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Finnra

HVS-NORDIC

The activity of the first period in Finland 1997 - 1999

Research programme for full scale accelerated pavement testing in Finland and Sweden 1997-2003

Finnish National Road Administration

Technical Research Centre of Finland

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ABSTRACT

An accelerated pavement-testing facility Heavy Vehicle Simulator (HVS) MARK IV was bought from South Africa. It is owned on a 50/50 basis by Finland the Technical Research Centre of Finland (VTT) and the Finnish National Road Administration (Finnra) and Sweden the Swedish Road and Transport Research Institute (VTI). HVS-NORDIC was used in Finland during 1997 98 and in Sweden, 1998 2000.

A six-year period of research collaboration between 1997 and 2003 has been agreed. The co-operation is organized on three levels; steering, programme and operative groups.

The test programme, its background and principles are described in the joint Finnish-Swedish Research Programme. A common test procedure including construction, quality control, instrumentation and test parameters was implemented.

A common Finnish-Swedish database was constructed. All the data from the tested constructions, and the observations and measurements are stored in the common database for all partners to use. All the Finnish data from tests in the first HVS period in Finland have been checked, corrected and stored in the database and partly analyzed.

The first pavements tested lasted much longer than expected, except for the thawing structures. The reasons for this good performance are not yet clear.

However, when the water-table level was raised close to the base layer, rutting increased dramatically and some cracks were found on the road surface.

Since deterioration occurred slower than expected, instrumentation and response measurements are important assets when modelling pavement performance.

The HVS uni-/bi-directional loading mode was not found to have any effect on road rutting. Therefore, the bi-directional loading mode can generally be used, which means double efficiency.

Despite some technical problems during the first period in Finland, the HVS testing time was 62 % , which is moderate for the first year.

It was found that accelerated pavement testing (APT) is a useful tool for pavement research but it requires careful test planning.

FOREWORD

This is the first report of HVS-NORDIC, the six-year joint Finnish-Swedish Research Programme on accelerated pavement testing. This report describes the activity of the first period in Finland.

This HVS-NORDIC research is a part of the Finnish National Road Structures Research Programme, TPPT, which is sponsored by the Finnish National Road Administration (Finnra). The HVS-NORDIC research is being carried out in co-operation with the Swedish National Road and Transport Research Institute (VTI), and the Swedish National Road Administration (SNRA).

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The report has been written by Matti Huhtala and Jari Pihlajamaki who are responsible for the HVS-NORDIC research in Finland. It was done according to the guidelines of the HVS-NORDIC Programme group, Aarno Valkeisenmaki and Kari Lehtonen from Finnra, Rolf Magnusson and Hans Wirstam from SNRA, and Kent Gustafson and Leif G. Wiman from VTI.

ABBREVIATIONS

APT	Accelerated Pavement Testing
HVS	Heavy Vehicle Simulator
Finnra	Finnish National Road Administration
VTT	Technical Research Centre of Finland
SNRA	Swedish National Road Administration
VTI	Swedish National Road and Transport Research Institute
NVF	Nordic Road Association
OECD	Organisation for Economic Co-operation and Development
STRO	Scandinavian Tyre and Rim Organisation
TPPT	Finnish National Road Structures Research Programme
LCPC	Laboratoire des Ponts et Chaussées, France
CAPTIF	APT facility in New Zealand
FWD	Falling Weight Deflectometer
AC	Asphalt Concrete
ACB	Asphalt Concrete in base course
ACBi	Asphalt Concrete in binder course
SMA	Split mastic asphalt
AC20	Asphalt Concrete, maximum grain size 20 mm
B80	Bitumen, penetration 80
Q1	Quality class of base layer material
Q2	“
Q3	“

CONTENTS

1 INTRODUCTION

1.1 Background

It was found that the TPPT research programme requires accelerated pavement testing (APT) in order to be successful. It was also soon found that this, and its use, is expensive for VTT to buy alone. Thus, negotiations were started with the Swedish National Road Administration (SNRA) and the Swedish National Road and Transport Research Institute (VTI). Their interest in accelerated pavement testing was known because the Nordic Road Association (NVF) had an ad hoc group for accelerated pavement testing in the late 1980s. At that time, it was not financially possible to buy a common APT facility. After new negotiations, an accelerated pavement-testing facility Heavy Vehicle Simulator (HVS) was ordered from South Africa. It is owned on a 50/50 basis by Sweden (VTI) and Finland (VTT and Finnra). It was used in Finland during 1997 98 and in Sweden, 1998 2000. A six-year period of research collaboration between 1997 and 2003 has been agreed /1/. The co-operation is organized on three levels with steering, programme and operative groups.

1.2 Technical specifications of the machine

The machine is called HVS-NORDIC. The HVS Mark IV is a mobile full-scale accelerated pavement-testing facility (Figure 1), whose loading is linear. It can be run over a short distance by itself at walking speed, in practice only at the same test site. It can be moved as a semi-trailer over longer distances to other test areas or to VTI in Sweden. Since it has steering wheels, it can turn even relatively sharp corners, in spite of its long length. Its highway speed is 50 km/h, and special permits are needed.

Figure 1. HVS-NORDIC accelerated testing facility.

The HVS-NORDIC has a heating/cooling system and thus temperature can be held constant. The air temperature inside the heating/cooling box is controlled in order to keep the pavement temperature constant. The standard temperature of bituminous layers is selected to be +10°C. The HVS can be run by diesel engine or by electric motor. The diesel engine also provides power for the heating/cooling system, which means it is not dependent on external power.

The main technical characteristics are: length 23 m, width 3.5 m, height 4.2 m and weight 46 t. The loading wheels are dual or single; standard dual wheel type is 295/80R22.5 and wide base wheel type is 425/65R22.5. Loading can be uni- or bi-directional, and lateral movement is 0.75 m. The wheel load is from 20 kN to 110 kN (corresponding axle loads 40...220 kN) at speeds up to 15 km/h. The number of loadings is 25 000 in 24 hours (including daily maintenance).

The HVS-NORDIC is the only mobile APT facility in Europe and the only mobile APT facility in the world with full temperature control. The loading of the HVS-NORDIC can be varied dynamically +/- 20 %. As far as we know there are no possibilities for dynamic loading in any other APT facility.

1.3 Test site

The test site is located a few hundred metres from the office of VTT's personnel. The site is smaller than planned because of the problems with the city planning office. The site includes two test pits. One test pit is made of concrete, the walls have thermal insulation and there is complete water table regulation. Its length is 36 m including a 16-m-long slope. Its depth is 2.5 m and its width 4 m at the top and 3 m at the bottom. There is a 3x3 m part of the test pit that is 4.5 m deep for special studies. Two or three test pavements can be constructed in a test pit.

Figure 2. Concrete pool in Otaniemi.

The second test pit is parallel to the first one. It is excavated mainly in rock and it has no water table regulation. It is roughly of the same size as test pit no. 1.

The test pits are situated outside but there is a tent that covers nearly the whole test pit which is also big enough to house the HVS-NORDIC. Another smaller tent was used when the road was constructed for thaw research.

1.4 Instrumentation

The instrumentation for the response measurements is mainly based on experience that has been gained at the Virttaa test site during the last 15 years /2, 8, 9/.

The basic instrumentation is based on strain gauges installed at the bottom and on the surface of the bituminous layers. VTT uses retrofit strain gauges.

The most common set of gauges comprises four longitudinal and four transverse gauges at the bottom and three longitudinal and three transverse gauges on the surface.

Stress in unbound layers is measured with stress sensors that have been bought from the University of Nottingham. These are installed three at the same level (triplicates because the installation may sometimes cause some problems). The height levels are in the middle of the base course and 100 mm and 350 mm in the subgrade.

Deflection under the moving wheel load is measured by a deflection rod anchored at the bottom of the subgrade near the concrete or rock bottom.

The position of the sensors is shown in Figure 3.

