PERIODICA POLYTECHNICA SER. CIVIL ENG. VOL. 40, NO. 2, PP. 115–125 (1996)

FACTORS INFLUENCING TRACK FORMATION IN ASPHALTS

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Received: Sept. 29, 1995

Abstract

At the TUB Department of Highway and Traffic Engineering track formation tests have been pursued for years. At this test a rubber wheel with $0.4\,N/mm^2$ load is moving up and down on the warm asphalt specimen. A test series has been made for studying the influence of natural sand content of the natural mineral carcass and the hardness of bitumen on track formation. Although mixtures made with 100% crushed sand have the minimum warm deformation, increasing natural sand proportion above 75/25% reduces warm deformation at a low rate. The application of hard bitumen also reduces track formation but it is important to say that near to the softening point of the applied bitumen asphalt properties change steeply.

Keywords: asphalt technology, warm behaviour of asphalts, track formation test.

Wheel track formation especially on the marginal traffic lanes is one of the most important causes of quality worsening and deterioration of asphalt concrete roads today. Recognizing this, developed countries started research and tests in this field decades ago. For economical keeping the state of the road network and for optimum measures the probable changes have to be known. Wheel tracking paths have an important role here.

Wheel imprints form where vehicles have to travel on a nearly identical path. The larger the traffic volume, the higher the temperature, and the lower the deformation resistance of the asphalt concrete, the deeper rut will be formed. The first two factors can only be altered conditionally; asphalt temperature can be lowered with a lighter colour (application of light colour stone, or light rubble surface coating). But road building specialists have a great influence on the third factor, the deformation behaviour.

Strength generally means the greatest resistance shown by the specimen at the so-called static tests. However, no static strength tests involve simulation of the actual stress, due to the following three main reasons:

- tests lack the fatiguing character concerning repeated stress;
- a stress of magnitude order corresponding to practice is not given at the static strength tests and deformation measurements;
- static tests are not performed at the standard test temperature of +50°C.

Laboratory tests and practical behaviour are two different processes, and no data on track formation can be expected from either of them. Wheel track formation on the roads is a consequence of numerous small viscoelastic slip processes, occurring at higher temperatures with each wheel passing. However, in the laboratory strength tests after a certain number of loads innumerable micro-cracks occur in the specimen finally causing a break.

With higher temperatures in summer, viscous properties of the asphalts prevail, and therefore elastics theory based mechanical tests are of less use. With high asphalt temperature, external mechanical work of the load is balanced by internal work produced by small internal stresses and large (mainly viscous, plastic) deformations.

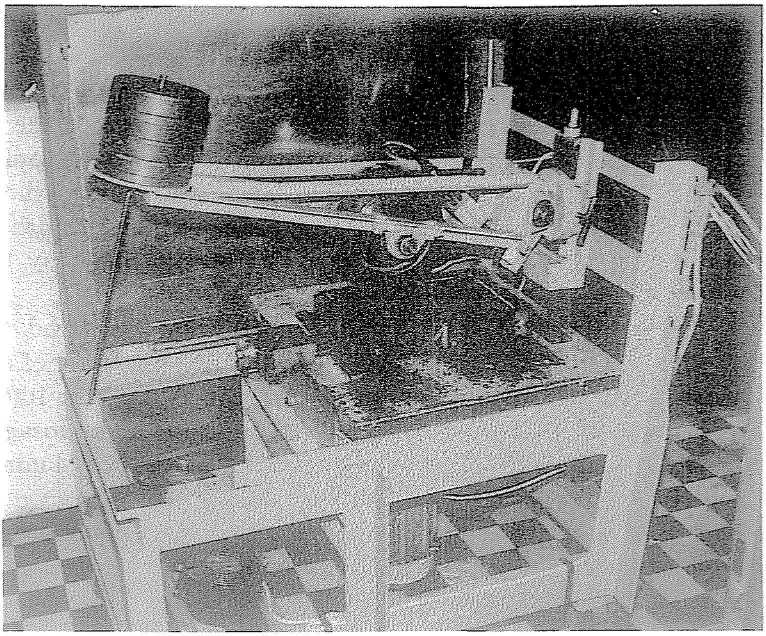
Load duration plays more determinative role in forming of large deformations than its magnitude, thus, at high temperature the so-called creeping, slow strain, asphalt mechanical properties related with sustained load prevail.

