches in maximum size.

Trusting that this information on practice in the United States will be of service to you. I am

Very truly yours,

T. H. MACDONALD.
Chief of Bureau.

The Asphalt Association.

New York.

*Dear Sir:*

Replying to your letter of November 25th, I have to advise that the question of slipperiness of asphalt pavements has been raised in this country from time to time but investigation has indicated that it is not as serious a matter as has been supposed by some. In this connection, I take pleasure in enclosing copy of a memorandum we have prepared upon the subject and also reprint of an article published in the "Surveyor" and "Municipal and County Engineer" October 1924.

Hoping that this information is what you wish to secure, I remain.

Yours very truly,

. . . . . . . .

Chemical Engineer.

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The Asphalt Association.

New York.

## NOTES ON SKIDDING.

An analysis of statistics which have been collected relative to accidents on highways reveals the fact that almost a negligible percentage of the total accidents can be attributed to skidding. This fact is of particular interest at the present time because of the agitation being raised in some quarters relative to the slipperiness of certain types of pavements with more or less resultant trouble from skidding.

A recent investigation of Maryland highways disclosed the fact that 90% of all automobile accidents in that state were due to speeding and that none of the fatal accidents was caused by skidding.

In San Francisco where asphalt is extensively used on steep grades, some of them being well over 10%, the city records for 1921 reveal the fact only 3.8% of the total accidents were due to skidding and that of the skidding accidents occurring on asphalt pavements 75% were the result of carelessness. This leaves less than 1% of the total accidents attributable to skidding where the driver was not known to have been careless. In addition to the steep grades prevalent in San Francisco, the climate is such as to favor skidding to the maximum extent owing to the almost constant rains during the winter periods and heavy fogs in summer.

Tabulation of some thousand reports on causes of automobile collisions filed with the Claim Department of the Inter-Insurance Exchange, Los Angeles, shows that only 6% of the accidents were due to skidding and that of these only 1.2% were due to unavoidable skidding.

A rigid investigation by the Iowa State Highway Commission during 1921 showed that out of nearly 5,000 accidents which occurred in that State, only 2.4% were due to skidding.

The United States Bureau of Public Roads has also analyzed the cause of automobile accidents and in connection with a careful investigation of the subject during 1923 in the States of Oregon and Washington reported that in those two States none of the accidents could be attributed to faulty highway conditions.

An analysis of motor vehicle accidents in Connecticut made during the current year by Prof. John. C. Tracy, of Yale University showed that 70.5% were due to the fault of operators, 22.8% were due to the fault of other persons, 4% were due to the fault of defective equipment and 2.7% were due to all other causes.

From the foregoing it is evident that skidding may be considered as only a minor cause of highway accidents and that the problem of producing less slippery pavements is not as urgent as some engineers have been led to believe.

## Asphalt No More Slippery than Other High Type Pavements.

An impression, perhaps fostered by competing industries, has in some quarters developed to the effect that asphalt pavements are inherently more slippery than most other types of pavements. From the limited investigations of the subject which have been made in this country, this impression appears to be unfounded although it is probably true that some asphalt pavements are more slippery than others.

It appears that skidding occurs when the tires of a motor vehicle are caused to lose their grip upon the pavement surface. The coefficient of friction between tire and pavement contact is a measure of the non-skid qualities of the surface over which the wheels pass. The greater the coefficient of friction the less the danger of skidding. Recent experiments were conducted in California for the purpose of determining the relative non-skid merits of certain types of pavements under varying conditions at various ages and under various weather conditions. The conclusion to be drawn from these tests are (1) there is very little difference between the non-skid qualities of the various types of pavement tested; (2) coatings of oil, wet clay, adobe or silt make pavements skiddy; (3) slight moisture loosens the surface coatings and brings about conditions most conducive to skidding; (4) skidding is dependent to a greater extent upon the coatings on the pavement than on the type of pavement itself; (5) increased rains cleanse the pavement and reduces the danger of skidding.

The following coefficients of friction have been determined for various types of pavement under different surface conditions:

Western Highways Builder, March 1924.