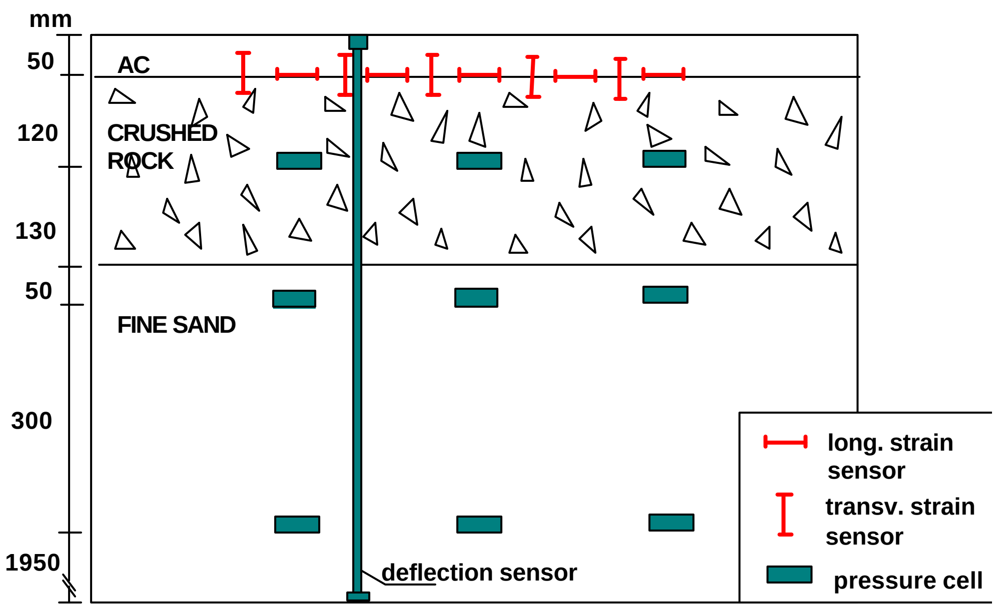

Figure 3. Instrumentation plan.

Deflection before and after the test is measured by a falling weight deflectometer. This cannot be done under HVS because it must be driven away, which also means that there is no temperature control during the measurements.

The deflections are measured during the test by a modified Benkelman beam. The present system is not good and a better system, based on laser, is under consideration.

Strains in unbound materials or subgrade are not being measured at the present in Finland. EMU coil system has been bought but tested only later in Sweden.

The temperature of bituminous layers is measured at three depths. Other specific measurements like water content, porewater pressure, suction, heat-flux, frost depth, radiometric water content and density measurements have been made. In situ plate-bearing tests in the subgrade have also been done.

1.5 Test procedure

A test is started first with a pre-run in order to relax possible residual stresses and cause some post-compaction. This is done with a small wheel load, usually 30 kN and with specific lateral distribution. The normal running time is one day (22 hours in practice) which means about 25 000 passes bi-directionally. If the pavement is weak, as in frost studies, a 20 kN wheel load is used with only 200 uni-directional passes. In this case, the lateral wander is different, uniform distribution.

After the pre-run, so-called zero measurements are made. They include a considerable amount of response measurements: strain, stress and deflection measurements at different wheel loads, tyre inflation pressures, lateral positions and temperatures. Both wide-base tyre and dual tyres are used. The same measurements are repeated later during the test but not so comprehensively. The initial measurement programme is presented in Table 1.

Table 1. Variables in the initial measurement programme (nearly all combinations are used).

Wheel load	(kN)	40	50	60	70	80
Tyre pressure	(kPa)	500	600	700	800	900
Speed	(km/h)	1	4	7	10	12
Pavement temperature	(°C)	0	5	10	15	20

For each wheel load from 40 kN to 80 kN, five tyre-pressure levels have been used. This means many measurements, but these measurements do not take too much time. The highest loads cannot be used if the pavement is weak.

The optimum tyre inflation pressure is used during the test (tables published by manufacturers or STRO), but because the tyres do not warm as much as on the road, 50 kPa is added.

The effect of speed is studied only with one wheel load and tyre pressure combination.

Two transverse positions have been used for all the measurements: sensors under the tyres and between the tyres. The effect of transverse position is measured with one axle load and one tyre inflation pressure as well as the speed.

The main measurements are taken at temperatures of 0°, 5°, 10°, 15° and 20 °C. The change in the temperature by five degrees takes a few hours depending on the thickness of the asphalt.

Basically the same programme is followed later during the test, but in a much simplified fashion.

The standard temperature of bituminous materials for the tests was selected at +10 °C, which is close to the weighted mean temperature in Southern Finland and in Sweden. The standard wheel load is 60 kN and tyre pressure 800 kPa. This corresponds to some overload and has been selected to slightly accelerate the test.

Transverse profiles are measured at five locations with a laser profilograph constructed at VTI for the HVS-NORDIC. Rutting is expressed as a mean value of those rut depths.

Cracks are drawn on paper with the aid of a 1x1 m grid that is divided into 100x100 mm squares.

1.6 Database

All the data is collected in a common database. VTT uses ORACLE and ACCESS, and VTI uses ACCESS. The structure is the same and there will be no dedicated application programs.

Tables include all the information on test fields, pavement structures, sensors and materials. Environment data as well as profile and FWD results are in their own tables. The driving history is complete only in the HVS files, and only selected information that is relevant to research is saved in the common database. Measurement signals are saved in their own signal files and only top values, etc. that will be used in data analysis are stored in the common database.

The data of the structures and response measurements are in the common database. In the first period in Finland a lot of manual work was needed to check and analyze the measured data. In future, measured data can be put into the database almost in real time, because the data acquisition system is later modified and very little manual work is needed.

1.7 Test programme

The test sections for the first period in Finland are described in Figure 3. The test programme, its background and principles are described in the joint Finnish-Swedish Research Programme /1/.

The goals for evaluating different pavement structures through tests with the HVS are:

- to clarify the performance and durability of various pavement structures and differences between pavement structures in these respects;
- to evaluate different design methods and to estimate the usability of results obtained with different laboratory methods when designing pavements;
- to develop performance models for different pavements.

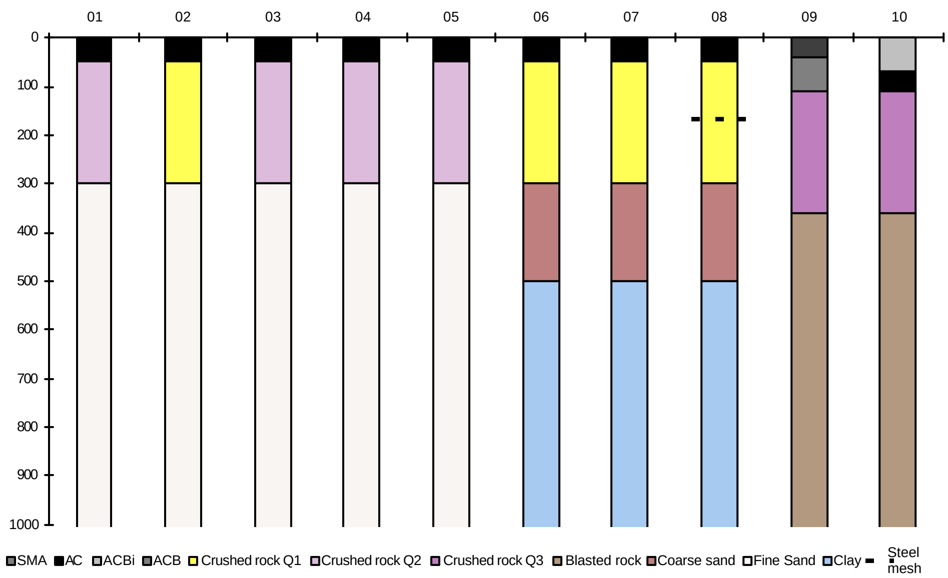

Figure 4. Test sections in Finland for the years 1997-1998. The abbreviations are described on page 3.

Test section 01 is the thin reference pavement. This is a typical pavement for low-volume roads in Finland. The research idea was first to study the lifetime and deterioration process of this common pavement. The purpose was also to gain experience of the facility and to complete the first test in reasonable time, within few weeks.

The number of expected passes needed to deteriorate the pavement was about 250 000 based on theoretical calculations and VTT experience from the OECD test in Nantes in 1990, in which VTT participated /2/.

Test section 02 has about the same construction, has apart from only a base course material of better quality.

Since the lifetime of the first construction was very much longer than expected, the 03 to 05 tests were planned with bituminous layer thicknesses of 40, 50 and 60 mm on the same unbound layers. It was planned to use the same high wheel load for each of the three tests to complete the tests in reasonable time. The research idea was to determine the fatigue curve for reference asphalt concrete with three points, three different strain levels and lifetime for each.

However, after construction the thickness of the asphalt concrete was 50 mm for each of the three test sections, and the pavements were exactly the same as that of test 01. It was decided to test section 03 with 70 kN single wheel uni-directional, section 04 with 70 kN single wheel bi-directional and section 05 with 70 kN dual wheel bi-directional, to study the effect of loading mode (uni-/bi-directional) and the effect of wheel type (dual/single). It was also at the same time a technical test for HVS-NORDIC machine.

A wide-base tyre was used in tests 03...04 and dual tyres in the other tests. Tests 01 02 and 06 08 were performed in test pit 1 (concrete pool) in Otaniemi, tests 03 05 in test pit 2 (rock pool) in Otaniemi and tests 09 10 were carried out on Ring Road II in Espoo, 5 km from VTT.

The tests were comparable in the following way:

The structures of the 01 and 02 tests were similar to each other, except only the unbound base layer was different (both TPPT reference materials). The pavement was very thin, reference pavement for low-traffic highways. The aim was to study the effect of different material base layers on the pavement performance.