Studying of warm behaviour properties is especially important at the wearing courses receiving the most stress of every kind. Wheel track and rib formation, the surface's becoming mortar-like (slippery) cause road quality deterioration at these courses in the warm summer period.

Wheel tracking is one of the most important warm behaviour tests. During this test a solid-rubber tyre wheel is passing up and down with a given load, section length, frequency and time duration on the asphalt specimen. The most important result of the test is the average rut depth in function of time (cycle number), also suitable for graphical representation.

Picture 1 shows the wheel tracking equipment, a modified and further developed version of the original English one, used at the TUB Department of Highway and Traffic Engineering.

The 200×305 mm wide and long, $30 - 100$ mm thick specimens are tempered in free air for 10 to 24 hours. Afterwards they are placed in the testing equipment where tests are performed in a tempered, closed room. The rubber wheel of 200 mm diameter with a $0.4\,\text{N/mm}^2$ load is passing up and down the specimen for 3 hours with a movement rate of 42 passes/minute. Deformation of the specimen is recorded and drawn by computer, through an electronic displacement transmitter.



Picture 1: Track formation testing equipment

Tests performed in West Europe in order to determine the factors causing wheel ruts give the following results:

The most important factors are the large axle load of heavy vehicles together with their traffic volume, and the high summer temperatures. However, from the road engineering viewpoint the composition of the applied asphalt courses is more important: the type and quality of the applied bitumen and mineral aggregate, and the different asphalt technological characteristics (bitumen content, voids, compactness, etc.).

Measurements performed on experimental roads show that growing of the wheel track depth slows down with the time of use.

Layers are changing by the effect of traffic and weather. The question of whether the road has enough stability can be answered positively if the recorded process of wheel track channel formation shows an explicit flattening. Regular depth measurements on representative sections allow the estimation of stability at a given time.

An important aim of the research is to elaborate methods for preventing and repairing harmful deformations.

For prevention, selection of wearing courses (and their materials) of characteristic features with maximum resistance against wheel track formation is the most important. On this ground, wheel track formation can be prevented — besides safer road construction — by the following methods:

a) Applying a harder bitumen. This is a solution of limited application, as cold behaviour in winter of asphalts made with harder binder is more unfavourable, hardening continuing in the finished pavement (ageing). Thus, correct tests are necessary for selecting the appropriate bitumen hardness. Here is to be mentioned the application of so-called modified bitumens, obtained by adding high molecular polymers. Thus, viscosity at high temperatures increases without the worsening of cold behaviour, but mixing and pouring may become problematic.
b) For aggregate, application of angular shape stone material, the increase of rubble content, and prescription of coarse grading of mineral aggregate are by all means favourable. For sand fractions, 100% rubbled sand – natural sand proportion is the best, but filler dosage must also be kept in mind: filler – binder proportion has to be 1.4 minimum, according to tests.
c) The third proposal concerns reduction of bitumen content but this may cause larger void content in the pavement leading to undesirable phenomena. Thus, the considerable reduction of bitumen content must be rejected, and the problem can only be answered after thoroughly performed special tests, or with studying and adapting reliable experience.

This last solution is also contradicted by today's 'success' mixes, the high crushed aggregate mastic asphalts.

Due to the above, we tested, first of all, the effect of bitumen quality change and the relation between temperature and bitumen quality. The effect of crushed sand to natural sand ratio was the other studied factor.

Bitumens Drawn in the Test

Six different bitumens have been used for tests, with most important characteristics contained in *Table 1*.

As seen in *Table 1* there are also soft, medium and very hard bitumens among the tested types.

Grading of Mineral Aggregate of the Asphalt Tested

During the testing we aimed at grading of mineral aggregate

- being well reproducible,
- corresponding to the most often applied wearing course,
- containing a relatively high amount of sand,
- having appropriate capacity for bitumen.

