Accident Statistics

Normally within the road network the percentage of wet road accidents ranges between zero and fifty per cent. If this percentage range is exceeded significantly on a section of road over a period of one or two years, then it is evident that on this section traffic safety during wet weather is reduced. Skid resistance measurements can show whether or not a slippery surface was involved and that some treatment or renewal work would be useful. In many cases however, other factors are also involved. On motorways the main problem arises from water accumulations on the road producing relatively thick water films. The consequence is that the avilable tyre-to-road friction drops significantly with increasing speed.

Two cases of water accumulation on the road can be distinguished:

1. Accumulations due to ruts in the wheel tracks (Fig. 6), and
2. Accumulations due to the geometry of the roadway.

Rutting is caused by winter tyres with studs, no longer permitted in the Federal Republic of Germany, and by irreversible deformations of the pavement system. Critical areas due to roadway geometry are the transition zone between right-hand and left-hand curves when the cross slope passes through zero. Here the water flows very slowly or takes a long path before leaving the roadway. Such transition zones can be avoided by applying a negative crossfall in left-hand curves so that the crossfall of the roadway does not change its direction at all. This is a possible solution for horizontal curves with large radii, say above 5000 m., where crossfall transition zones are unavoidable countermeasures against reduced safety in wet conditions.

The systematic evaluation of accident statistics to identify "black spots" under wet conditions has been carried out in the Federal Republic of Germany since the middle of the sixties. This is now part of an accident evaluation scheme that covers all aspects of accident occurrences and is operated by the Federal Road Institute at Cologne.

In contrast to some other European countries you will not find in German implementation strategies the concept of regularly monitoring the entire network of main rural roads. Indeed, we are not convinced that such surveys performed once or twice a year would help very much in skidding accident prevention. The answer can be given in five steps:

1. Our recommended minimum friction numbers do exclude the most dangerous low friction levels, but for economic reasons they are not high enough to be regarded as definitely "on the safe side".
2. With the exception perhaps of newly laid surfacings, surfaces falling short of the recommended minimum values are relatively rare. Therefore, cost-effectiveness considerations do not favor regular survey tests.
3. Surfaces where friction numbers exceed the recommended minimum can also be the scene of repeated skidding accidents in wet conditions depending on factors other than the measured friction number of the road surface. Such factors include roadway geometry and deep ruts causing water accumulations on the road.
4. Unless the friction numbers measured are extremely low and fall short of the recommended minimum, it is clear that one needs accident figures and the other factors mentioned in interpreting the results of skid resistance measurements with regard to safety.
5. If this is true, then it is more effective in our opinion to make the accident figures and the other factors mentioned the primary input in safety investigations, and make the measuring of friction numbers the secondary input, and not vice versa as in the monitoring concept.

APPLICATION OF KNOWLEDGE OF PAVEMENT SURFACE PROPERTIES IN JAPAN

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Proposed recommendations of friction coefficients in Japan for newly constructed pavement are 0.35 at 80 km/h for expressways and 0.40 at 60 km/h for national roads. The manual for asphalt pavements, which has been the national standard for design and construction of asphalt pavements since in 1950, was revised in 1975 for standard asphalt mixtures applicable both in general and snowy districts. Skid-resistant mixtures used for wearing courses are either open-graded asphalt concrete or gap-graded dense asphalt concrete for general districts, and gap-graded dense asphalt concrete with high filler content for snowy districts. The background of recent revisions is as follows:

1. The effect of open-graded asphalt concrete on pavement skid-resistance has been evaluated mostly through practical uses.
2. In general rubber-asphalt is added to open-graded asphalt concrete. However, the abrasion resistance is not necessarily sufficient compared with gap-graded asphalt concrete.
3. In snowy districts gap-graded asphalt concrete with high filler-asphalt ratio is needed from the point of view of abrasion-resistance against the action of tyre chains and studded tyres.

In Japan, with its many mountainous roadways, there is a growing recognition of the importance of skid-resistant pavements particularly for express highways. Depending on the slope and length of incline some regional highway authorities are considering the adoption of skid-resistant pavements. The Local Road Section of the Ministry of Construction has recommended their use for inclines greater than 6% and total length more than 200 m. At these locations coarse grade asphalt concrete is normally applied rather than a special non-skid pavement. In the past various successful application of non-skid pavements have been reported. Emery or calcined bauxite is sprayed with synthetic resin binder onto the road surface at approaches to urban road crossings. To provide durability, the binder used is mainly an epoxy resin with a desirable elongation of more than 50%.

