Lateral skid resistance on bends

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Summary
The introduction of SKM (Side Way Force) measurements in the Netherlands was the reason for conducting a study into the lateral skid resistance on bends. This has shown that the skid resistance in the SKM measuring direction on older road surfaces can deviate significantly on bends. This concerns a bend that faces the opposite side and the measured values on the straight track. This is the reason for advancing the thesis of using various maintenance standards for skid resistance for SKM measurements, that are dependent on the location and position of a road surface (left bend / right bend / straight track / potential braking locations).

Keywords: Skid resistance, bends, lateral, SKM, SRT, maintenance standards

1. Reason for the study

The skid resistance of roads in the Netherlands has been measured for more than 50 years using the 86% retarded wheel, whereby the skid resistance of the road surface is measured in the longitudinal direction. The Directorate-General for Public Works and Water Management (Rijkswaterstaat) has decided that from 2017 the skid resistance measurements will be conducted in a different manner, whereby the skid resistance is no longer to be measured longitudinally but rather at a fixed angle to the direction of driving. This change in measuring method is the reason for studying the effect of skid resistance measurement in a direction that differs from the direction commonly used to date. This study focuses on the aforementioned effects in bends.

2. Skid resistance measuring method

Three methods of measuring the skid resistance are important for this study. Firstly, the current “86% retarded wheel” measuring method, secondly the new “SeitenKraft Messverfahren” (SKM) measuring method which Rijkswaterstaat wishes to use from 2017 and, thirdly, a measuring method with which the direction sensitivity of skid resistance is studied. The latest measuring method is called the Skid Resistance Tester (SRT). These three measuring methods are described further in this section.

2.1 Measuring method 86% retarded wheel (test 72 RAW Standard Conditions 2015)

This measuring method is undertaken when driving at 50 or 70 km/h. This measuring system is mounted on a measuring trailer, whereby a standardised non-profiled measuring wheel which is 86% retarded is mounted between and parallel to these running wheels. This measuring wheel is pressed against the road at a normal force of 1962N and water is sprayed in front of the measuring wheel so that the measurement is conducted on a wet road surface. The pulling power required to pull along the continuously skidding measuring wheel is recorded; the friction coefficient can be calculated by dividing this pulling force by the normal force.
For this measurement the skid resistance is therefore measured in the longitudinal direction (= driving direction).

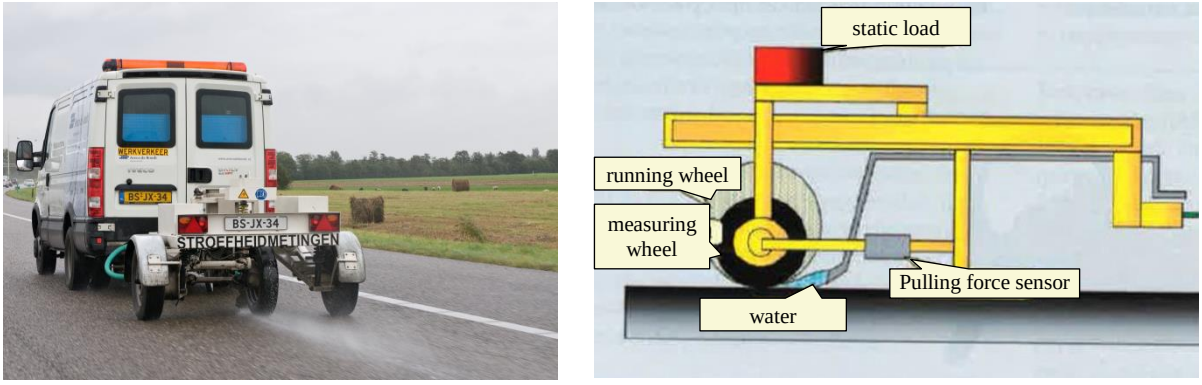

Figure 1 86% retarded wheel measuring method

2.2 SeitenKraft Messverfahren (SKM) measuring method

This measuring method is used at speeds of 40, 60 or 80 km/h. The SKM measuring method is a Side Way Force (SWF) measurement, whereby a freely-rotating measuring wheel is mounted in the right-hand wheel track at an angle of 20° to the direction of travel.