Table 1
Characteristics of used bitumens

Bitumen type	Ring and ball softening point [°C]	Penetration [0.1 mm]
SzB-90	48.0	86
B80	48.4	76
B65	52.0	49
SzB-50	57.0	47
SzB-30	66.0	29
DMB-80	67.2	83

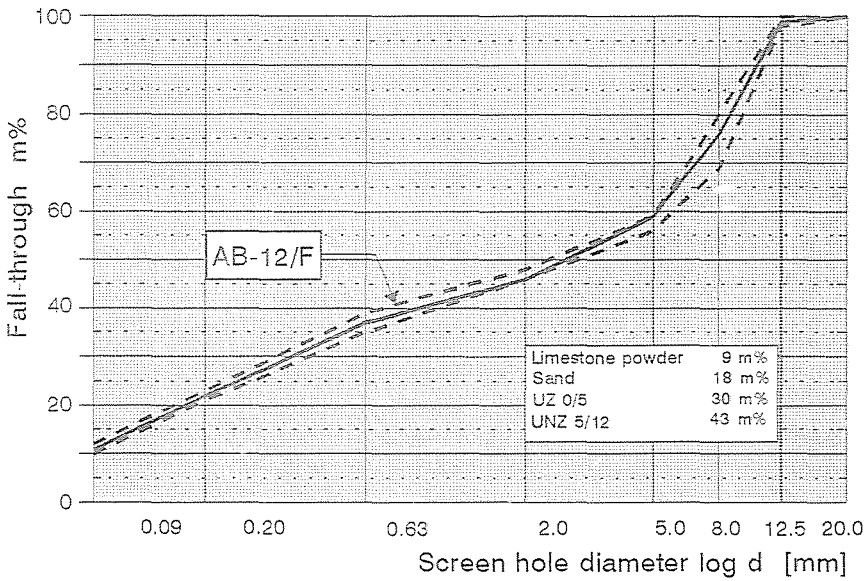


Fig. 1. Grading of mineral aggregate of asphalt used in the test

All these resulted in the application of a grading of mineral aggregate type AB-12 seen in *Fig. 1*, designed within very narrow grading of mineral aggregate curve domain. The 35% sand content also provided an opportunity to test the effect of sand quality.

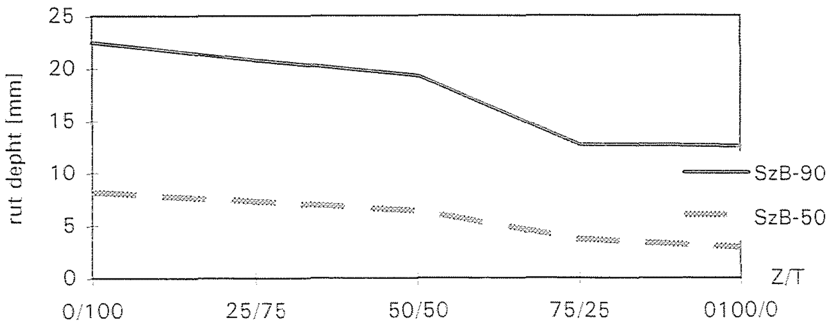


Fig. 2. Effect of crushed and natural sand ratio on rut depth

In order to eliminate effects due to different bitumen content, mixes have been made uniformly with $B = 6.3\%$ bitumen. Suitability tests showed that this bitumen content gave near optimum asphalt mix composition for asphalt technology even when using bitumens of different hardness.

Effect of Crushed and Natural Sand

In the first test series the above introduced grading of mineral aggregate curve has been produced in an unchanged form but with crushed/natural sand proportions $Z/T = 100/0$, $75/25$, $50/50$, $0/100$.

Asphalt mixes prepared so have been tested by the application of soft and hard bitumen at 60°C regarded as standard temperature. Results are seen in *Fig. 2*, showing that until Z/T of $75/25$ ratio track formation considerably reduces but this reduction stops at this point, that is, a Z/T ratio of $100/0$ does not considerably improve resistance of asphalt against deformation. Therefore asphalts of this composition have been tested afterwards. It is also seen that the effect of Z/T ratio is lower when applying hard bitumen.