Recommendations for Skid-Resistance Standards

There are no compulsory standards in Japan. In 1967 the Public Works Research Institute proposed minimum friction coefficients. In 1974 the committee of the Japan Road Association proposed new recommendations for skid-resistance standards. They established a minimum friction coefficient for newly constructed pavements of 0.35 at 80 km/h for expressways, and 0.40 at 60 km/h for national roads (normal sections), and 0.45 at 60 km/h for national roads (dangerous sections).

On the other hand the anti-skidding requirements of the Japanese Highway Public Corporation demands that a newly constructed road should have a Polished Stone Value (PSV) of more than 60. If values less than 55 are found and are confirmed by repeated measurements the suspected section is tested with a heavy test car. If the braking force coefficient is found to be higher than 0.35 at 80 km/h no other action is taken. If it is lower than 0.28 at 80 km/h the road may not be opened to traffic before adequate measures have been carried out for improving the skid resistance. Where values are between 0.28 and 0.35 the road may be opened to traffic but repairs must be considered in case of accidents.

Standard Asphaltic Concrete for Skid-Resistant Pavements

The "Asphalt Paving Manual" published by the Japan Road Association has been the standard since 1950 for the design and construction of asphalt pavements in Japan. The standard was extensively revised in 1975. Skid-resistant pavement mixtures have been newly specified for use in the wearing course of the pavement structure shown in Fig. 1. The wearing course has a standard aggregate grading as shown in Table 1. The main characteristic to be noted is that a gap-graded mixture has been adopted instead of the previously applied open-graded mixture.

The new grading was decided by statistical analyses of more than 3,300 survey results covering all parts of Japan. For general application the conventional open-graded asphalt concrete is used. However, because of its high porosity and scattering of coarse aggregate for low durability the gap-graded dense asphaltic concrete with an increased fine aggregate content is applied for use in relatively low speed roads.

The term "snowy area" distinguishes areas where it is necessary to take into consideration the ravelling effect caused by studded tyres or tyre chains. Thus in order to maintain the skid resistance of the wearing course while achieving resistance against ravelling effect a mixture with a high filler to asphalt ratio is applied.

Skid-Resistance and Stripping Phenomena of Open-Graded Asphalt Concrete

Table 2 shows skid resistance coefficients and their decrease with respect to speed variation for asphalt paved road surfaces measured in 1974 - 1975 on national roads in the western parts of Japan. Although the coefficients of resistance for the open-graded asphaltic concrete at 60 km/h is not necessarily high, its effectiveness for traffic safety on high speed traffic roads is clearly demonstrated by the lowest decrease when the measured speed is increased to 60 km/h from either 20 km/h or 40 km/h.

It is not rare that traffic accidents associated with the slipperiness of the road surface occur to vehicles traveling above speed limits. The remarkable effectiveness of applying open-graded asphalt concrete at these locations has been a widely accepted empirical fact.

As shown in Table 3, the high permeability of open-graded asphaltic concrete is a great advantage in promoting surface water drainage. At the same time it is also the cause of stripping due to the permeated surface water. Contrary to the normal spot for stripping, i.e., the bottom face or binder base course directly in contact with the graded crushed rock base, an investigation in the Shikoku district of stripping phenomena for a road pavement structure composed of wearing, surface and base courses found that in many cases, as shown in Table 4, stripping was also proceeding at the interface of wearing and surface courses due to retained permeated water.

It is considered that the stripping phenomena occurs as the result of climatic conditions and the influence of aggregate materials. Past surveys have shown that out of about 800 sites half of them have shown marked stripping in base course mixtures. As an effective countermeasure the addition of hydrated lime or Portland cement has already been confirmed. Its effective application for wearing course mixture is under investigation.

The main objective in developing the gap-graded dense asphalt concrete is to achieve a reduced permeability with a minimum loss in the surface texture compared to open-graded asphalt concrete, while simultaneously improving the resistance against fretting.

Properties of Gap-Graded Dense Asphaltic Concrete

The skid resistance coefficients of gap-graded dense asphaltic concrete tend to shown the highest value (Fig. 2) for various road surfaces trafficed for about 90 days. Furthermore, the range of resistance coefficients is the narrowest indicating its stable skid resistance characteristic. Compared to the conventional standard asphalted pavement mixture in Japan, i.e., continuous dense graded asphaltic concrete, the superior performance can be expected of gap-graded dense asphalted concrete. Figure 3 indicates the evaluation by laboratory tests of comparative abrasion losses on continuous and gap-graded mixtures with respect to the amount passing 2.5mm sieve. Figure 4 shows the results of measurements on abrasion losses due to tyre chains on one selected mixture from above actually applied on experimental road surfaces.