The structures of the 03 05 tests were exactly the same, because the contractor could not construct the pavements according to plans. This is why the aim was changed to studying the effect of loading mode (uni-/bi-directional) and the effect of wheel type (dual/single).

The 06 08 tests were thawing tests. The structures of the 06 08 tests were similar to each other except 08 was reinforced with steel mesh in the unbound base layer. The subgrade was made of frost-susceptible material. The road was frozen to about 1.5 m depth during winter. The structures were loaded by the HVS when the pavement was thawed to a depth of 0.9 m from the road surface (the most critical situation for a road).

The structures of the 09 and 10 tests were ones for heavy–traffic highways. One was conventional, and the other a so-called innovative structure. The aim was to study the effect of different materials and different location of bituminous layers on the pavement performance.

1.8 Reporting of the research programme

The reporting of the research programme will be made at six different levels. The reporting is focused for different reasons.

A **Test chart** is made for each test, in principle one A4 page. It includes the pavement structure, research idea, instrumentation, loading parameters and schedule; completed tests also include the number of loadings. The test charts are made for all planned tests.

The **Weekly report** is information about test running. It includes the pavement structure, loading parameters, figures of the number of loadings vs. time, and rutting/cracks vs. the number of loadings. It includes also information about problems and HVS-NORDIC group meetings if any. It is sent every week by e-mail to “HVS-NORDIC group”.

The **Test report** is a description of one single test. The first draft of the report will be available one month after the test is completed. The content is rather informative than scientific, and will be available soon just to inform other HVS-NORDIC members and to provide help according to the experiences gained if modifications to the research programme are needed.

The **Periodic report** includes a summary of each test made during period the HVS-NORDIC was located in Finland or in Sweden. The results of the measurements are presented if they are available at that time. The report provides an update of the database situation after the HVS-NORDIC has been moved to the neighbouring country. In addition, the report includes a discussion of the experiences from the HVS-NORDIC, and its ability to test road distress. The test plans and actual situation, and whether the testing went according to plans are also discussed.

The first draft of the report will be available two months after the HVS-NORDIC has been moved to the neighbouring country. The aim of the report is rather informative than scientific. The purpose is to rapidly inform other HVS-NORDIC members if modifications to the research programme are needed. Therefore, this report only includes those results that are available at that time.

The **Research report** is a conventional (scientific) research report. Preferably, it will include several similar tests, like thawing tests, bitumen stabilized base course tests, etc. It is the compilation of similar kinds of tests. In principle, the report may include tests made both in Finland and in Sweden. The first draft of this report will be made during the six months following the last test.

The **Conference papers** are information about the research programme. Depending on the conference subjects, the papers can be written by individual member or by both countries. The target is to inform and market HVS-NORDIC. Up to now, five presentations have been made in international conferences /3-7/.

2 DESCRIPTION OF THE TESTS

2.1 Test 01, base course test

The first test structure was constructed in test pit no. 1 in Otaniemi (Figure 5). It consists of 50 mm asphalt concrete with bitumen of penetration 80, a 250 mm unbound base layer and subgrade of fine sand. These two test structures act as reference pavements for the research programme. The first tests were carried out at 10 km/h because the HVS was new and needed some run-in.

It was estimated, based on calculations and experience, that about 250 000 passes with wheel load were needed before failure of the pavement.

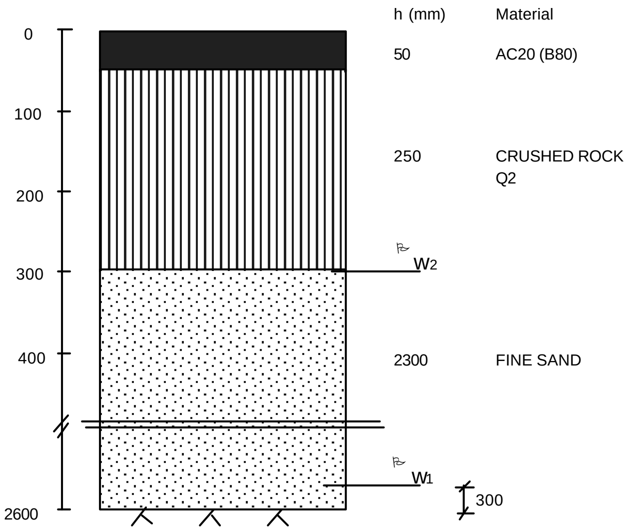

Figure 5. The structure of test 01.

The test had the basic instrumentation without deflection gauge. Response measurements were taken in the beginning of the test (initial measurements) and during loading.

The development of ruts can be seen in Figure 6. It lasted for 1.6 million repetitions without cracks, only 25-mm rutting was found.

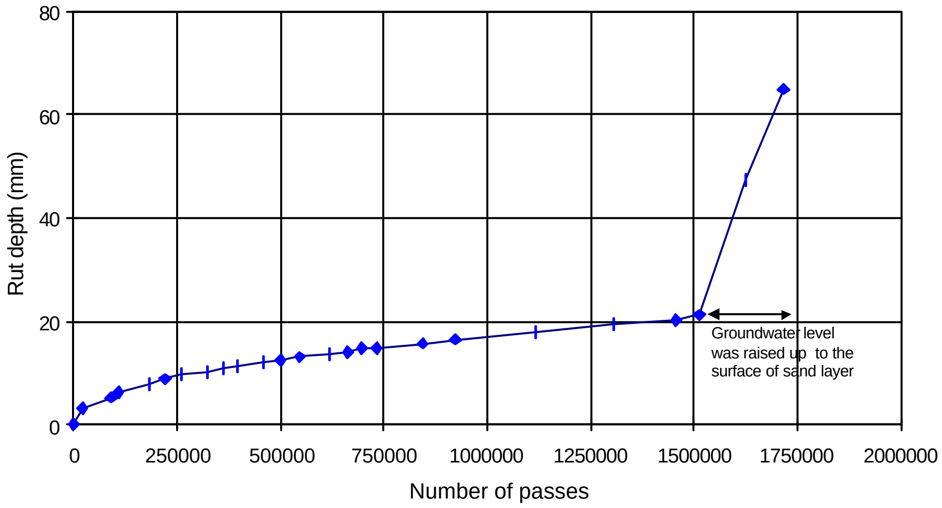

Figure 6. Rut depths vs. number of passes during test 01.

The water-table level was raised from the original level (2.3 m from the road surface) to the level 0.3 m from the surface (at the bottom of the base course) in order to see the effect of moisture, and in order to accelerate the test after 1.6 million load repetitions. Only 0.1 million load repetitions were needed to increase rutting from 21 mm to 65 mm and cause some transverse cracks to appear in the road surface.

When the pavement was opened, it could very clearly be seen that the rut was due to rutting in the subgrade, and the base course was badly deformed.

2.2 Test 02, base course test

The second test structure was also constructed in test pit no. 1 in Otaniemi (Figure 7). The only difference was that the quality of the base course material was high, but both are reference materials in the TPPT research programme. The water-table level was the same as in the beginning of test 01, about 2.3 m from the road surface.

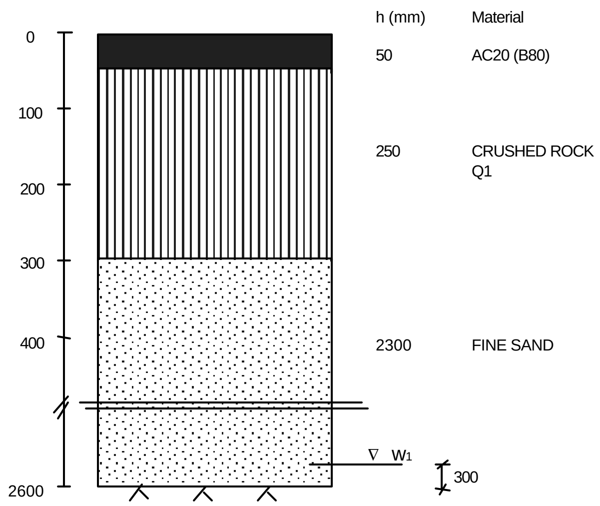

Figure 7. Structure of test 02.

Since it was decided to carry out thawing tests in the first winter, there were only two weeks in which to load test 02. Therefore it was decided to use 80 kN dual wheel load after the initial response measurements.

After 0.17 million passes only 18 mm rutting could be seen but no cracks (Figure 8). After these loadings, the test had to be stopped and thawing test constructions were made in the same test pool.