**Coefficients of Friction Under Various Weather Conditions.**

| Condition | Hydraulic Concrete | Asp. Con. Coarse | Asp. Con. Fine | Sheet Asphalt |
|---|---|---|---|---|
| Dry as taken from Highway. | 0.783 | 0.806 | 0.789 | 0.723 |
| Wet, Condensed Fog or Mist. | 0.579 | 0.665 | 0.658 | 0.592 |
| Wet, Heavy Rain . . . . | 0.974 | 0.890 | 0.930 | 0.832 |
| Dry After Heavy Rain . . | 1.051 | 0.997 | 0.979 | 0.975 |

**Coefficients of Friction With Various Foreign Materials on Surface.**

| Material | Hydraulic Concrete | Asp. Con. Coarse | Asp. Con. Fine | Sheet Asphalt |
|---|---|---|---|---|
| Sacramento Valley mud . . | 0.230 | 0.283 | 0.371 | 0.310 |
| Berkeley clay. . . . . . | 0.336 | 0.354 | 0.353 | 0.354 |
| Black Point cut-off red clay. | 0.265 | 0.354 | 0.266 | 0.327 |
| Willows soil. . . . . . | 0.221 | 0.283 | 0.266 | 0.336 |
| Hollywood soil . . . . . | 0.433 | 0.450 | 0.415 | 0.380 |
| Lubricating oil . . . . . | 0.389 | 0.398 | 0.212 | 0.300 |
| Lubricating oil and water . | 0.318 | 0.300 | 0.194 | 0.274 |
| Grease . . . . . . . . | 0.203 | 0.177 | 0.150 | 0.194 |
| Water and grease . . . . | 0.176 | 0.186 | 0.132 | 0.177 |

From the foregoing it would appear that in general asphalt pavements are but slightly if any more slippery than concrete pavements and that when dry or thoroughly wet little danger is to be expected from slipperiness of the surface. Slipperiness is primarily caused by deposits of extraneous material on the pavement surface which reduces the coefficient of friction between the tire and the pavement if the extraneous material is moistened by a light rain or sprinkling.

## Avoidance of Accidents When Pavements are Slippery

Carelessness upon the part of drivers in travelling over a slippery pavement is undoubtedly the cause of most of the skidding accidents. Although such accidents are but a small portion of the total, the driver can materially reduce the number by cautious, careful and common sense driving. Warning signs at dangerous places are of great assistance in this matter. It has been repeatedly advised by Traffic Experts that a reduced speed on corners and curves, allowance of more space to make a deviation from the line of traffic, less snapping and sudden jerking of the steering wheel, the use of low and intermediate gears, avoidance of unnecessary stops and the use of four wheel breaks, all tend to materially reduce skidding.

### General Modifications in Design of Pavement To Reduce Danger from Skidding

Most skidding accidents occur when the vehicle is forced to make a sudden deviation from its previous line of travel and such deviation is most common at corners and curves. Modifications in the layout of curves in the United States which are now being recommended materially reduce the tendency to skid when the pavement is slippery. Among these may be mentioned the banking and widening of curves. The adoption of wider pavements and the lowering of the usual crown also help to minimize this trouble. With regard to the banking and widening of curves the following recommendation recently made by the Superintendent of the New York State Department of Public Works is worthy of consideration.

"At no point, except on village streets or around precipices, should a curve have a radius of less than 500 feet. The minimum vertical curve should have a radius of 200 feet on moderate grades, while a vertical curve at the apex of two 7 per cent grades should have a radius not less than 500 feet. In New York we strive to have not less than 300 feet of unobstructed view at all horizontal curves."

"The radius, however, is not the only factor to be studied carefully, when laying out a curve. In spite of the assertion that banking and widening at curves encourages speeding, I consider that it would be as shortsighted not to bank curves on a modern highway as it would be to attempt to level tracks on a railway curve. Our steepest banking is $1^1/_4''$ to the foot, which means that on short curves 18 feet of pavement is $27^1/_2''$ higher at the outer than at the inner perimeter and the pavement is widened to 22 feet."

"One of the most frequent causes for wrecks on New York roads is the heighth of crown, especially on old waterbound roads which have been given a bituminous surface. These pavements were frequently designed with a crown 1" to the foot."

New York has in recent years designed its pavements with a crown of only $^1/_4''$ to the foot but the State Highway Department reports that this has been decreased to 1/8" to the foot and were it not for the advisability of ridding the pavement quickly of water he would build them with no crown at all.

