Wet ice friction of conventional M+S tyres and of a retreaded M+S tyre with a special aggregate in the tread rubber

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Summary

The investigation comprised tests with a total of eight passenger car tyres classified M+S, without studs. One of the tyres had a special hard aggregate added to the rubber compound to increase the grip on ice.

The tests were carried out in the VTI tyre testing facility on smooth wet ice at a speed of 30 km/h. Both braking tests and steering tests were performed.

Results from the braking tests was presented as maximum braking friction, braking friction at 13 % longitudinal slip and friction with a locked wheel. The steering tests were presented as maximum lateral friction and friction at 3, 5, 10 and 20 degree side slip angle. 20 degree side slip angle represents conditions of skidding of the whole vehicle or excessive steering angle when entering a curve.

1 Background

Studded tyres cause road wear especially in countries with pavements with low wear resistance against studs, primarily due to the type of stone aggregate used in the pavement. In several countries studs are banned for these reasons. Tyre manufactures try to develop winter tyres without studs with comparable friction. On ice this has still not succeeded under all conditions. The special aggregate mixed into the tread rubber, included in one of the tyres tested here, is an attempt to improve ice friction without significant increase in pavement wear.

2 Commission

The commission entailed comparative testing of braking and lateral friction on wet ice of seven types of tyres of which one was tested both with the special aggregate added to the rubber compound (tyre number 8) and without the special aggregate (tyre number 1). The other tyres were different commercially available winter tyres (M+S) without studs.

3 Test objects

In table 1 and figure 1 below the eight winter tyres included in the test is described. All tyres except number 8 and number 1 were new. Number 8 and number 1 was both slightly worn. All tyres were of size 195/65R15.

Table 1 List of tyres included in the tests

Tyre no.	Tyre name	Speed and load index	Remark
1	Green Diamond	91T	Without hard aggregates
2	Gislaved SoftFrost	91Q	
3	ContiVikingContact 2	91Q	
4	Bridgestone Blizzak MZ-02	91Q	
5	Cooper Weather-Master	91Q	
6	Good Year UltraGrip 5	91T	
7	Michelin Alpin	91T	
8	Green Diamond	91T	Hard aggregates in rubber