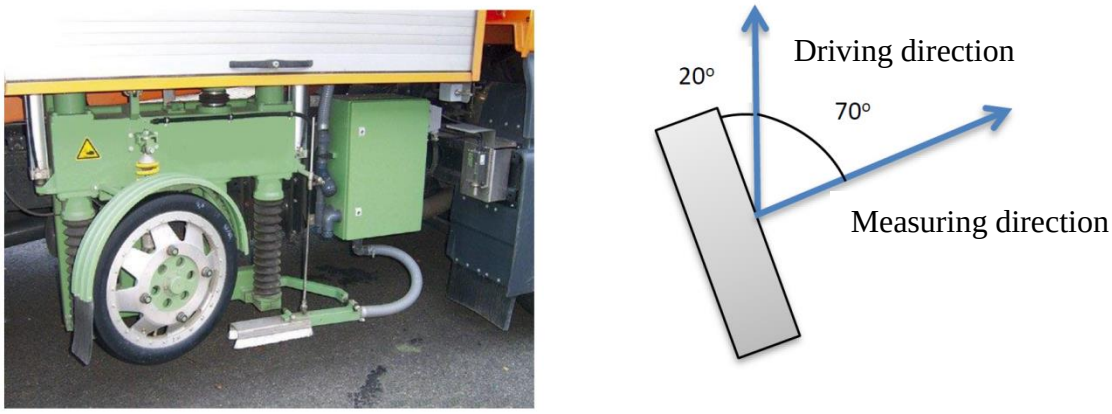

Figure 2 SKM measuring method

The measuring wheel is a standardised narrow pneumatic tyre (3 inches wide) without a profile, which is pushed against the road surface at 1960N. Because the measuring wheel can rotate freely a lateral force is exercised on the tyre (therefore at an angle of 70° to the direction of travel). This lateral force is recorded; the friction coefficient is determined by dividing this force by the normal force. As with the 86% retarded wheel measuring method, water is also sprayed in front of the measuring wheel so that this measurement is also conducted in wet conditions.

2.3 Skid Resistance Tester (SRT) measuring method

SRT measurements are stationary measurements conducted on the road. The SRT is a pendulum device that is placed horizontally on the road surface to be tested. A standardised rubber foot is fixed on the end of the pendulum. The road surface and the rubber foot are sprayed wet prior to measuring, so that these measurements are also conducted under wet conditions.

Figure 3 SRT in start position prior to measuring and SRT foot on road surface

In the start position the pendulum is horizontal, after which it is released and falls. The rubber foot then skids over the road surface being tested and the degree to which the pendulum

continues its swing is a measure of the skid resistance. For this, the device is set at a height that allows the rubber foot to always skid over the road surface by a length of 126 mm. A skid indicator records the degree to which the pendulum continues to swing and that value is read off. These measurements are repeated a minimum of five times in a single position, after which the average value is corrected for the temperature. This value is called the Pendulum Test Value (PTV).

Because the measurements are conducted stationary on the road the SRT can be used to measure the skid resistance in any required measuring direction.

3. Study structure

3.1 Aim

This study investigates the effect on bends of measuring the skid resistance in a direction different from the one that was normally used. With the 86% retarded wheel method, the skid resistance is only measured in the longitudinal direction and with the SKM method the skid resistance is measured at an angle of 70° to the direction of travel. SRT measurements have been used in order to study the directional sensitivity of the skid resistance on bends. The SRT can be placed in any desired direction on the road, so that the skid resistance can be measured in all directions.

This study specifically does not examine how the measured values of the 86% measuring method relate to the SKM measured values. These are completely different measuring methods and each has its own specific characteristics. This study therefore only examines the directional sensitivity of the skid resistance based on SRT measurements.