The details of methodology for laboratory experiments and open-air investigation are omitted here, but the gap-grading is now being recommended as a mixture possessing excellent skid-resistance while also having abrasion resistance.

The normal remedial measure taken in Japan in improving the abrasion resistance against tyre chains is to increase the asphalt content and the filler to asphalt ratio. The effectiveness need not be discussed here. An actual example of proportioning used in Hokkaido area is shown as follows:

Fig.-1 Typical structure of asphalt pavement for general national highways

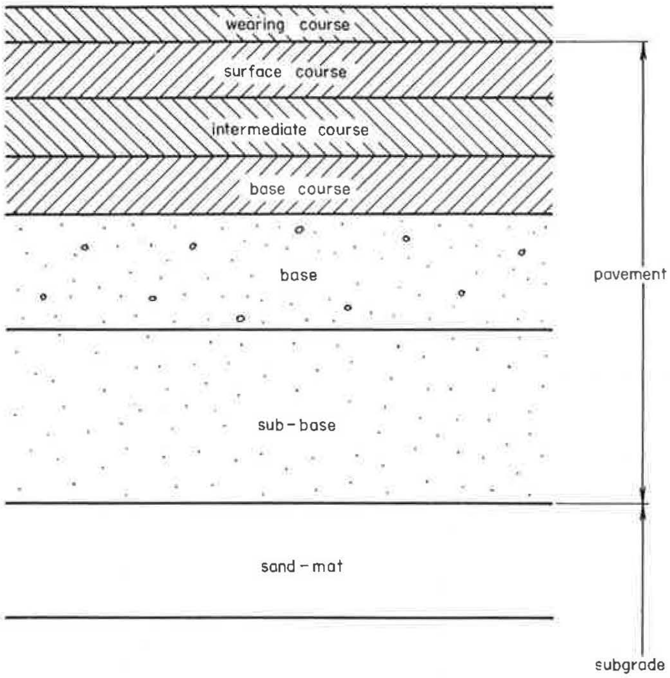

Table-1 Standard Gradation of Asphalt Concrete for Skid-Resistant Pavements (revised in 1975)

Mix		General District		Snowy District
		Open-graded Asphalt Concrete	Gap-graded Dense Asphalt Concrete	Gap-graded Dense Asphalt Concrete High Filler C.
Layer thickness(cm)		3 - 4	3 - 4	3 - 4
Maximum size (mm)		13	13	13
Sieve size (mm)	20	100	100	100
	13	94 - 100	95 - 100	95 - 100
	5	23 - 45	35 - 55	45 - 65
	2.5	15 - 30	30 - 45	30 - 45
	0.6	8 - 20	20 - 40	25 - 40
	0.3	4 - 15	15 - 30	20 - 40
	0.15	4 - 10	5 - 15	10 - 25
	0.074	2 - 7	2 - 10	8 - 15
Asphalt content (%)		3.5 - 5.5	4.5 - 6.5	5.5 - 7.5
Asphalt penetration grade		60 - 80 , 80 - 100		

Table-2 Coefficient of Skid-Resistance and Its Percent Decrease with Speed Increase on Various Surface Mixtures

Mixtures	Number of Site	at 60 Km/h (f_{60})				$\frac{f_{20}-f_{60}}{f_{20}}\times 100$	$\frac{f_{40}-f_{60}}{f_{40}}\times 100$
		average	min	max	δ		
Open-graded	178	0.48	0.37	0.61	.0378	26.3	13.3
Coarse-graded	673	0.50	0.38	0.64	.0432	27.7	16.1
Dense-graded	1,724	0.44	0.27	0.69	.0563	32.8	20.9
Topeka	70	0.49	0.40	0.61	.0538	34.2	21.7

Table-3 Some Result of Permeability Test on Open-graded Asphalt Concrete

Site No.	Coefficient of Permeability (cm/sec)
1	9.5×10^{-4}
2	7.3×10^{-3}
3	1.1×10^{-3}
4	1.8×10^{-3}
8	2.8×10^{-5}
9	2.1×10^{-5}
10	1.2×10^{-2}
11	5.5×10^{-5}
12	5.1×10^{-4}
13	8.7×10^{-3}
14	1.3×10^{-3}
16	1.3×10^{-4}
21	7.7×10^{-3}
22	1.3×10^{-2}