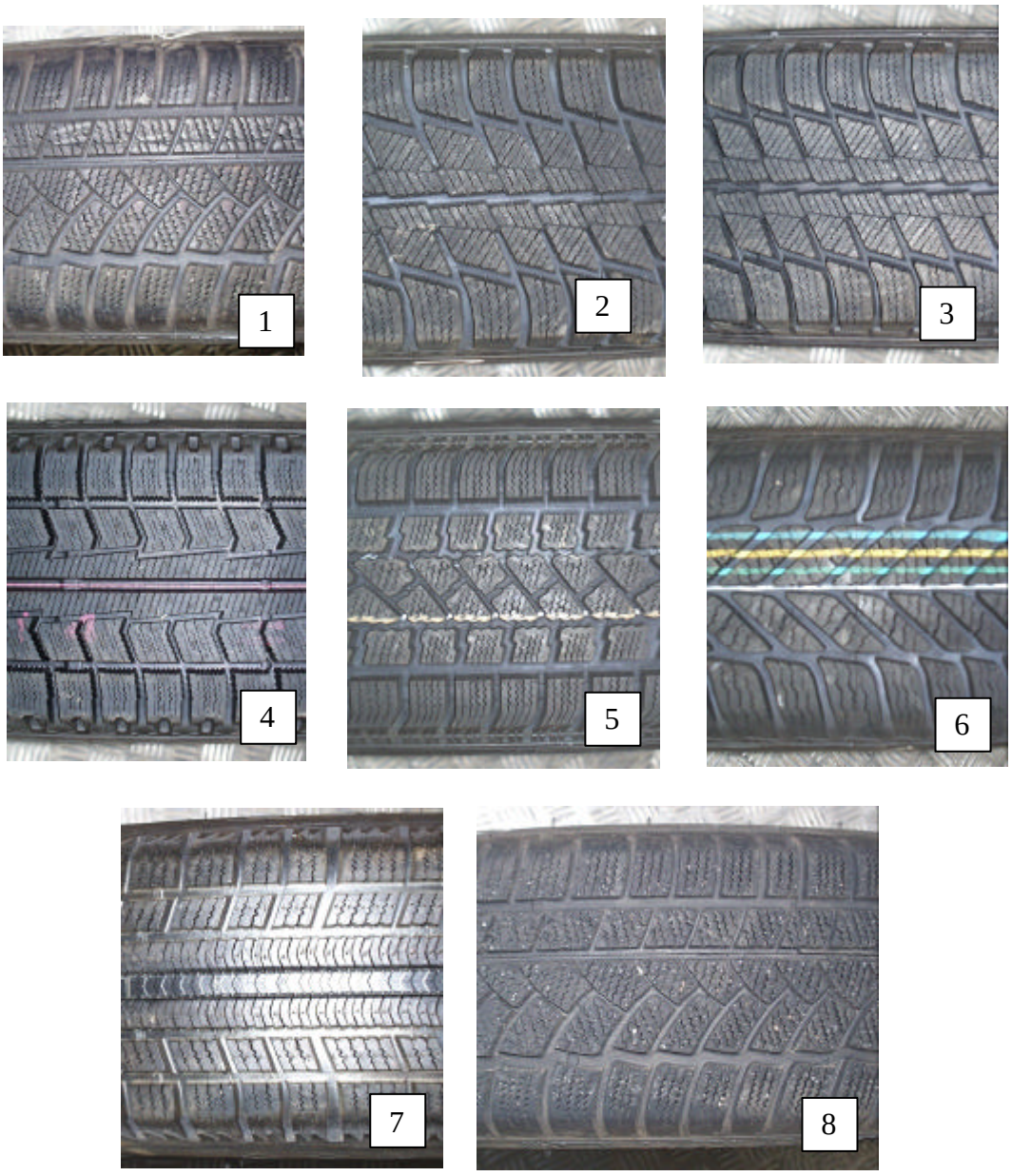

Figure 1 Tread pattern of the tested tyres.

Tyre number 1 was used as a reference tyre and has also been used in a previous test on wet ice [2].

4 Test equipment

The tests were carried out on a wetted smooth ice surface at the VTI tyre testing facility. The facility has a 55 meter long and 0.6 meter wide moving road pavement in an air-conditioned building. The test wheel is mounted on a stationary measuring wheel rig with a maximum wheel load of 10 tons and a test speed of up to about 10 m/s. The wheel rig can be rotated during measurement to simulate steering manoeuvres. Both truck and passenger car tyres can be tested in the machine. More detailed descriptions are given elsewhere [1]. In figure 2 the test rig is shown adapted with a passenger car tyre