3.2 Road surfaces

No polishing has yet taken place on new unused road surfaces, as a result of which it is expected that the skid resistance will be the same in all directions. A conscious decision has therefore been made for road surfaces with a relative old surface so that the effect of road surface polishing by traffic is included in the study. In collaboration with the Province of Gelderland, the following two bends were selected on a secondary road:

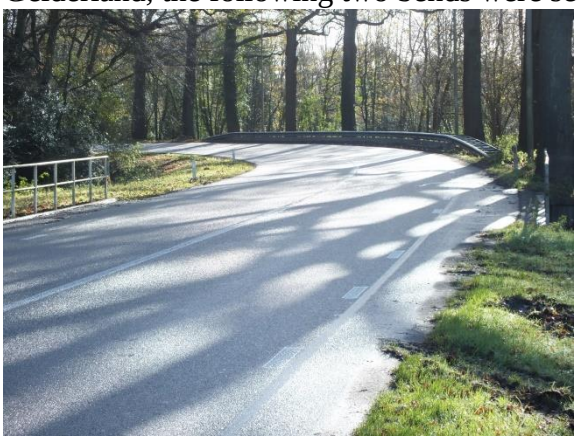

Figure 4 Bend N319 *Bend N330*

Road name	From [km]	To [km]	Bend radius	Surface	Age
N319	12.755	13.030	approx. 150 m	DAB 0/16	19 years
N330	6.350	6.700	approx. 210 m	SMA 0/8	11 years

3.3 Measuring locations and measuring directions

Each bend can be regarded once as a left bend and (when viewed from the other side) once as a right bend. SRT measurements were conducted in different directions on both lanes on each bend and in both wheel tracks. The more detailed measuring schedule is shown in Figure 5.

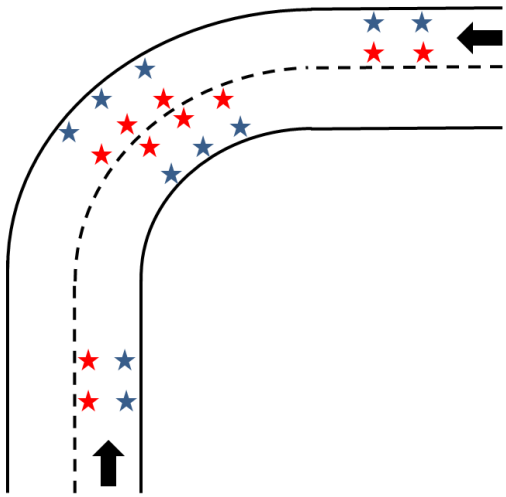

Figure 5 Overview of SRT measuring locations on and close to bends

SRT measurements were carried out in the right-hand wheel track at locations indicated with a blue star and the measurements were carried out in the left-hand wheel track at the locations indicated with a red star. SRT measurements were carried out at 3 locations per wheel track on the bends and at 2 locations in the wheel track on the straight section close to the bend. On the straight section the preference was to carry out measurements at 3 locations, however, due to time restrictions for measurements only 2 measurements were carried out at these locations. SRT measurements were carried out in different directions at the locations shown in Figure 5. The direction of the measurements in the left-hand and right-hand wheel track are shown in Figure 6.

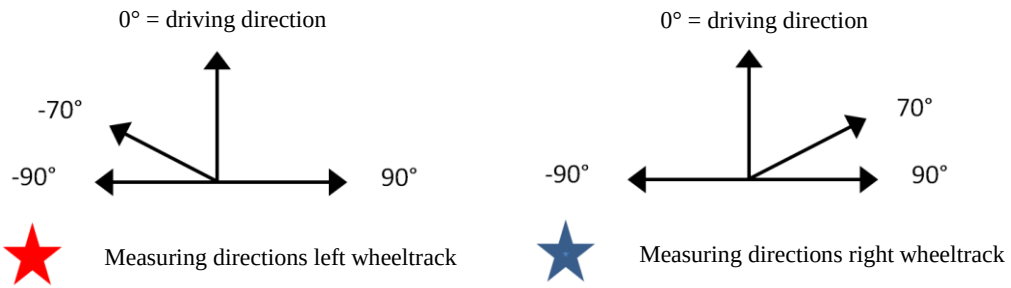

Figure 6 Overview of measuring directions in the left-hand and right-hand wheel track

Measurements were carried out in both wheel tracks in the longitudinal direction (the direction in which the skid resistance is measured using the 86% retarded wheel). In the right-hand wheel track measurements were also carried out at an angle of 70° (SKM measuring direction) and in the left-hand wheel track measurements were carried out at an angle of -70°.