Table-4 Survey on Starting Places of Stripping in Pavement Structure due to Permeated Water

Bottom of Base Course	1
Interface of wearing course and surface course	2
Bottom and interface of courses	12
Total	15

Fig.-2 Comparison of skid resistance on various surface mixtures

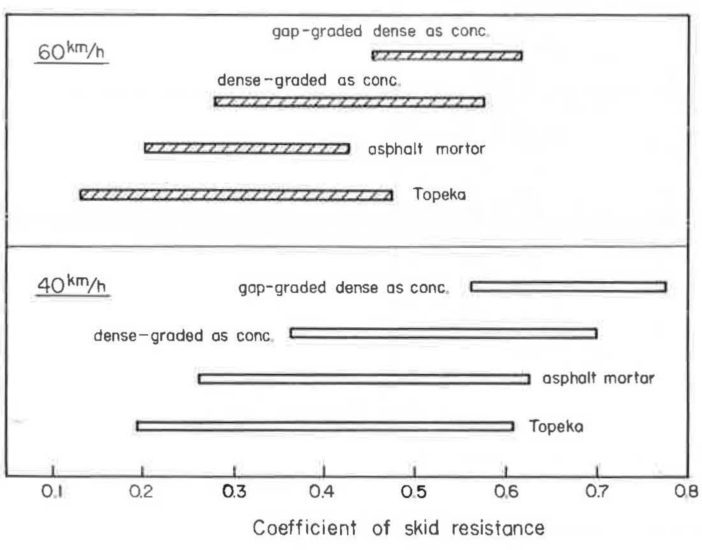

Fig.−3 Comparison of abrasion resistance between continuous and gap grading (laboratory test)

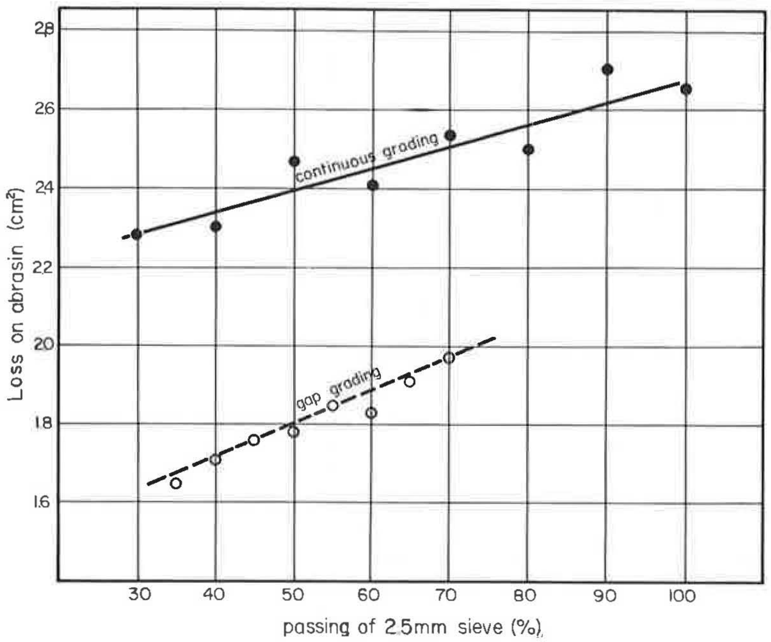

Fig.−4 Abrasion loss on experimental pavement during the winter (in field)