Effect of Bitumen Quality

The test had two objectives: it aimed at studying the behaviour of different binding materials in identical mineral carcass, and at drawing conclusions from tests carried out at four temperature values on the behaviour of mixes

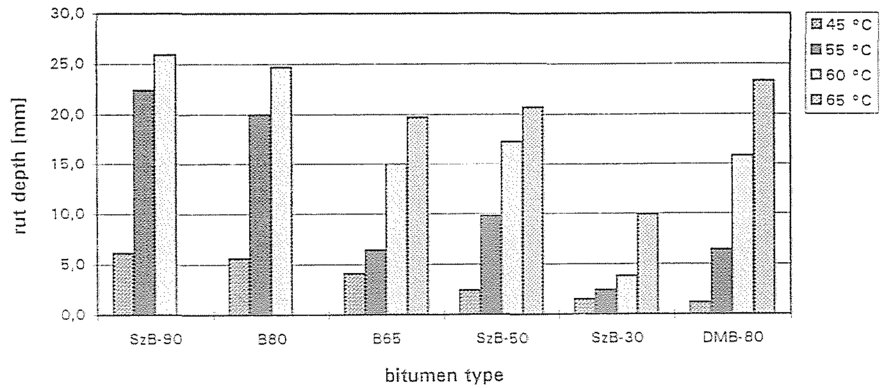


Fig. 3. The formed track depths

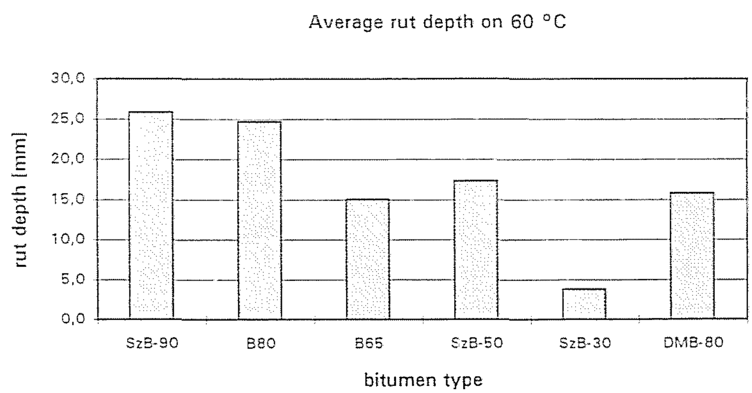


Fig. 4. Track depths of tests at 60°C

made with different bitumens in the temperature range of +45 – +65°C and on their temperature sensitivity.

Table 2 contains average rut depths obtained at the end of the three-hour test.

Table 2
Results of the wheel tracking tests

Bitumen type	SzB-90	B80	B65	SzB-50	SzB-30	DMB-80
Temperature [°]			Average rut depth [mm]			
45	6.1	5.6	4.1	2.4	1.5	1.2
55	22.4	20.0	6.4	9.8	2.4	6.4
60	—	—	15.0	17.3	3.8	15.8
65	—	—	19.7	20.7	9.9	23.3

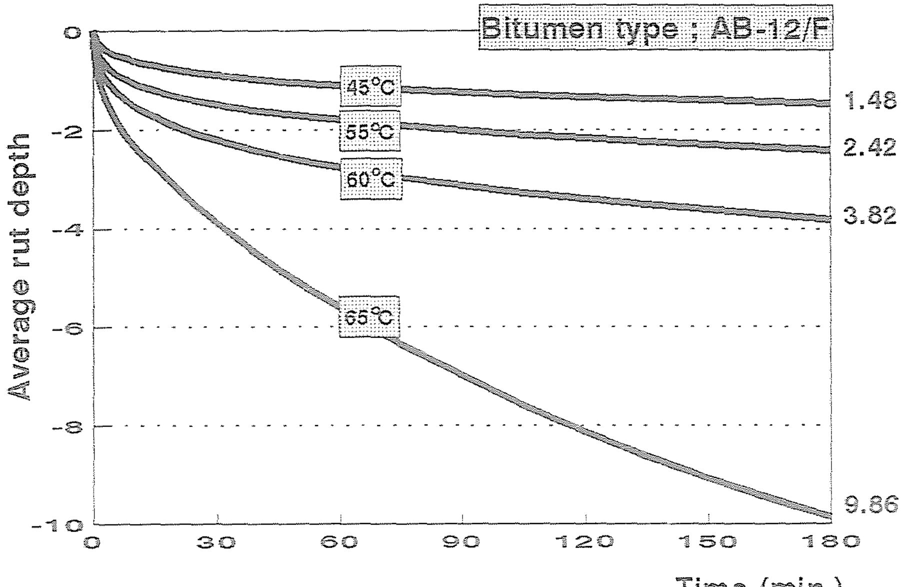


Fig. 5. Track formation curves of mix made with SzB-90 bitumen

Fig. 3 also shows graphically the rut depths of the individual mixes obtained at different temperatures.