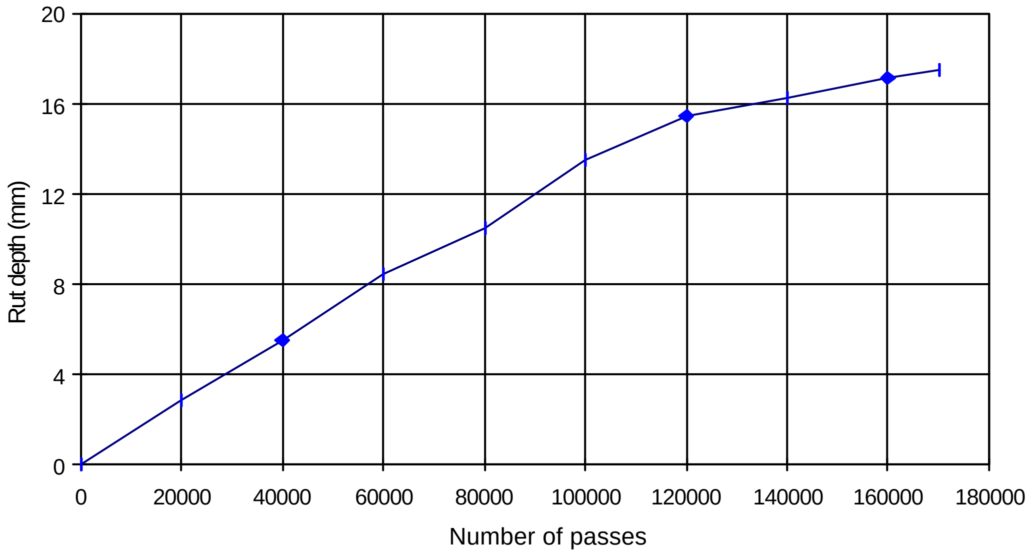

Figure 8. Rut depths vs. number of passes during test 02.

2.3 Test 03, loading mode test

The original research idea of the tests 03-05 was to determine the fatigue curve for reference asphalt concrete at three points, three different strain levels and life time for each. The plan was to construct 40-mm, 50-mm and 60-mm thick asphalt layers for these tests, respectively.

However, the thickness of the asphalt layer was 50 mm for each test section. It was decided to test section 03 with 70 kN single-wheel uni-directional, section 04 with 70 kN single-wheel bi-directional, and section 05 with 70 kN dual wheel bi-directional, to study the effect of loading mode (uni-/bi-directional) and the effect of wheel type (dual/single).

The research idea was to test, in the reference pavement, the effect of loading mode (bi-directional, single-wheel) and compare the results to those loaded with different modes (uni-directional, single-wheel; test 04) and (bi-directional, dual wheel; test 05).

The third test structure was constructed in test pit no. 2 (rock pool) in Otaniemi (Figure 9).

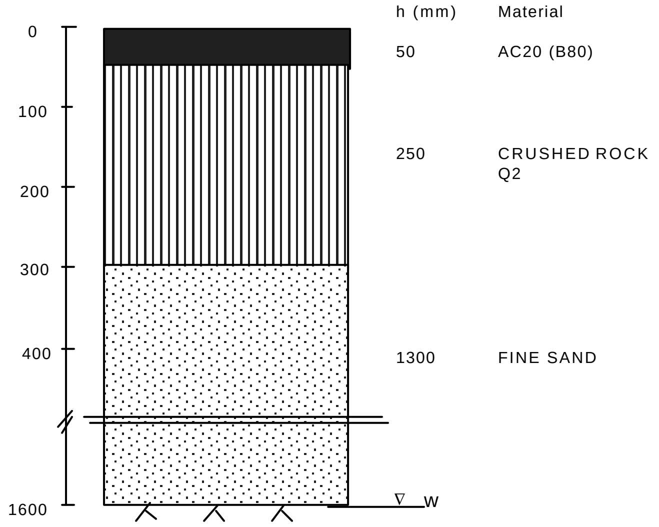

Figure 9. Structure of test 03.

In the beginning of the test, rut depth increased very much but after 0.2 million loadings, rutting increased slowly but linearly (Figure 10).

The first crack was found after 0.9 million load repetitions. Loading was continued up to 1.4 million passes in anticipation of many cracks. However, after the first crack, only two more cracks were found and they did not get wider during the test. All these cracks were longitudinal and the length was about 0.4 m.

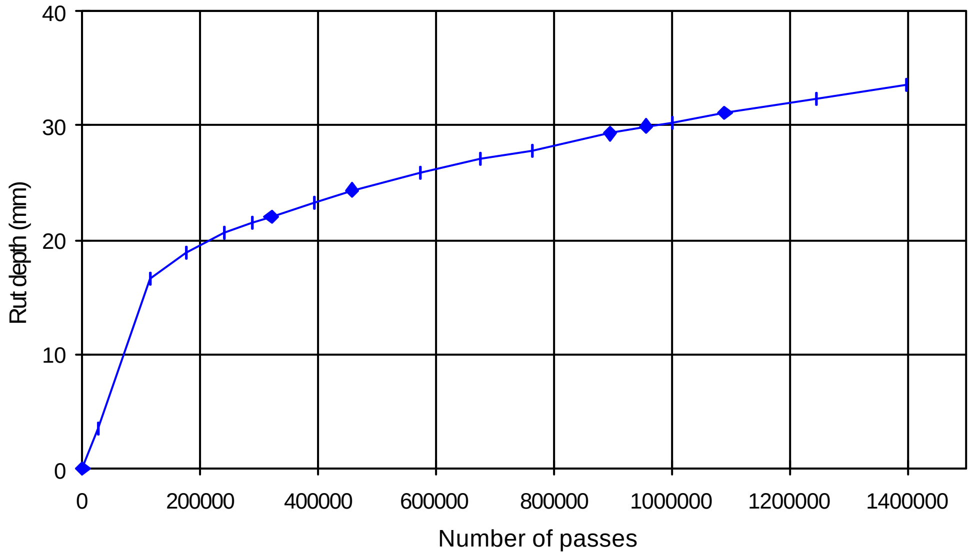

Figure 10. Rut depths vs. number of passes during test 03.

2.4 Test 04, loading mode test

The research idea was to test in the reference pavement the effect of loading mode (uni-directional, single-wheel) and compare the results to those loaded with different modes (bi-directional, single-wheel; test 03) and (bi-directional, dual wheel; test 05).

The fourth test structure was constructed in test pit no. 2 (rock pool) in Otaniemi (Figure 11).

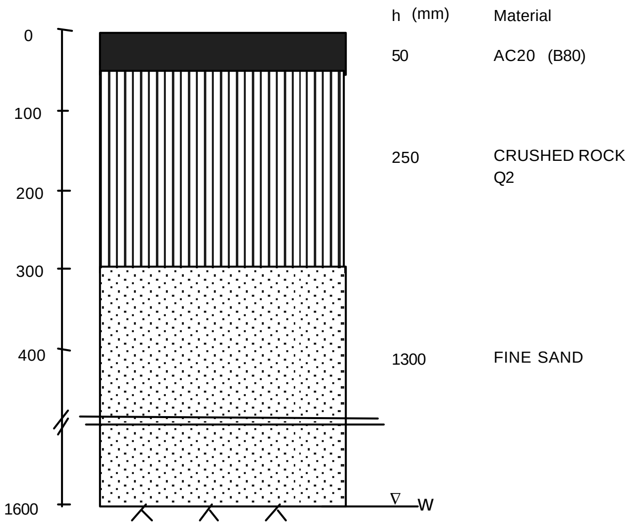

Figure 11. Structure of test 04.

In the beginning, up to 75 000 load repetitions, rut depth increased very much (Figure 12). After that, rutting increased slowly but linearly. No difference was found in rutting during tests 03 and 04 although the loading mode (uni-/bi-directional) was different. The test was interrupted after 0.32 million load repetitions, because the HVS had to be moved to load thawing tests at that time.

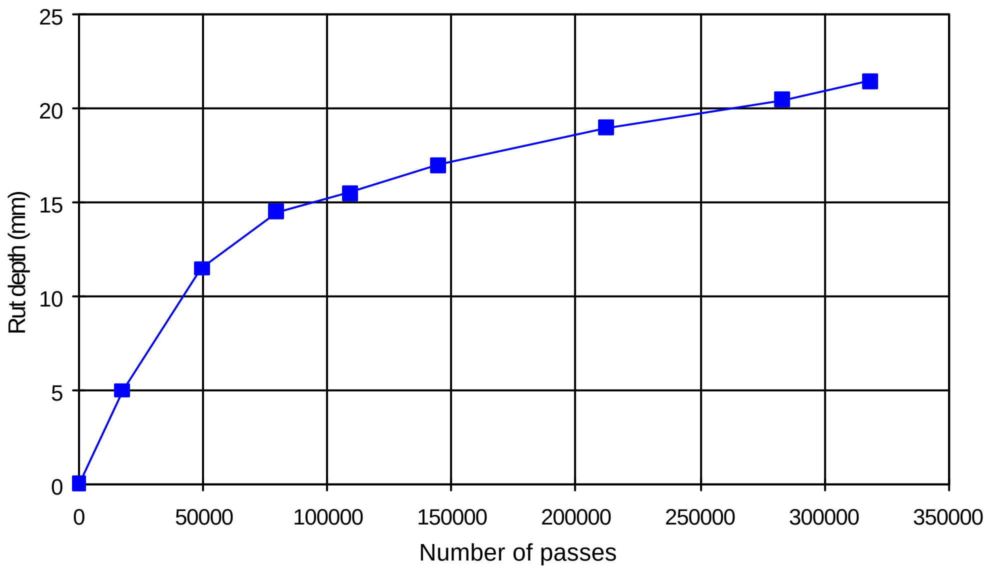

Figure 12. Rut depths vs. number of passes during test 04.