### Treatment of Pavements to Prevent Skidding

It has been shown that slipperiness on pavement surface is primarily due to a fine film of extraneous materials in a semimoist condition and not to the character of the pavement surface itself. Any method of ridding the surface of accumulations of oil, earthy material, etc., will, therefore, greatly assist in the prevention of skidding accidents. Where possible the roads should be frequently swept or flushed to remove extraneous material and on country roads as is now the custom in England sanding of the surface during rainy periods will also be of assistance. In such cases, for the sake of economy, sanding should be confined to those portions of the road where skidding is most likely to occur, namely, at curves and on down grades. The sand should be of hard clean quartz. If it contains clay or if it is of a soft friable character which will pulverize under the weight of traffic the skidding properties of the pavement may be increased rather than diminished.

### Suggested Modifications in Asphalt Paving Mixtures

Among the various types of asphalt pavements it is probably true that those constructed with a wearing surface of very fine mineral aggregate are more slippery than those constructed with coarser aggregate. Thus the rock asphalt whose mineral aggregates consist mainly of pulverized limestone is more slippery than the sheet asphalt which in turn is more slippery than asphaltic concrete and asphalt macadam. However in the coarse aggregate types of asphalt pavements where a seal coat is required the surface may be as slippery as the fine aggregate types if constructed with very fine or soft mineral aggregate. The use of a limestone aggregate in the pavement surface is particularly conducive to slipperiness and should be avoided where it is desired to produce a non-skid surface. Trap rock, flint and granite are to be preferred.

In some cases on the coarse aggregate asphaltic concrete and the asphalt macadam pavements, it may be desirable to eliminate the seal coat on those portions of the road where skidding is likely to occur. Such practice, however, will probably result in greater maintenance costs on the portions where the seal coat has been omitted.

Sheet asphalt is probably the most popular of all of the types of asphalt pavements although a modification of this type known as fine aggregate asphaltic concrete or modified sheet asphalt has become very popular in certain sections of the United States. This pavement is covered by Asphalt Association Specification A-3 which call for a total of from 20 to 35 % mineral aggregate passing a 5/8″ or 1/2″ screen and retained on a 10-mesh sieve. It is believed that use of the maximum amount of this size aggregate will tend greatly to reduce slipperiness of the surface, particularly if this aggregate is of a hard flinty character. If this type is not in common use in England, it is suggested that it be given a thorough trial in an endeavor to produce a less slippery surface than has heretofore been secured.

J. E. PENNYBACKER.

General Manager.

# A PRACTICAL AND EXPERIMENTAL STUDY OF THE CAUSES OF SKIDDING WITH RESULTS SHOWING HOW IT MAY BE PREVENTED.

Reprinted from October 10, 1924 issue of Surveyor and Municipal and County Engineer London, England.

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The sensation experienced by the occupants of a skidding automobile is so unusual and the results of a skid are very often so spectacular, that the impression prevails in some quarters that skidding is the cause of a great number of automobile accidents. As a matter of fact, a careful tabulation of the causes of automobile accidents in various localities in California shows that a very small number, about 2.5 % during 1922, were due to skidding. Statistics compiled by the National Bureau of Casualty and Surety Underwriters of New York show about 3.4 % of accidents due to skidding, and an analysis of auto accidents in Iowa during 1922 made by the Highway Commission shows that 3.9 % of the accidents were due to skidding.

Skidding occurs when an automobile loses its grip upon the surface with which its wheels are in contact. This grip is obtained by the friction between the tire of the automobile and the road surface, or between the tire and any coating which may be on the road surface.

The study of the causes of skidding is essentially a study of forces. The force which tends to cause an auto wheel to slide along a road surface is opposed by the force of friction between the tire and the surface. As long as the sliding force does not exceed this frictional force, the wheel will not slide. As soon as the sliding force becomes greater than the force of friction, however, the wheel will slide and we have the effect of skidding. If the surface on which the wheel moves is a clean section of highway then the frictional force opposing sliding is the friction between tire and pavement, but if the surface is a highway section on which some foreign material such as dirt, oil or grease is present then the frictional force is the friction between the tire and the thin layer of foreign material on the pavement.