If the SKM had been fitted with a mirrored measuring system in the left-hand wheel track, the skid resistance in the left-hand track could have been measured in this direction using the SKM. Both wheel tracks were also measured in the bends at an angle of -90° and 90°. On the straight sections the skid resistance was only measured laterally in the left-hand and right-hand wheel track at an angle of -90° and 90° respectively.

3.4 Position of normative wheel track

To be able to determine the normative position (location with the least skid resistance) of the left-hand and the right-hand wheel track on the road, 4 or 5 SRT measurements were carried out for each track with a spacing of 150mm in order to determine the position with the least skid resistance. On the bend these SRT measurements were carried out in the direction towards the outer bend (the expected polishing direction on bends). On straight sections these measurements were carried out in the direction of travel. Below is an example of the way in which the normative track is determined on a left-hand bend. In this example the least skid resistance was measured at measuring point 2 in the left-hand wheel track, after which the right-hand track was sought by moving 2200mm to the right from that point (maximum axle width) and then re-conducting the SRT measurements every 150mm.

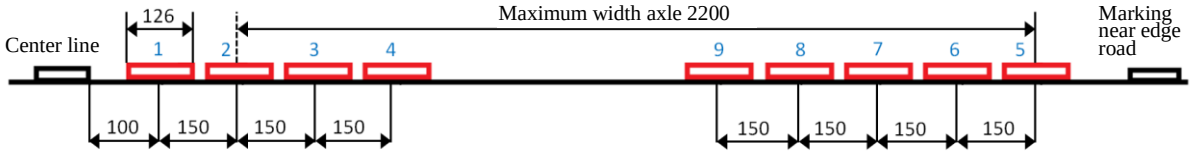

Figure 7 Example of the way in which the normative track is determined on a bend

For each lane and each bend the positions of the normative tracks were determined once in this way. On the bends examined in this study, in all cases the normative tracks had a mutual spacing of 1600mm. The position of the right-hand track on the straight sections was determined in a similar manner. The position of the left-hand track on straight sections is at a distance of 1600mm from the right-hand track.

4. Study results

4.1 Distinctiveness in skid resistance by longitudinal direction and lateral direction on bends

To provide an insight into the skid resistance in the lateral direction on bends the skid resistance in the longitudinal direction was plotted against the skid resistance in the lateral direction. A distinction is made here on the one hand in the lateral direction, whereby the measuring direction is towards the inside bend and, on the other hand, the lateral direction whereby the measuring direction is towards the outer bend. In Figure 8 the skid resistance in the longitudinal direction is plotted against the skid resistance in the direction of the inner bend and in Figure 9 against the skid resistance in the direction of the outer bend. In these figures a distinction is made between the bend on the N319 and the bend on the N330.