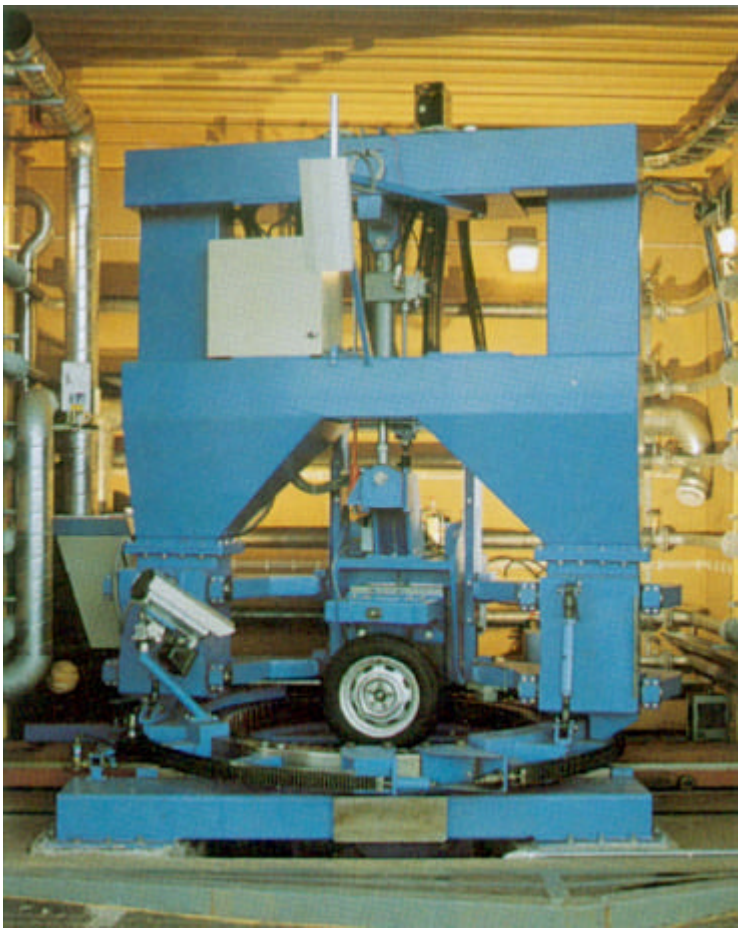

Figure 2 VTI tyre test facility. Test rig with passenger car tyre

5 Test method

The tests were performed at a speed of 30 km/h on smooth ice, wetted by a water jet in front of the tyre producing a water film of about 0,1 mm. Before wetting the ice had a temperature of –3,5 C ± 1.5 C. Both braking tests and steering tests were carried out. Due to problems with the machinery the steering tests had to be interrupted and therefore only two repetitions was made instead of four as planned.

In the evaluation of the braking tests, the maximum braking friction, the friction at 13 % longitudinal slip and friction with a locked wheel was calculated. The results from the steering tests are maximum lateral friction and friction at 3, 5, 10 and 20 degrees side slip angle.

Wheel load was 4,5 kN and tyre pressure 250 kPa.

The measuring programme comprised four braking tests with each tyre plus some extra tests for the reference tyre (tyre number 1). The tests were performed with a time interval of 6 to 10 minutes in series starting and ending with the reference tyre. At the start of each test day repeated tests with the reference tyre was made until stable values were obtained. The reason is an initial polishing effect that gradually reduces friction. About three initial polishing runs were required.

Program for braking tests Day 1	*Program for Steering tests* Day 2
1,2,3,4,1	1,2,3,4
1,5,6,7,8	1,5,6,7,8
1,4,3,2,1	1,4,3,2
1,8,7,6,5	1,8,7,6,5,1
1,5,6,7,8	
1,2,3,4,1	
1,8,7,6,5	
1,4,3,2,1	

6 Results

Results from braking tests on wet ice are presented in tables 2 and figures 3 and 4 below. The results are presented as mean values and standard deviation.

Table 2 Results from brake tests on wet ice

Tyre no	Peak friction		Locked wheel		Friction at 13% slip	
	Mean	Stdv	Mean	Stdv	Mean	Stdv
1	0.088	0.003	0.081	0.003	0.063	0.008
2	0.126	0.002	0.120	0.003	0.067	0.012
3	0.120	0.009	0.114	0.009	0.067	0.015
4	0.113	0.004	0.107	0.003	0.082	0.009
5	0.107	0.007	0.098	0.002	0.066	0.009
6	0.093	0.005	0.084	0.005	0.062	0.013
7	0.076	0.015	0.059	0.002	0.065	0.012
8	0.117	0.013	0.100	0.002	0.112	0.011

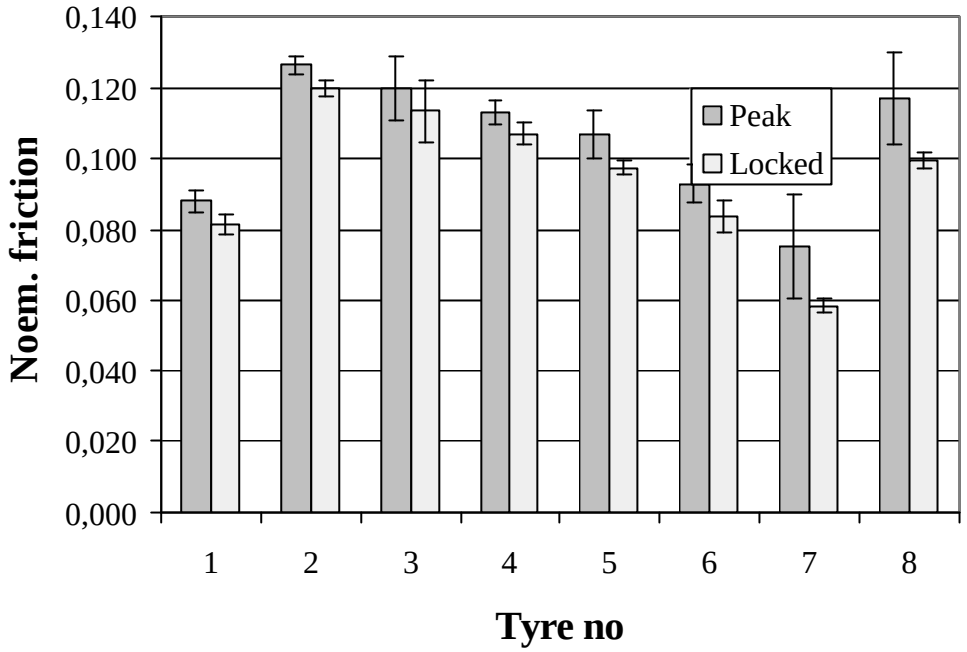

Figure 3 Peak and locked wheel friction from brake tests.