It follows therefore that in order to prevent skidding, we must regulate these two forces so that the force which tends to cause sliding never exceeds the force of friction between the tire and pavement. This can be accomplished practically in two general ways, — first, by using care in driving and various mechanical appliances, thus reducing to a minimum the force which tends to cause sliding, and second, — by providing tires and pavements which show a high coefficient of friction between their surfaces of contact.

In this connection it is interesting to consider the origin of the force which tends to cause sliding. Power is applied to the wheels of a machine through the drive shaft and the axles. This power tends to cause the wheels to revolve and move the car forward. In stopping the car, the power is shut off and the brakes are applied. The brakes are applied in order to dissipate the energy of motion which the car has gained while moving. This is accomplished by the sliding friction between the brake drum and brake band. If the car has attained a high speed and the brakes are applied so hard that the wheels lock, the energy of motion can no longer be dissipated through the sliding friction between the brake band and the drum. At this point we have the force which tends to cause sliding present in large amount and the energy of motion will have to be dissipated by the friction between tire and pavement as the car slides. It appears therefore that the ability of a car's brakes to dissipate the energy of motion through sliding friction between brake band and drum, has a very important relation to skidding.

Recent developments in automotive practice indicate that this particular point has been given very careful consideration. A number of the new models of cars have been equipped with brakes on all four wheel, instead of brakes on the two rear wheels only. It is very evident that with brakes on four wheels, the energy of motion can be dissipated twice as rapidly as with brakes on two wheels, if the same pressure is applied in both cases. It follows that with this increased ability to dissipate the energy of motion through sliding friction the danger of skidding is correspondingly reduced.

Practical demonstrations of the following nature have been made.

A section of street was made slippery by application of some foreign substance, and a car equipped with four wheel brakes was driven toward this section at a speed of about 30 miles per hour. When the car reached the slippery street the gears were thrown out and the brakes applied. The car stopped within a short distance with no appreciable sideways motion and with no sliding of the wheels.

The brakes on the front wheels were then disconnected and the car was again driven toward the slippery street at the same speed as before. The gears were thrown out and the brakes applied as in the preceding case. The car skidded completely around in the street before stopping.

It seems reasonable, therefore, to say that when this type of equipment comes into wider use, the danger of skidding will be reduced many fold, and the number of accidents due to skidding will be even smaller than during the past.

This same question has been approached from a different angle by the automobile manufacturer who equips his cars with the new balloon tires.

The balloon tire has a greatly enlarged diameter and is designed and constructed so as to have great strength under low soft inflation.

The balloon tires have more surface in contact with the road than the ordinary tire, and they are inflated to very low pressures. This increased area of contact gives more traction and consequently reduces the danger of skidding. Almost every driver is familiar with the expedient of partially deflating his tires in order to give increased traction before climbing a steep grade, or in traversing sandy roads. This same idea is put into practice in balloon tires, and careful experiments made by automobile manufacturers indicate that the balloon tire is of great value in the prevention of skidding.

Another refinement in automobile design which tends to reduce the danger of skidding is the attention paid to the balancing of the weight of the car so as to prevent the building up of complicated forces under driving conditions. There has been a noticeable improvement in this feature of automobile construction in the past and the careful attention given to the design of autos today indicates that further improvements in stability with increased resistance to skidding will be achieved in the future.

A careful consideration of the foregoing facts shows that recent improvements in automobile design and construction have reduced the danger of skidding many fold, and as these features are improved and refined in future years, the danger will undoubtedly be even more greatly reduced.

The remaining feature to be considered is the friction between tire and pavement. Much has been said on the relation of various types of pavement to skidding, and some have been led to believe that certain types of highway surfaces are conductive to skidding and are consequently dangerous to drive upon. In order to definitely decide this point, it was determined to conduct a series of exhaustive experiments and obtain accurate information on this subject.

In considering the forces at work in skidding, it is evident that the force which tends to cause the car to slide is opposed by the force of friction between tire and pavement. It therefore follows that if we can measure the friction that exists between an automobile tire and any given surface, we will have a measure of the non-skid qualities of the surface tested.

It was decided that the most accurate measure of the non-skid qualities of various types of pavement could be obtained by making the test on a section of pavement taken directly from service conditions. Sections of various types of pavement surfaces were accordingly taken from streets and highways in widely separated districts throughout California. The size of the sections ranged from 15 to 30 inches in length, and from 10 to 30 inches in width, and great care was taken that the surfaces were in no way cleaned or washed before the test was started. All of the sections of pavement tested were taken directly under the wheels of traffic from roads that had been in service for several years.