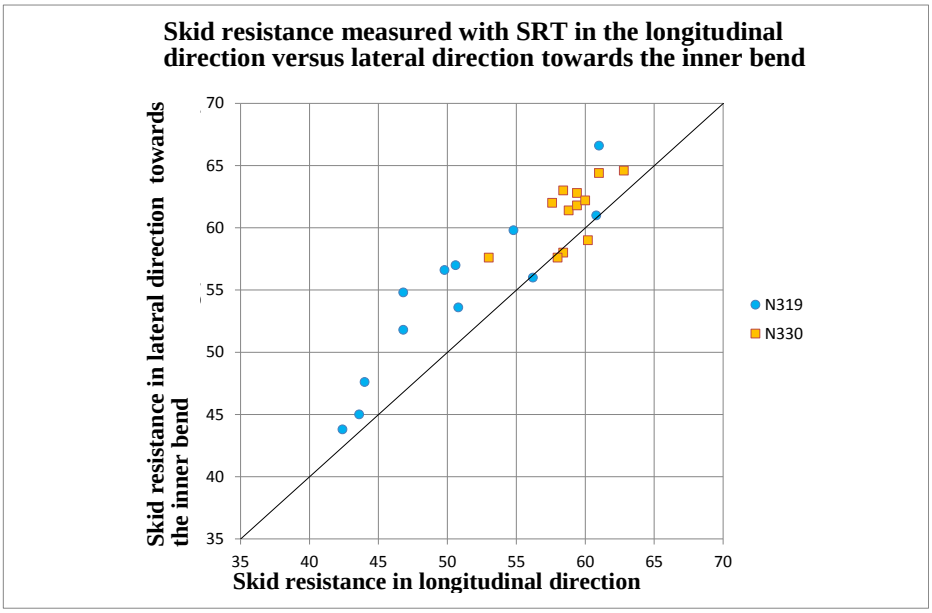

Figure 8 Skid resistance in the longitudinal direction versus skid resistance in the lateral direction towards the inner bend

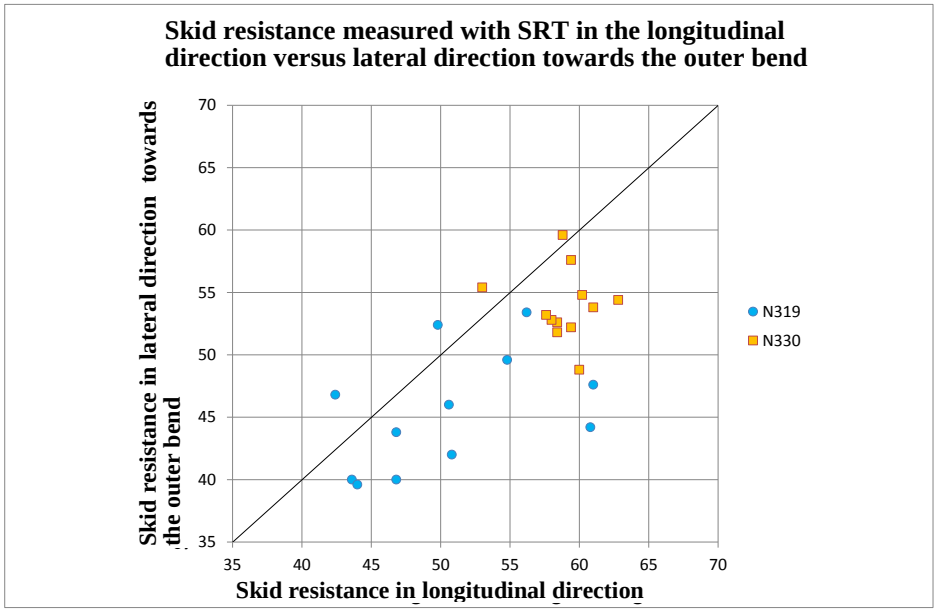

Figure 9 Skid resistance in the longitudinal direction versus skid resistance in the lateral direction towards the outer bend

There appears to be a significant difference in the skid resistance measured in the lateral direction towards the inner bend and towards the outer bend. In Figure 8 it can be seen that the skid resistance in lateral direction towards the inner bend is clearly higher than the skid resistance measured in the longitudinal direction. In Figure 9 it appears, on the other hand, that the skid resistance in the lateral direction towards the outer bend is clearly lower than the skid resistance in the longitudinal direction. This difference also appears to be significant.

4.2 Underlying cause of the difference in skid resistance in the lateral direction

This difference can be explained because the traffic on the bend clearly tests or uses the skid resistance in the lateral direction towards the outer bend due to the centrifugal force of the vehicles. As a result of this, polishing occurs on the road surface of the sections of the aggregate that are loaded in the direction towards the outer bend by vehicles. The result of this is a reduction in the skid resistance in this direction.

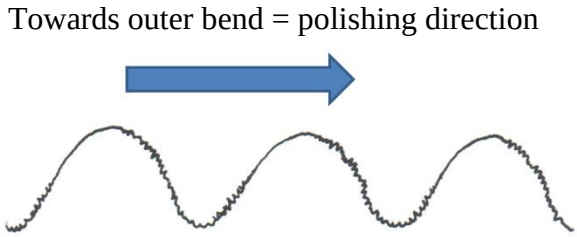

Figure 10 Effect of micro-texture on aggregate due to polishing in one direction

If the skid resistance is measured in the opposite direction, in other words towards the inner bend, sections of the aggregate are also tested or used that are not or are seldom loaded by forces from the traffic towards the outer bend. As a result, these sections of the aggregate are clearly less polished and a higher level of skid resistance will therefore be measured in this direction.