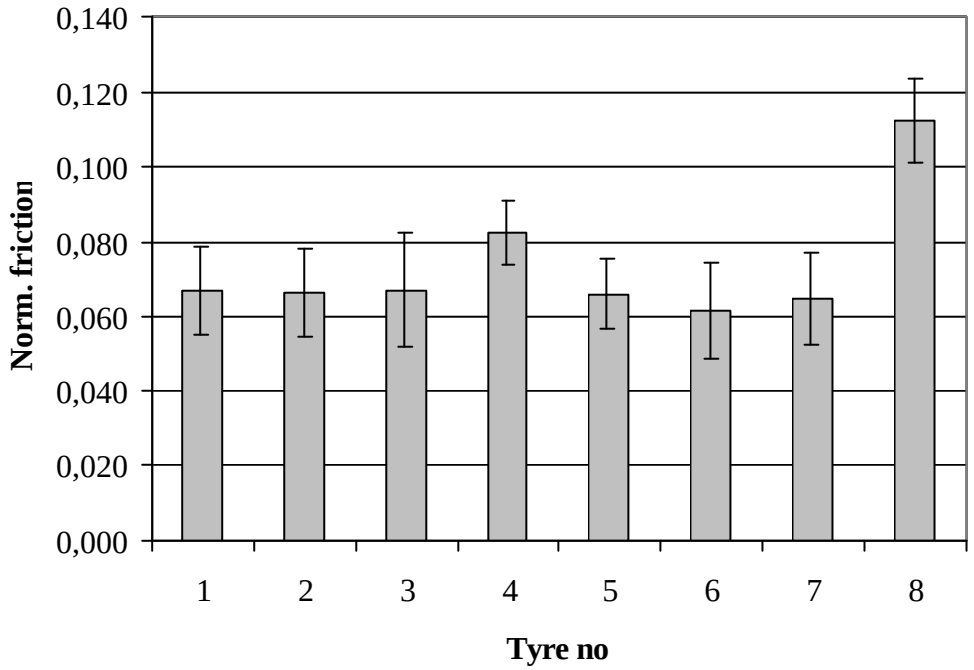

Figure 4 Brake friction at 13 % longitudinal slip

Results from the steering tests are presented in table 3 and in figure 5. In the steering tests the data was somewhat irregular and therefore an averaging routine was used to find the lateral friction values presented in table 3 and figure 5.

Table 3 Results from steering tests on wet ice

Tyre no	Friction at slip angle								Peak friction	
	3 deg		5 deg		10 deg		20 deg			
	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv
1	0,069	0,004	0,073	0,004	0,081	0,003	0,089	0,003	0,089	0,003
2	0,068	0,000	0,077	0,000	0,086	0,000	0,102	0,004	0,102	0,004
3	0,072	0,002	0,078	0,001	0,088	0,001	0,102	0,001	0,102	0,001
4	0,093	0,001	0,095	0,000	0,103	0,000	0,104	0,000	0,104	0,000
5	0,085	0,002	0,088	0,003	0,089	0,001	0,093	0,004	0,093	0,004
6	0,074	0,001	0,075	0,000	0,080	0,001	0,087	0,003	0,087	0,003
7	0,086	0,000	0,080	0,003	0,078	0,003	0,077	0,002	0,088	0,001
8	0,127	0,009	0,124	0,007	0,124	0,003	0,122	0,004	0,137	*

Because of problems with the test equipment only two steering tests with each tyre could be made. For most of the tests the maximum (or peak) lateral friction coincides with the friction level at 20 degrees slip angle. Only for tyre 7 and 8 could a peak friction, at slip angles below 20 degrees, be found, see also table 3 and figure 5.