To determine the friction between an automobile tire and a pavement, an apparatus was constructed by means of which a section of pavement could be held firmly in place in a level position. A section of automobile tire heavily weighted was then drawn across the pavement surface at a uniform rate of speed and the force necessary to start the tire sliding across the surface was observed. This force represented the force necessary to overcome the friction between the tire and the pavement. From this force the coefficient of friction was calculated. The coefficient of friction offers a convenient measure of a pavement's skid resisting qualities.

In order to duplicate most of the possible conditions in which highways are apt to be found in practice, each type of pavement used was tested under fourteen different conditions, as follows:

Under various weather conditions.

(1) Dry as taken from highway,
(2) Dew, condensed fog, mist or shower,
(3) Light rain,
(4) Heavy rain,
(5) Dry after heavy rain,

With various foreign materials present.

(6) With Sacramento Valley Mud,
(7) With clay from Berkeley,
(8) With red clay from Black Point Cut-off,
(9) With soil from Willows, Cal.
(10) With soil from Hollywood, Cal.
(11) With Lubricating Oil,
(12) With Lubricating Oil and Water,
(13) With grease,
(14) With grease and water.

The tests shown here were made on four samples of hydraulic concrete, four samples of asphaltic concrete, coarse aggregate type, three samples of asphaltic concrete, fine aggregate (Topeka) type, and two samples of asphaltic sheet surface. The average coefficient of friction for each type was used in tabulating the results. It is well to remember that the coefficients of friction will vary somewhat with the individual pavement, but the average results obtained here show very definitely what may generally be expected from each type of pavement.

The results obtained by testing the different pavements under various weather conditions may be described as follows:

### Asphaltic Concrete

(*Coarse Aggregate Type*)

This type for the condition as taken from the highway showed a coefficient of friction of 0.806; after being subjected to the cleansing action of water and allowed to dry this type showed a coefficient of friction of .997.

When this type of pavement was wet to correspond to the condition of dew, condensed fog or mist, the coefficient of friction was .665; when wet during the heavy rain condition, the coefficient of friction was .890.

### Asphaltic Concrete

(*Topeka Type*)

This type for the condition as taken from the highway showed a coefficient of friction of .789; after being subjected to the cleansing action of water and allowed to dry this type showed a coefficient of friction of .979.

When this type of pavement was wet to correspond to the condition of dew, condensed fog, or mist, the coefficient of friction was .658; when wet during the heavy rain condition the coefficient of friction was .930.

### Asphaltic Sheet Surface

This type for the condition as taken from the highway showed a coefficient of friction of .723; after being subjected to the cleansing action of water and allowed to dry, this type showed a coefficient of friction of .975.

## COEFFICIENTS OF FRICTION UNDER VARIOUS WEATHER CONDITIONS

Legend

==================== Asphaltic Concrete  •-••-••-• Sheet Surface

|||||||||||||||||||| Topeka  XXXXXX Hydraulic Concrete

If we consider the coefficient of friction of the clean, dry pavement as 100 %, the percentage of this figure which represents the coefficient of friction under other conditions is shown in the column at the extreme right of the page.

| Condition of Pavement | Coefficient of Friction | Percentage compared with clean, dry pavement |
|---|---|---|
| **Dry as Taken from Highway** | | |
| ==================== | 0.806 | 80.9 |
| |||||||||||||||||||| | 0.789 | 80.9 |
| •-••-••-••-••-••-••-••-••-• | 0.723 | 74.1 |
| XXXXXXXXXXXXXXXXXX | 0.783 | 74.5 |
| **Wet — Dew Condensed Fog or Mist** | | |
| ================= | 0.665 | 66.6 |
| ||||||||||||||||| | 0.658 | 67.4 |
| •-••-••-••-••-••-••-• | 0.592 | 59.5 |
| XXXXXXXXXXXXX | 0.579 | 54.9 |
| **Wet — Heavy Rain** | | |
| ====================== | 0.890 | 89.3 |
| |||||||||||||||||||||| | 0.930 | 95.0 |
| •-••-••-••-••-••-••-••-••-••-• | 0.832 | 85.6 |
| XXXXXXXXXXXXXXXXXXXXX | 0.947 | 90.0 |
| **Dry after Cleaning or Heavy Rain** | | |
| ======================= | 0.997 | 100.0 |
| ||||||||||||||||||||||| | 0.979 | 100.0 |
| •-••-••-••-••-••-••-••-••-••-••-••-• | 0.975 | 100.0 |
| XXXXXXXXXXXXXXXXXXXXXXXXX | 1.051 | 100.0 |