Fig. 4 demonstrates rut depths measured at 60°C of mixes made with different bitumens. It is well seen that mix made with the hardest bitumen had the smallest track depth.

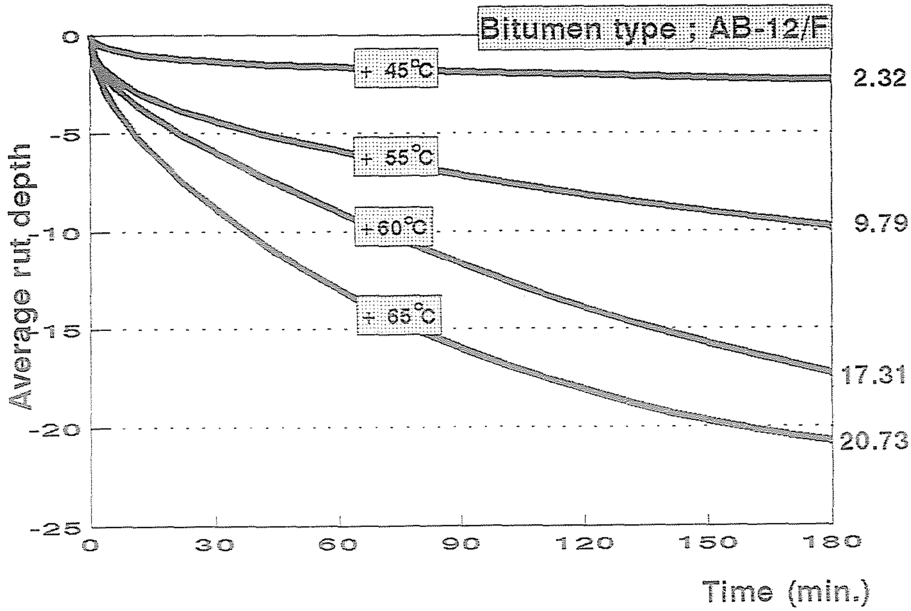


Fig. 6. Track formation curves of mix made with SzB-50 bitumen

Figs 5 – 7 depict track formation curves of mixes made with three different bitumen types. Average track depth has been demonstrated as a function of time, for tests carried out at different temperatures.

As soft bitumen tests could not be finished within the usual 3 hours *Fig. 8* shows track depth formed in the 60th minute in the function of testing temperature.

Evaluating the results regarding temperature sensitivity it can be found that harder and softer binding materials behave differently with increasing temperature. As the diagram of *Fig. 8* demonstrates hard bitumen (SZB-30) reacts less to the increase of temperature the track depth curve rising with uniform slope until 60°C and having a leap at 65°C first. Medium hard bitumens DMB-80, B-65, and SzB-50 have similar curves rising uniformly with similar values. (A slight break may be observed in the curve of B65, at +55°C). Mixes made with the soft B80 and SzB90 binders show great difference between values measured at +45°C and +55°C, and after this the curve also rises nearly uniformly, and the specimens suffer great deformations everywhere.

Thus, according to our tests, hard bitumen reacts more intensively to temperatures above +60°C but below this it endures well the increase of the temperature, with values rising uniformly and steeply. At the same