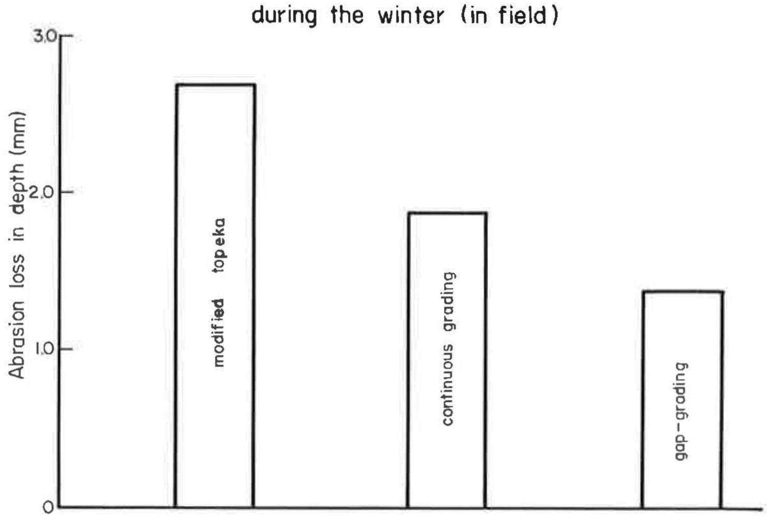

Table-5 Mix-Proportion and Permeability

Crushed Stone (%)	Coarse Sand (%)	Fine Sand (%)	Portland Cement (%)	Lime-stone Powder (%)	Asphalt (%)	Air Void (%) on Marshall Specimen	Coefficient of Permeability (cm/sec)
55	8.5	19.7	-	10.7	6.1	5.4	0
60	7.5	17.6	-	9.5	5.4	6.2	6.5×10^{-5}
65	6.6	15.3	-	8.3	4.8	7.6	4.5×10^{-4}
55	8.5	19.7	2.1	8.6	6.1	6.2	0
60	7.5	17.6	1.9	7.6	5.4	9.0	0
65	6.6	15.3	1.7	6.6	4.8	8.7	3.8×10^{-4}
55	8.5	19.7	5.35	5.35	6.1	6.7	0
60	7.5	17.6	4.75	4.75	5.4	7.3	0
65	6.6	15.3	4.15	4.15	4.8	8.5	1.5×10^{-5}
55	8.5	19.7	10.7	-	6.1	7.1	0
60	7.5	17.6	9.5	-	5.4	7.9	4.4×10^{-4}
65	6.6	15.3	8.5	-	4.8	9.1	6.6×10^{-4}

Asphalt content 5.5 - 6.0%
Filler/Asphalt Ratio Approximately 1.7
Crushed Stone 55 - 60%
Abrasion loss measured in laboratory test for asphalt mortar less than 1.3 cm

As mentioned earlier, it is important to reduce the permeability coefficient of the mixture in view of preventing frost damages. Thus, as shown in Table 5, it is not desirable to have a crushed stone content of more than 65%, and the air void in total mixture should be less than 5.5%.

It should also be noted that in connection with the application of gap-graded dense asphaltic concrete in general areas, its superior resistance to plastic flow has been pointed out when compared to the continuous graded type. This aspect as a countermeasure to rutting on heavy traffic routes is under investigation using experimentally paved surfaces on a national basis.

CONCLUSIONS

The standard asphalt mixture for non-skid pavement in Japan is introduced in this paper. Open-graded asphaltic concrete and gap-graded dense asphaltic concrete are used in general areas, while gap-graded dense asphaltic concrete which has high filler to asphalt ratio is used in snowy areas. Gap-grading can be recommended for mixtures satisfying durability such as abrasion resistance and, at the same time, requiring comparatively high skid resistance.

APPLICATION OF KNOWLEDGE OF PAVEMENT SURFACE PROPERTIES IN THE NETHERLANDS

P.M.W. Elsenaar, Head of the Road Measurement Department of the State Road Laboratory, The Netherlands

In the Netherlands routine investigations of the state road network have taken place since 1954. Criteria for skid resistance values in use for maintenance of roads are based on accident analyses. Such criteria also exist for rut depths. Routine investigations of rut depths by means of continuous measurement at traveling speed (50 km/h) are made possible by means of the Dutch rut meter.

For contract work a minimum value of the skid resistance of new roads has to be met by the contractor. If these requirements are not met, a penalty or, if skid values are very low, restoration of the road surface at the cost of the contractor will be demanded.

Details and figures on the use of routine investigations of surface characteristics can be found in the paper presented by Mr. C. van de Fliert at the 1977 Transportation Research Board Annual Meeting (1).

REFERENCES

1. C. van de Fliert and H. Schram. Quality Control of Pavements in the Netherlands, Transportation Research Board, Transportation Research Record 652, 1977.

APPLICATION OF KNOWLEDGE OF PAVEMENT SURFACE PROPERTIES IN OTHER COUNTRIES

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By means of a questionnaire (1) on this subject sent at random to a number of PIARC member countries all over the world more understanding about the problem and the status of implementation of skidding knowledge has been achieved.

Skidding is more of a problem to a state if its climatic conditions cause long periods of wet roads. On wetroads the accident rate will be two or three times higher than on dry roads.

In most of the countries where skidding is a major problem attention is given to the initial skid resistance of new roads. Most states have specifications for the Polished Stone Value (PSV) of aggregates, sometimes in combination with regulations concerning the geometry of stones.

Guidelines for levels of desired skid resistane are in use, and a majority of states reported routine investigations of skid resistance of the road network.

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