The above drawing brings out the fact that slight moisture loosens the surface coating of foreign matter and produces the most slippery condition. It is also evident from the drawing that the Pavement is less slippery after being cleaned and that the coefficients of friction of ALL types of pavement when clean, are very similar.

When this type of pavement was wet to correspond to the condition of dew, condensed fog, or mist, the coefficient of friction was .592; when wet during the heavy rain condition the coefficient of friction was .832.

### Hydraulic Concrete

This type for the condition as taken from the highway showed a coefficient of friction of .783; after being subjected to the cleansing action of water and allowed to dry, this type showed a coefficient of friction of 1.051.

When this type of pavement was wet to correspond to the condition of dew, condensed fog or mist, the coefficient of friction was .579; when wet during the heavy rain condition, the coefficient of friction was .947.

An examination of these results indicates the following facts:

1. In all cases the condition of dry after cleaning showed the pavement less slippery than as taken from the highway. This shows that the dirt and foreign matter present on the pavement before cleaning are important factors in determining the slipperiness of a street surface.

2. The condition of dew, condensed fog or mist, produces the most slippery condition on all of the different pavement types. Slight moisture loosens and moistens the surface coating of foreign matter and produces the most slippery condition.

3. As the amount of rain or washing continues, the foreign matter is removed from the pavement and the coefficient of friction is increased with a corresponding increase in resistance to skidding.

4. The coefficients of friction of all types of pavement when clean are very similar.

The difference between these coefficients of friction is, however, not very great in any case, and it cannot safely be said that any one type of pavement has greater non-skid qualities under all weather conditions than any other type. The most significant fact brought out by these results is the general tendency of all types of pavement to have a higher coefficient of friction after being cleaned. This brings out the fact that when clean the pavement is most resistive to skidding. The many little sand or grit particles, together with such foreign matter as oil, clay and dirt, which are present before a rain or before the street is cleaned make the pavement slippery. This brings out an exceedingly important fact, namely, the importance of the foreign matter in skidding.

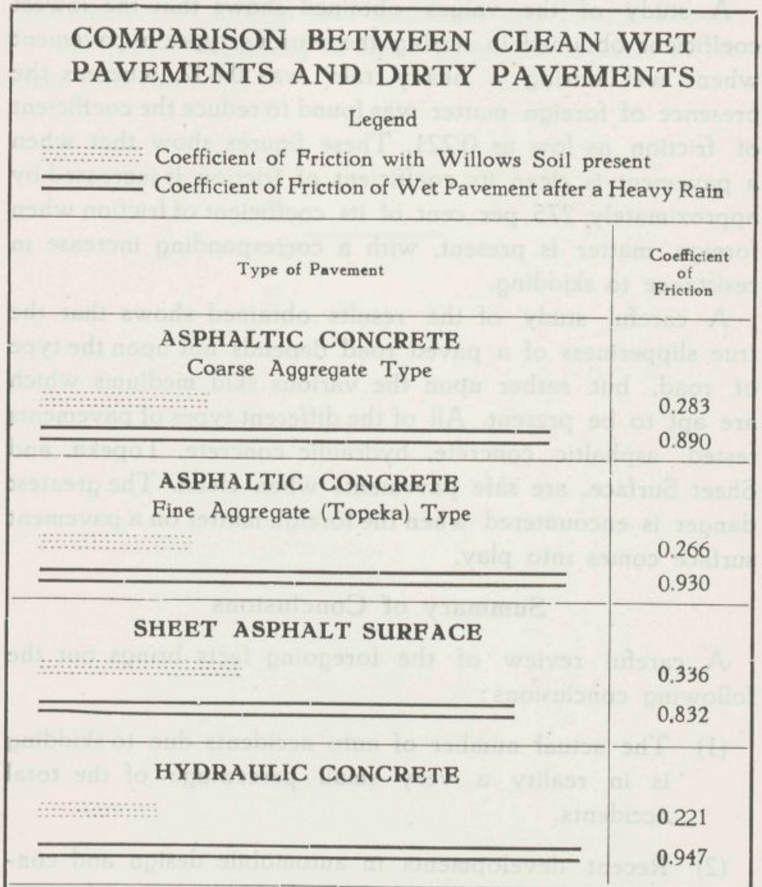
The results discussed above are presented graphically on the attached drawing.