4.3 Skid resistance in SKM measuring direction

For the SKM, measurements were only carried out in the right-hand wheel track at an angle of 70° to the direction of travel. On a left bend this SKM measuring direction only makes an angle of 20° to the (polishing) direction towards the outer bend. On a right bend the SKM measuring direction makes an angle of 160° to the direction of the outer bend (see Figure 11)

Measurements at an angle of -70° (fictive SKM measuring direction left-hand track) to the direction of travel were also carried out in the left-hand wheel track. For a left bend this measuring direction makes an angle of 160° to the direction towards the outer bend and for a right bend it makes an angle of 20° to the direction of the outer bend.

Because the aforementioned angle differences between the -70° measuring direction in the left-hand track on a left bend are the same as the angle differences between the 70° measuring direction on a right bend, these measured values are regarded as a single population in the further analysis: “SKM measuring direction on right bend”. The same applies for the measuring values at an angle of -70° in the left-hand track on a bend and the measured values at an angle of 70° in the right-hand track on a left bend. These are jointly regarded as the “SKM measuring direction on left bend” population.

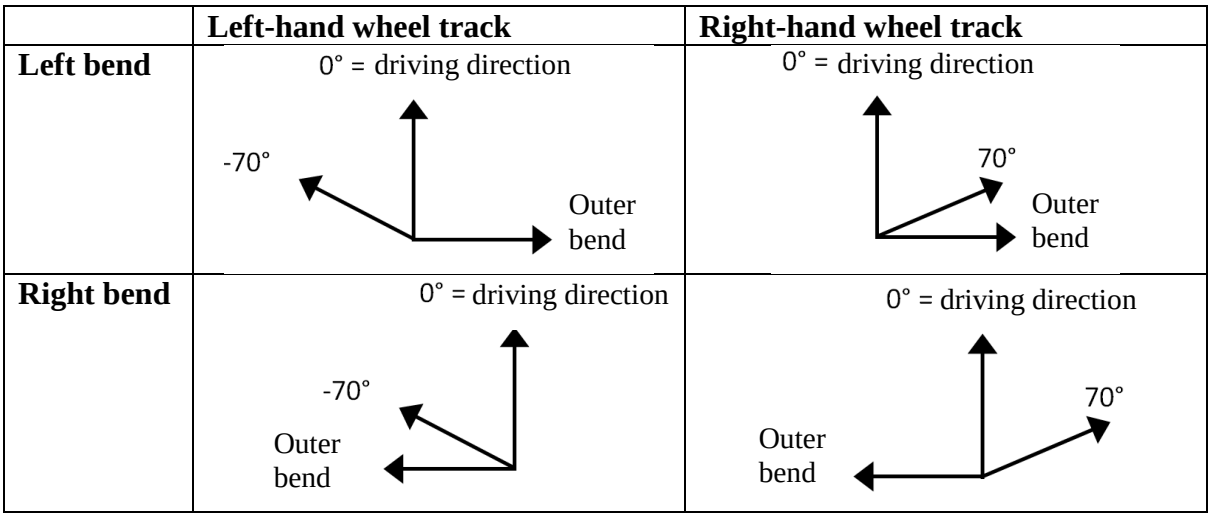

Figure 11 Overview of SKM measuring directions in study of left-hand and right-hand wheel tracks

The effect of measuring the skid resistance in the SKM measuring direction on a left and right bend is clear in Figure 12 then both measuring values are plotted against the skid resistance measured in the longitudinal direction.