2.5 Test 05, loading mode test

The research idea was to test in the reference pavement the effect of loading mode (bi-directional, dual wheel) and compare the results to those loaded with different modes (bi-directional, single-wheel; test 03) and (uni-directional, single-wheel; test 04).

The fifth test structure was constructed in test pit no. 2 (rock pool) in Otaniemi (Figure 13).

The test has not yet been started because of the lack of time.

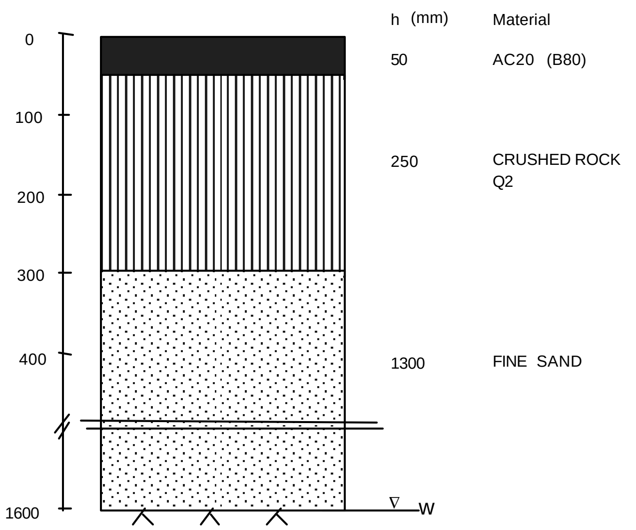

Figure 13. Structure of test 05.

2.6 Test 06, thawing test

The sixth test structure was constructed in test pit no. 1 in Otaniemi (Figure 14). The research idea was that the subgrade was made of frost-susceptible material. Above it was a thin (0.50 m) pavement with a 50-mm asphalt concrete (AC) surface layer. It was planned to freeze and thaw the subgrade so that the thaw-weakening conditions would correspond to the natural state. The road was frozen to about 1.5 m depth during winter. Before HVS testing, the pavement was thawed to a depth of 0.9 m from the surface (most critical situation in subgrade).

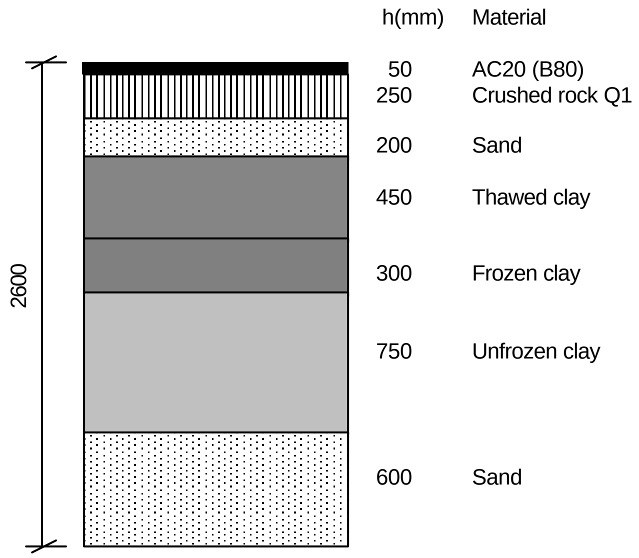

Figure 14. Structure of test 06.

The test wheel load was 50 kN. The rut depth reached 40 mm in about 1 250 overpasses (Figure 15). The wheel load that was used was high regarding the bearing capacity of the frost-susceptible pavement. The test wheel speed (10 km/h) was low in comparison with normal traffic speeds. Thus, the load impacts took a longer time, and the loading effect in the subgrade was long-term. This caused a fast development of rutting and cracks.

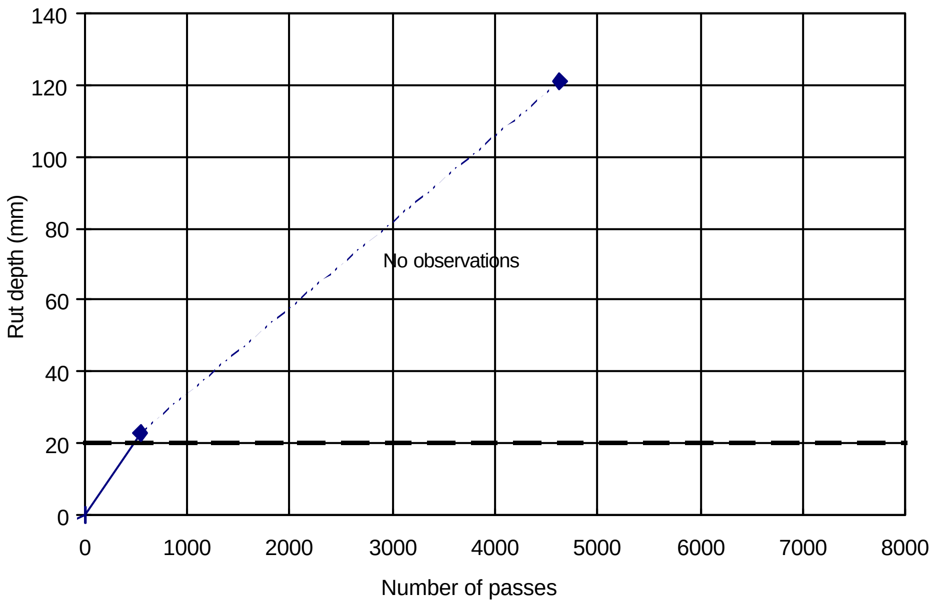

Figure 15. Rut depths vs. number of passes during test 06.

Because the overlay was relatively thin, the critical location for deformation was the surface of the soft subgrade. The material modulus of thawed clay was low, so deflections under the wheel loads were high. The majority of the elastic and plastic deformations developed in the thawed clay. Tensile stress and strains at the bottom of the asphalt concrete exceeded material strength. This caused a fast development of cracks at the bottom of the bound layer and fast deterioration of the overall pavement.

According to the measurements, the moving test wheel with fast stress pulse caused a transient pore pressure increment under undrained conditions in saturated clay.

2.7 Test 07, thawing test

The seventh test structure was constructed in test pit no. 1 in Otaniemi (Figure 16). The subgrade was made of the same frost-susceptible material as previously, but this area was tested with a lower wheel load. The road was frozen to about 1.5 m depth during winter. Before HVS testing, the pavement was also thawed to a depth of 0.9 m from the surface (the most critical situation in subgrade).

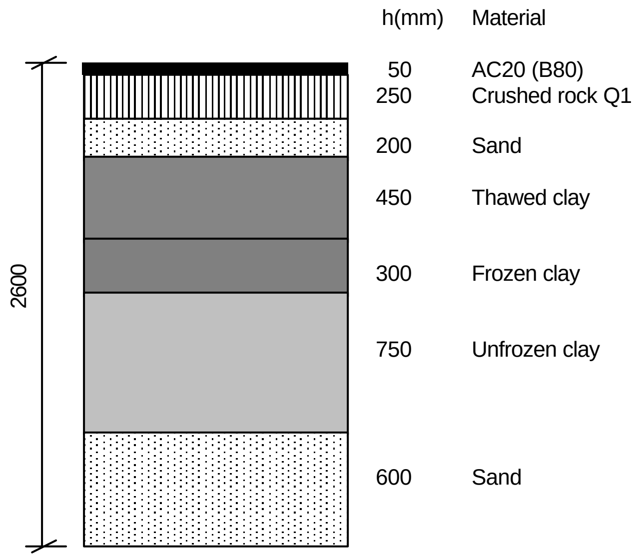

Figure 16. Structure of test 07.

With the unidirectional dual wheel load of 40 kN, this un-reinforced test road constructed on frost-susceptible subgrade reached a rut depth of 40 mm in about 2 050 overpasses (Figure 17).