The results obtained by testing different pavement types with various foreign materials present on the surface, are shown in the following table:

**COEFFICIENT OF FRICTION USING DIFFERENT FOREIGN MATERIALS**

| Type | Sacramento Valley Mud | Berkeley Clay | Black Point Cut-off Red Clay | Willows Soil | Hollywood Soil | Lubricating Oil | Lubricating Oil and Water | Grease | Water and Grease |
|---|---|---|---|---|---|---|---|---|---|
| Hydraulic Concrete | 0.230 | 0.336 | 0.265 | 0.221 | 0.433 | 0.389 | 0.318 | 0.203 | 0.176 |
| Asphaltic Concrete Coarse Agg. Type. . . . | 0.283 | 0.354 | 0.354 | 0.283 | 0.450 | 0.398 | 0.300 | 0.177 | 0.186 |
| Asphaltic Concrete Fine Aggr. Type. . . . . | 0.371 | 0.353 | 0.266 | 0.266 | 0.415 | 0.212 | 0.194 | 0.150 | 0.132 |
| Sheet Asphalt Surface | 0.310 | 0.354 | 0.327 | 0.336 | 0.380 | 0.300 | 0.274 | 0.194 | 0.177 |

The difference between these results and those obtained by testing the pavements under various weather conditions is evident at a single glance. These figures are conclusive evidence of the fact that a pavement is very much more slippery when the foreign matter is present. Of course, different materials present on the surface wil give different coefficients of friction, but every one of the materials used makes a pavement many times more slippery than when it is clean and wet. A very good idea of the difference between the clean and dirty pavement may be obtained from the drawing which presents this difference graphically.




A study of the above drawing gives definite proof of the fact that foreign matter on a pavement surface is largely responsible for slipperiness. An examination of the values shows that the clean pavement, even when wet, is about three times as resistive to skidding as the dirty pavement.

The drawing shows graphically the difference between the coefficient of friction of a pavement when it is wet and the coefficient of friction of the same type of pavement when the skid medium of Willows soil present. The effect which the foreign matter has upon the slipperiness of the pavement can be seen at a glance. The dirty pavement is many times more slippery than the clean.

A study of the values obtained shows that the lowest coefficient obtained in testing the various types of pavement when wet during a heavy rain was 0.832, whereas the presence of foreign matter was found to reduce the coefficient of friction as low as 0.221. These figures show that when a pavement is clean its coefficient of friction is increased by approximately 275 per cent of its coefficient of friction when foreign matter is present, with a corresponding increase in resistance to skidding.

A careful study of the results obtained shows that the true slipperiness of a paved road depends not upon the type of road, but rather upon the various skid mediums which are apt to be present. All of the different types of pavements tested, asphaltic concrete, hydraulic concrete, Topeka, and Sheet Surface, are safe pavements when clean. The greatest danger is encountered when the foreign matter on a pavement surface comes into play.

## Summary of Conclusions

A careful review of the foregoing facts brings out the following conclusions:

(1) The actual number of auto accidents due to skidding is in reality a very small percentage of the total accidents.

(2) Recent developments in automobile design and construction reduce the danger of skidding to a fraction of the previous hazard.

(3) The true slipperiness of a paved highway depends not on the type of pavement but upon the presence of dirt or foreign matter on the surface.

We may therefore say that the following are the best safeguards against skidding. — First, use proper care in driving so that complicated forces which tend to cause skidding are not built up; Second, use the latest improved devices which have been proven to reduce the danger of skids; Third, provide pavements free from irregularities and consequently non-retentive of foreign skid mediums; and Fourth, Provide for the proper cleansing of these pavement surfaces at frequent intervals.