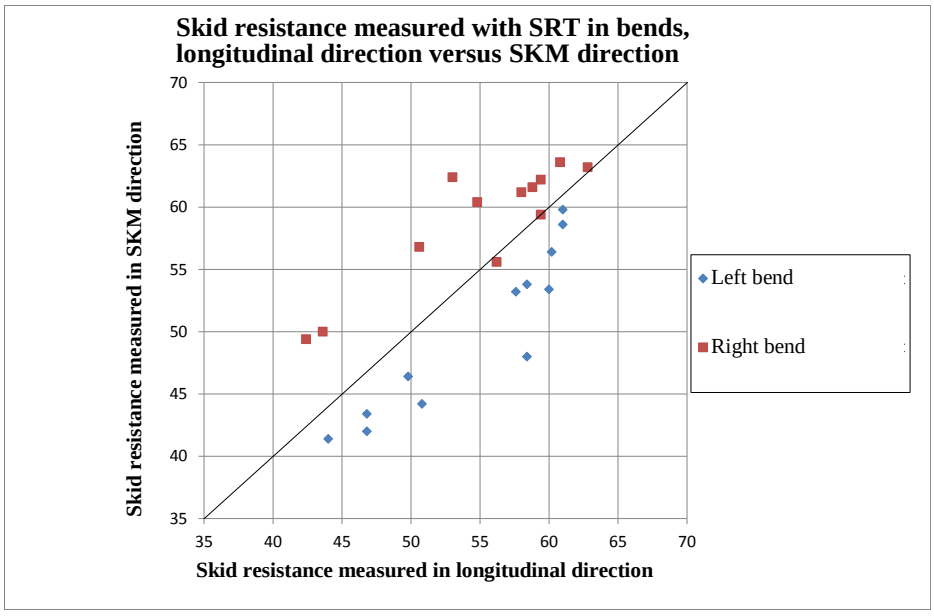

Figure 12 Effect skid resistance of SKM measuring direction on left and right hand bends

Table 1 Differences found in this study

Type of bend	Mean difference of skid resistance measured using the SRT	
	compared to skid resistance in the longitudinal direction	compared to normative skid resistance
Left bend	- 8%	+ 5%
Right bend	+ 8%	+ 18%

The differences in the SKM measuring direction between a left and a right bend appear to be significant. On a left bend, the SKM measuring direction shows 8% lesser skid resistance on average compared to the longitudinal direction. On the other hand, on a right bend the skid

resistance is an average of 8% higher compared to the longitudinal direction. Compared to the normative skid resistance on a bend, which is often measured towards the outer bend at right angles to the direction of travel, these differences are even greater. On a left bend an average of 5% higher skid resistance is measured and on a right bend the measured skid resistance is on average 18% higher than the normative skid resistance at that point.

If the skid resistance measurements on the straight sections are also included in the study it appears that the skid resistance in the SKM direction on a left bend is significantly lower than on the straight sections.

5. Summary

The extent of this study may indeed be limited, however, it does provide a clear indication that the skid resistance in the SKM measuring directions on older road surfaces can deviate considerably on bends. This is the case with regard to a bend facing the opposite side and with regard to the measured values on straight sections.

For the skid resistance measured in the longitudinal direction (the measuring direction of the 86% retarded wheel method) there is a significant difference between the skid resistance on a left bend and the skid resistance on a right bend. After all, the differential angle between the measuring direction and the polishing direction is the same. The skid resistance on bends does not differ significantly compared to the skid resistance measured on straight sections.

The SKM measured value on a left bend is closer to the normative skid resistance compared to the skid resistance measured in the longitudinal direction. The reason for this is that the SKM measuring direction on this bend only has a small differential angle to the normative polishing direction.

However, at locations where the polishing mainly occurs in the longitudinal direction (potential braking locations such as zebra crossings, in front of junctions, in front of roundabouts and suchlike) the differential angle between the polishing direction and the SKM measuring direction is specifically greater, as a result of which at these locations larger differences can occur compared to the normative skid resistance.

The thesis is therefore advanced that when conducting SKM measurements different maintenance standards for the skid resistance are to be used, which are dependent on the location and position of a section of road (left bend / right bend / straight section / potential braking locations).

Further research is required at different locations (road type, type of surfacing, curve radii, in front of junctions, in front of zebra crossings, et cetera) in order to determine the difference between the normative skid resistance and the skid resistance measured in the SKM direction.