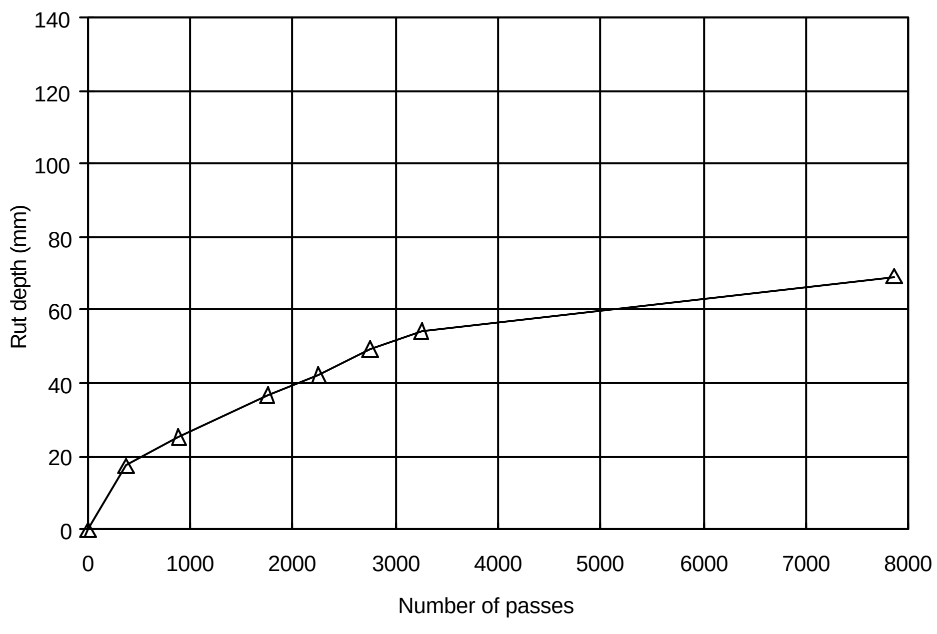

Figure 17. Rut depths vs. number of passes during test 07.

Tensile stress and strains at the bottom of the asphalt concrete exceeded material strength. This caused a fast development of cracks at the bottom and surface of the bound layer (Figure 18).

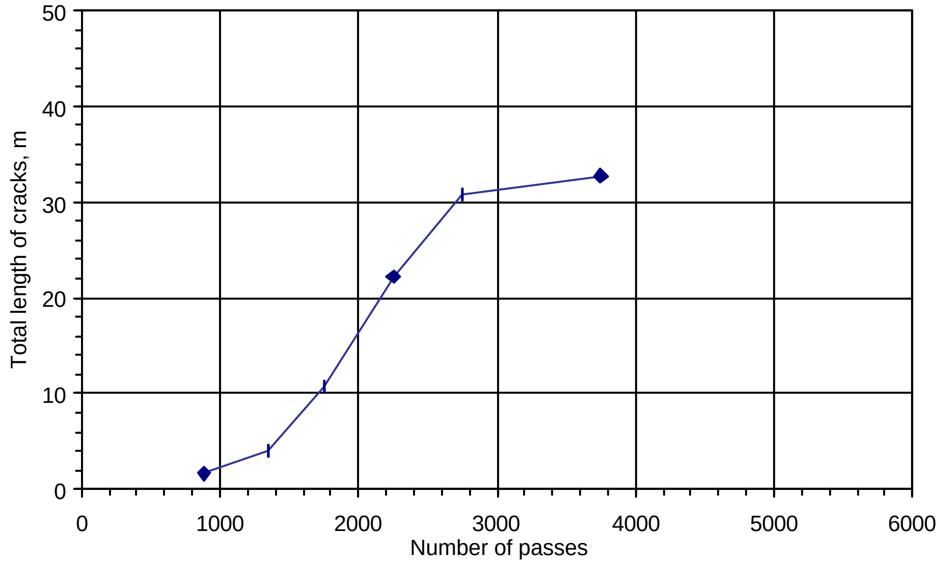

Figure 18. Total length of AC's surface cracks vs. number of passes.

2.8 Test 08, thawing test

The eighth test structure was constructed in test pit no. 1 in Otaniemi. The subgrade was made of the same frost-susceptible material as previously, but in this area, a reinforcing steel mesh was installed in the base layer (Figure 19). The road was frozen to about 1.5 m depth during winter. Before HVS testing, the pavement was also thawed to a depth of 0.9 m from the surface (most critical situation in subgrade).

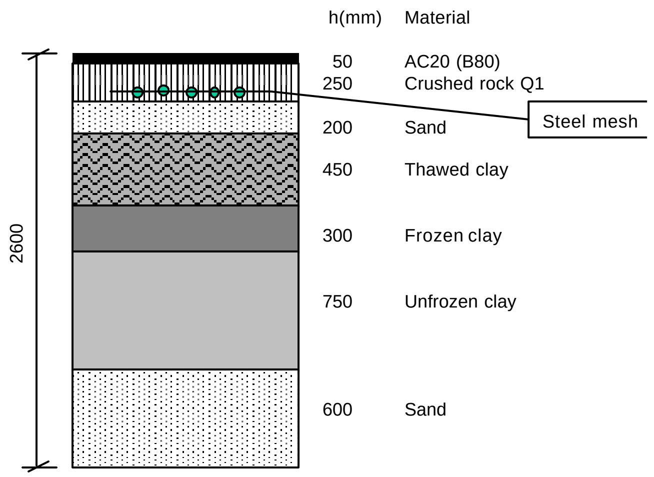

Figure 19. Structure of test 08.

The test load was 40 kN. On the reinforced area, for the rut depth of about 40 mm the number of overpasses was about 4 600 (Figure 20). The results showed about twice as good wheel load capacity for the steel mesh reinforced section compared to that without steel reinforcement.

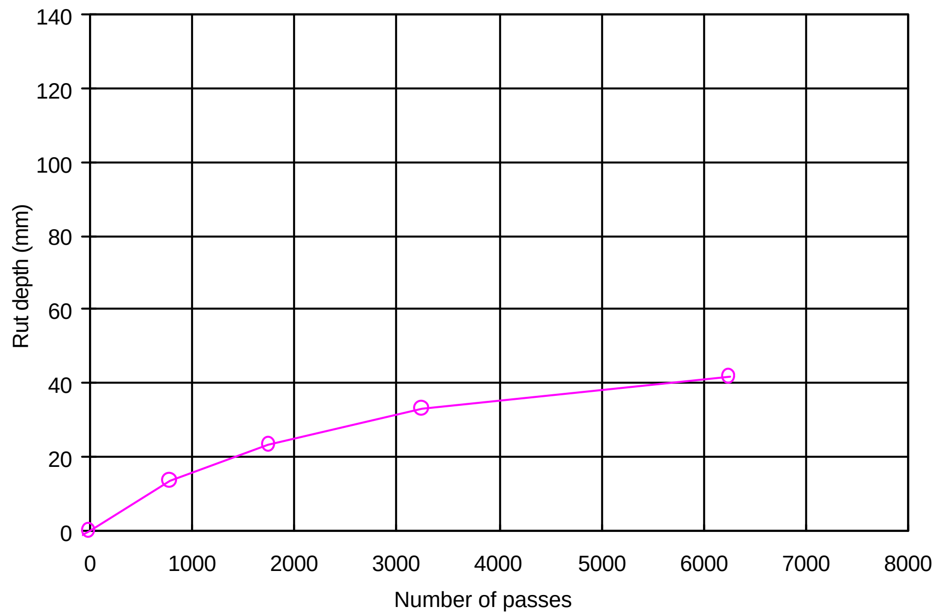

Figure 20. Rut depths vs. number of passes during test 08.

Cracking versus the number of passes is presented in Figure 21. One can see that cracks appear on the road surface later than in the case without steel reinforcement in the base layer.

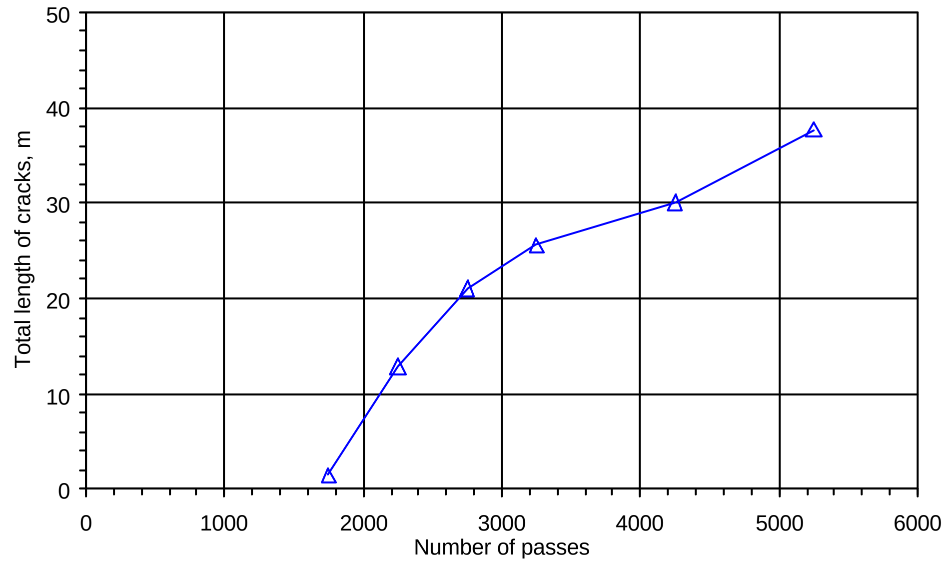

Figure 21. Total length of AC's surface cracks vs. number of passes.