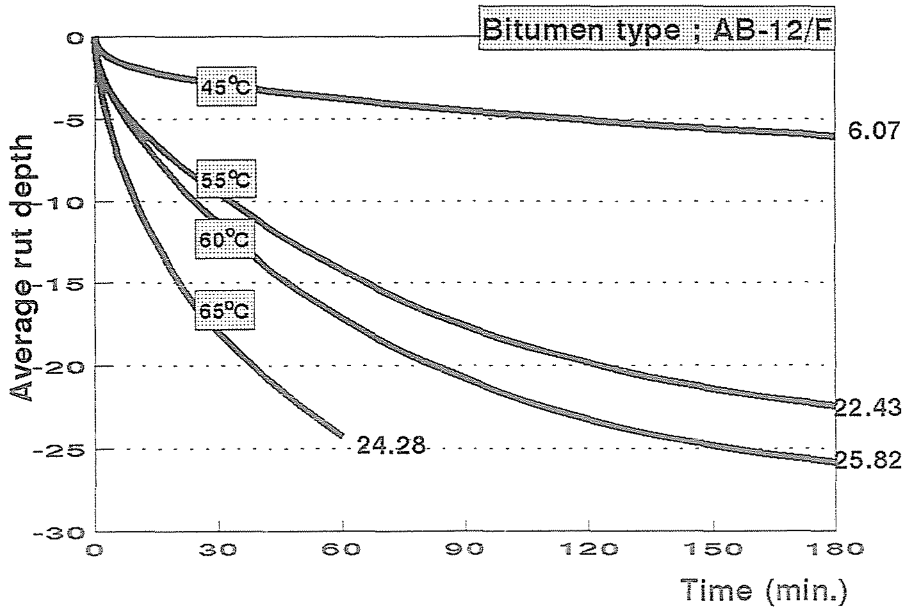


Fig. 7. Track formation curves of mix made with SzB-30 bitumen

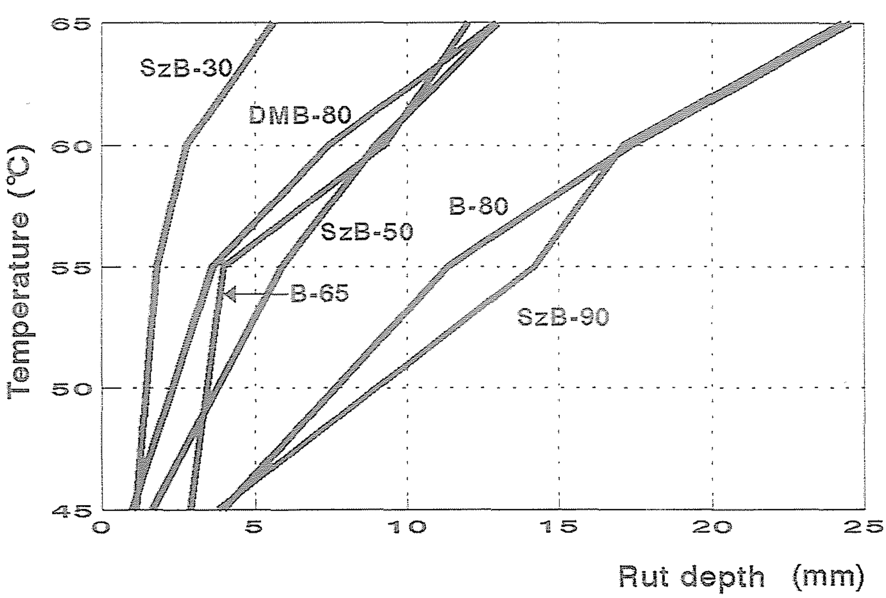


Fig. 8. Track depth versus testing temperature

time, soft bitumens considerably deform already at low temperatures and also considerably and uniformly deform in higher temperature ranges. Bitumens of medium hardness fall between the two extremities deforming relatively uniformly.

Summarising Evaluation

Warm behaviour of asphalts is a very important field of asphalt technology worth of further analysis. Our tests performed show that both sand quality and bitumen hardness are of great importance for asphalt mixes of traditional composition.

From the tests it can be seen that although mixes prepared with 100% crushed sand have minimum warm deformation, with crushed per natural sand proportion over 75/25%, warm deformation decreases only slightly.

Observations concerning temperature sensitivity also meet the expectations. The behaviour of the harder or modified bitumen is also the most favourable here, that is, the properties of these materials only deteriorate fast above +60°C. Thus, the behaviour of a specific binding material will only be considerably worsened at a test temperature higher than the material's softening point.

Unambiguous and reliable connections between laboratory tests and real wheel tracks forming on the roads can only be established and relations for the individual asphalt types recognised by carrying out further tests until we thoroughly learn the materials' properties.

Results of the test series unequivocally show that the application of hard binder materials is favourable regarding warm behaviour. However, the complete solution also needs thorough tests performed on cold behaviour properties of bitumen as we may obtain — and probably obtain — opposite results.

Parallel evaluating the two tested groups and comparing the results, solutions can be found for compromise between the two different asphalt behaviours at extreme temperatures.