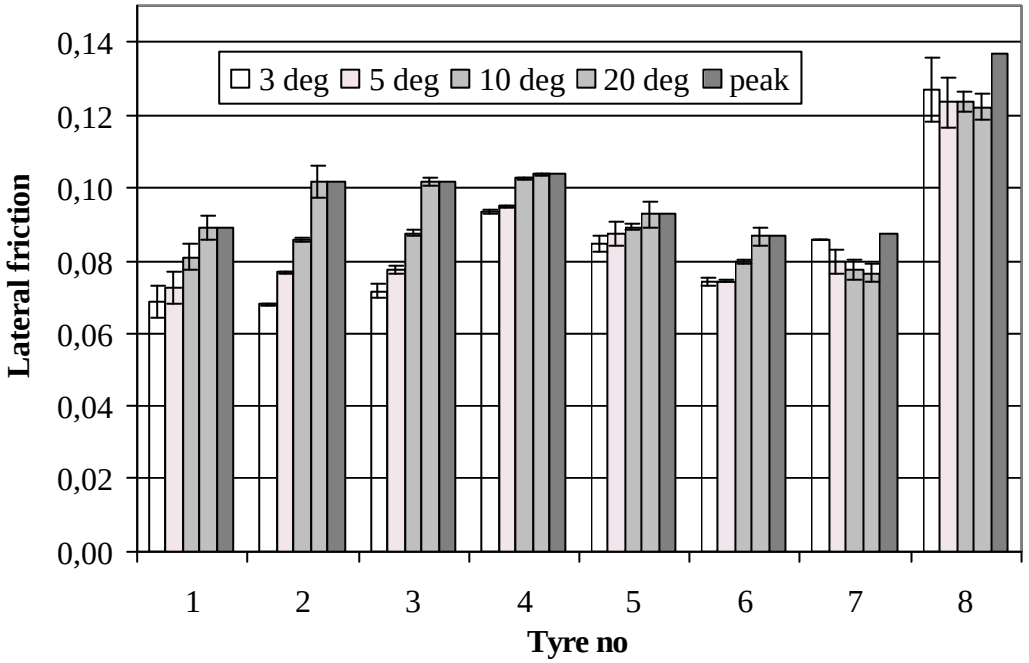

Figure 5 Lateral friction from steering tests

* Only one peak value could be evaluated

7 Discussion and conclusions

Water covered ice can be regarded as one of the most slippery road conditions. It is clear from these results that the hard aggregates added to the rubber in tyre number 8 increase the brake and steer friction on wet ice. For the peak and locked wheel braking friction, tyre number 8 is at the same level as the best of the other non studded M+S tyres, seen in figure 3. At 13 % slip, representing an ABS braking situation, tyre number 8 has a significantly higher friction than all other tyres tested, seen in figure 4. The friction-slip curve for tyre number 8 is also nearly flat at longitudinal slip between 10 and 100 %. The other tyres either have a strong decrease in friction after the initial peak (tyre number 7) or a steadily increasing friction up to the maximum at 100 % slip, e.g. tyre number 1. Examples of these friction-slip curves are shown in figure 6.

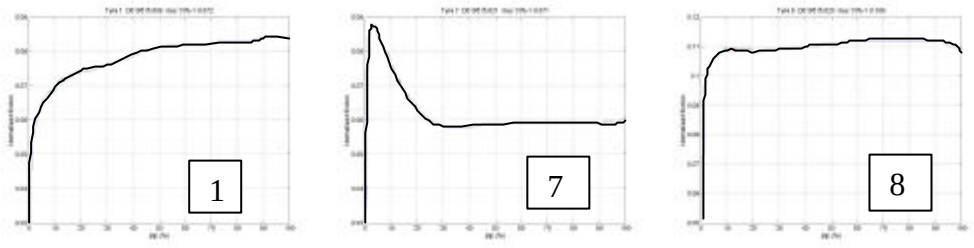

Figure 6 Examples of typical friction-slip curves for tyres number 1, 7 and 8.

Also in the steering tests the hard aggregates added to the rubber improve the lateral friction and thus the steering capabilities of the tyre on wet ice. Tyre number 8 has significantly higher lateral friction on wet ice compared to the other tyres in this test.

It is clear that the aggregates added to the rubber increase the friction on wet ice. The hard aggregates act like small studs imbedded into the tyre surface thus improving the frictional properties of the tyre under very slippery conditions.

8 References

1. Nordström O: **The VTI flat bed tire test facility - A new tool for testing commercial tire characteristics.** SAE technical paper series. Vol 933006. 1993.

2. Nordström O: **Comparative test of the effect on wet ice friction of adding a special aggregate in the tread rubber of a retreaded M+S tyre type.** VTI notat 15A-2001. VTI. Linköping. 2001.