According to the FWD measurements, the initial bearing capacity was not higher in the reinforced area 08 than in the un-reinforced areas 06 and 07. This indicates that the mesh needed some deformation before it could strengthen the overlay. It was also revealed that surface deflection under the moving wheel was smaller in area 08 than in the un-reinforced area.

2.9 Test 09, field test

Test 09 (Figure 22) was done on Ring Road II in Espoo, 5 km from VTT. This is a reference structure for heavy traffic roads in Southern Finland. The next SMA layer is usually constructed one or two years after opening a road for traffic.

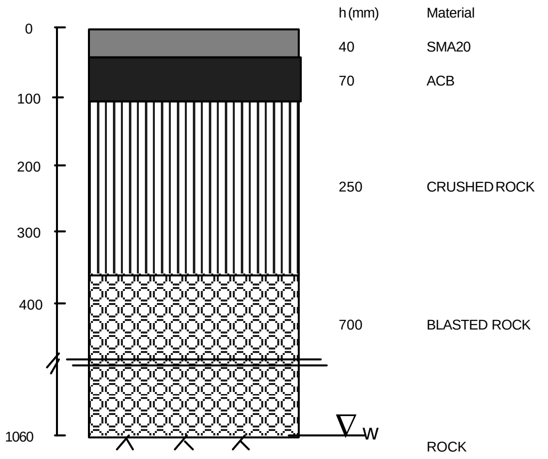

Figure 22. Structure of test 09.

After initial response measurements only 0.14 million loadings were done in this test because the HVS chain broke. Very little rutting could be seen on the road surface (Figure 23) and naturally no cracks.

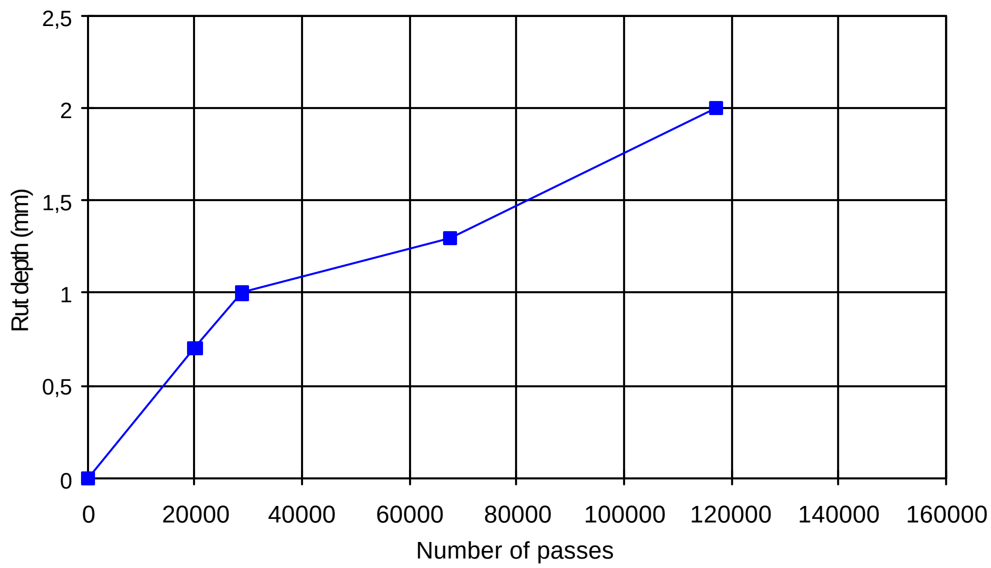

Figure 23. Rut depths vs. number of passes during test 09.

2.10 Test 10, field test

Test 10 (Figure 24) was done on Ring Road II in Espoo, 5 km from VTT. This is a so-called innovative structure. The research idea is that the lowest bound layer is a conventional asphalt concrete, which has high resistance to fatigue but is not very stiff. Above this layer is an asphalt concrete binder coarse, which is made with Gilsonite and is very stiff, three times stiffer compared to conventional asphalt concrete. This layer spreads the traffic load, thus reducing strains in the subsequent layers.

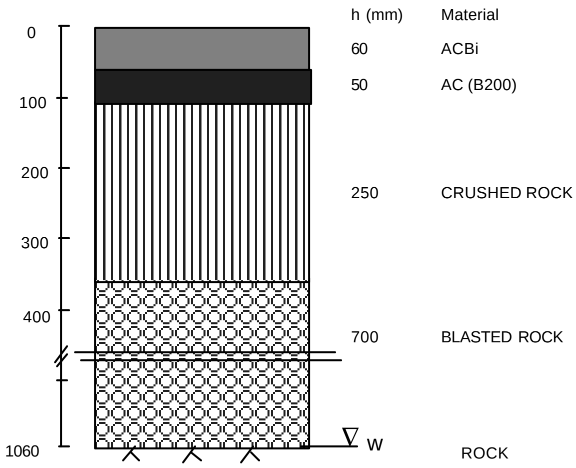

Figure 24. Structure of test 10.

After the initial response measurements, only 0.5 million loadings were done in this test. Less than 4-mm rutting could be seen on the road surface (Figure 25) and naturally no cracks. This test was interrupted because the HVS was transported to Sweden for the VTI tests.

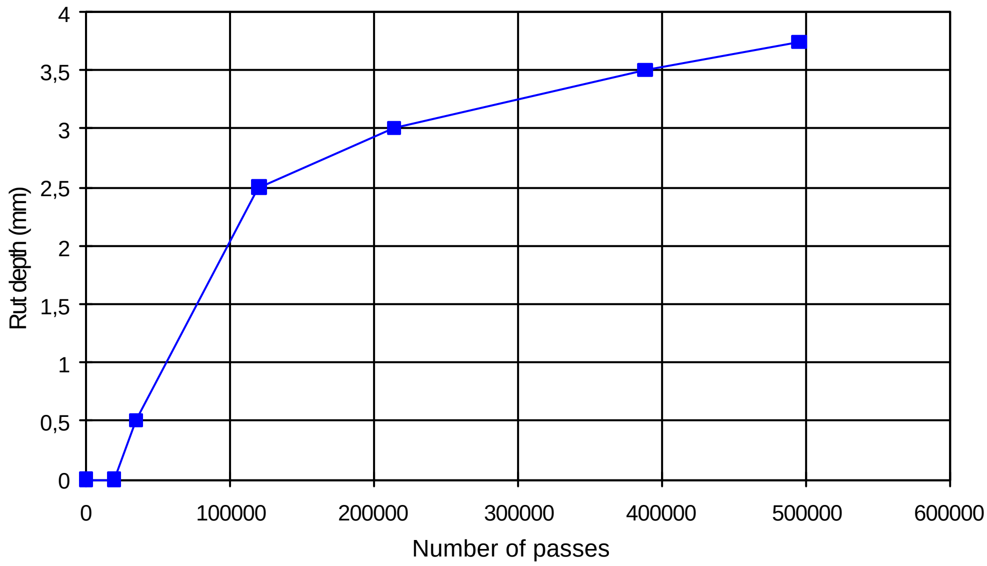

Figure 25. Rut depths vs. number of passes during test 10.

3 EVALUATION OF RESULTS

The results of each test made in Finland during the first period are briefly presented in Appendix 1 at the end of this report.

3.1 The effect of wheel load and base course material

Test section 01 and 02 were thin reference pavements, typical pavements for low-volume roads in Finland. Test section 01 had a low-quality base course and test section 02 had the same construction, except that the base course material was of high quality. The research idea was to learn how to perform accelerated testing, to study the lifetime and deterioration process of these common pavements, and to compare the effect of base course material.

Table 2. Test parameters of tests 01 and 02.

Test	Objective	Pavement structure	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed
FIN01	Reference pavement, low-quality base material wheel load	50 mm, Asphalt 250 mm, Crushed rock 2300 mm Sand	60 kN, bi-directional 800 kPa Dual 10 °C 10 km/h
FIN02	Reference pavement, high-quality base material wheel load	50 mm, Asphalt 250 mm, Crushed rock 2300 mm Sand	80 kN, bi-directional 800 kPa Dual 10 °C 10-12 km/h

The number of expected passes needed to deteriorate pavement 01 was about 250 000, based on theoretical calculations and VTT experience from the OECD test in Nantes 1990, in which VTT participated /2/. However, the section lasted for longer. This was because section 02 was loaded with 80 kN wheel load for only 0.17 million passes due to the lack of time. The effect of the quality of base layer material in dry circumstances (water-table level 2.3 m from road surface) is very little. The difference in rutting (Figure 26) between the sections is because of different wheel loads

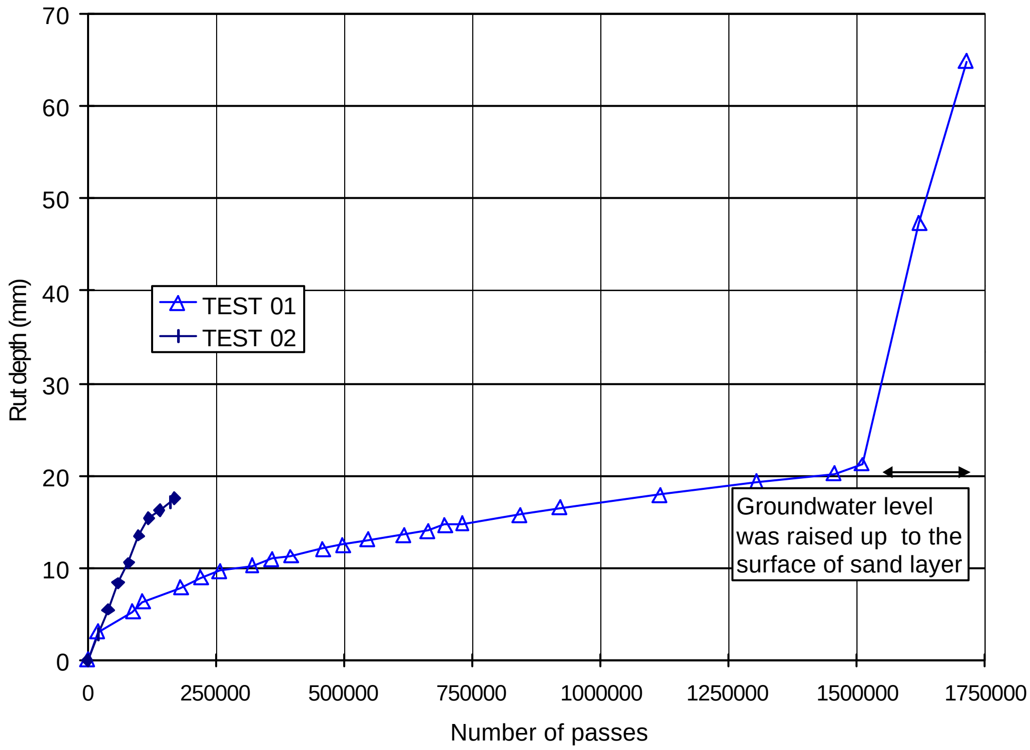

Figure 26. Rut depths vs. number of passes, test 01(low-quality base, 60 kN dual wheel load) and test 02 (high-quality base, 80 kN dual wheel load).

3.2 The effect of loading mode

Since the life-time of the first construction was very much longer than expected, tests 03 to 05 were planned with bituminous layers of 40, 50 and 60 mm thicknesses on the same unbound layers. It was planned to use the same high wheel load for each of the three tests to complete the tests in reasonable time. The research idea was to determine the fatigue curve for reference asphalt concrete at three points, three different strain levels and life-time for each.

However, after construction, the thickness of asphalt concrete was found to be 50 mm for all three test sections, or the thickness of asphalt layer was exactly the same as that of test 01. It was then decided to study the effect of wheel type (dual/single) and loading mode (uni-/bi-directional) on road deterioration. Test section 03 was planned for testing with 70 kN single-wheel uni-directional, section 04 with 70 kN single-wheel bi-directional, and section 05 with 70 kN dual wheel bi-directional (Table 3).

Table 3. Test parameters of tests 03 and 04.

Test	Objective	Pavement structure	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed
FIN03	Reference pavement, low-quality base material loading mode	50 mm, Asphalt 250 mm, Crushed rock 1300 mm Sand	70 kN, bi-directional 800 kPa Single 10 °C 12 km/h
FIN04	Reference pavement, low-quality base material loading mode	50 mm, Asphalt 250 mm, Crushed rock 1300 mm Sand	70 kN, uni-directional 800 kPa Single 10 °C 12 km/h

In the beginning of test 03, rut depth increased very much. After 0.2 million loadings, rutting increased slowly but linearly. The first crack was found after 0.9 million load repetitions. Loading was continued up to 1.4 million passes in anticipation of many cracks. However, after the first crack only two more cracks were found, and they did not get wider during the test. All these cracks were longitudinal and the length was about 0.4 m.

Test 04 was interrupted after 0.32 million load repetitions because the HVS had to be moved to load thawing tests at that time. The comparison of cracking cannot be made because section 04 does not yet have any cracks. Test 05 has not yet been started.

No difference was found in rutting during tests 03 and 04, although the loading mode (uni-/bi-directional) was different (Figure 27). Therefore, it is reasonable to use the bi-directional loading mode to double the load repetitions in the set time.

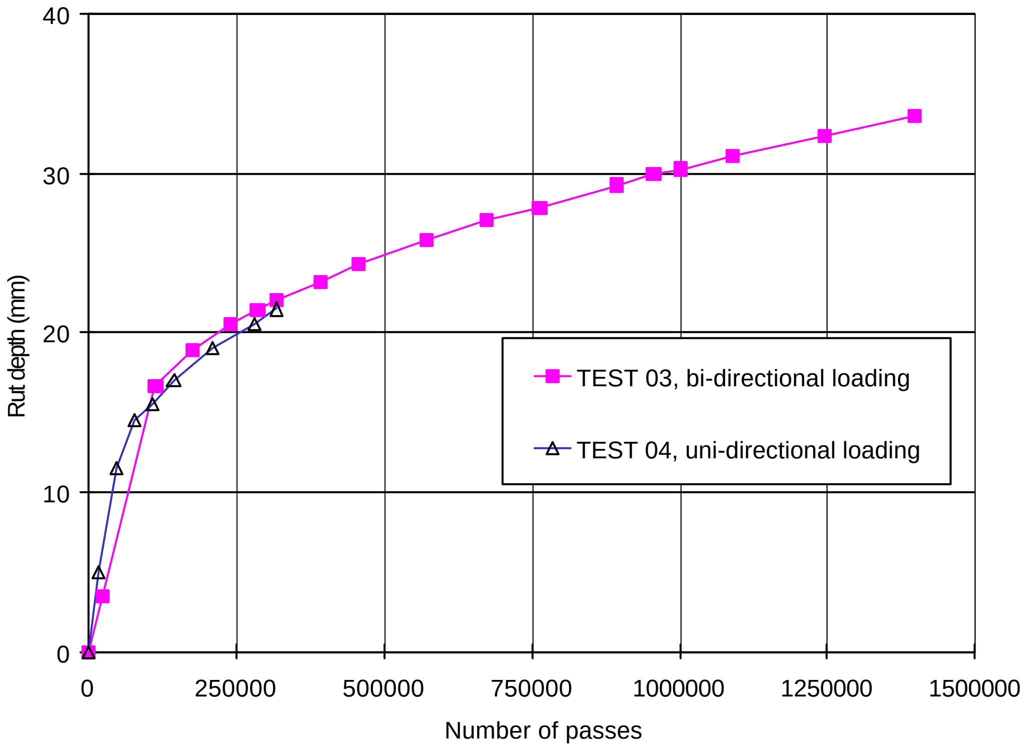

Figure 27. Rut depths vs. number of passes, test 03(70 kN single-wheel load, bi-directionally) and test 04 (70 kN single-wheel load, uni-directionally).

3.3 Thawing tests, the effect of steel reinforcement

The tests 06-08 were so called thawing tests. The structures of the tests 06-08 were similar to each other, except for 08 which was reinforced with steel mesh in unbound base layer. Subgrade was made of the frost-susceptible material. The road was frozen to about 1.5 m depth during winter. The structures were loaded by HVS when the pavement was thawed to a depth of 0.9 meter from the road surface (most critical situation for road).

Tests 07 and 08 can easily be compared because they had the same wheel load (Table 4). The results showed about twice as good wheel load capacity against rutting for the steel mesh reinforced section compared to that without steel reinforcement (Figure 28).

Table 4. Test parameters of tests 07 and 08.

Test	Objective	Pavement structure	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed
FIN07	Thawing test, frost-susceptible subgrade	50 mm, Asphalt 250 mm, Crushed rock 200 mm Sand 1500 mm dry crust clay 600 mm Fine Sand	40 kN, uni-directional 550 kPa Dual 10 °C 12 km/h
FIN08	Thawing test, frost-susceptible subgrade, steel mesh reinforcement in crushed rock	50 mm, Asphalt 250 mm, Crushed rock 200 mm Sand 1500 mm dry crust clay 600 mm Fine Sand	40 kN, uni-directional 550 kPa Dual 10 °C 12 km/h

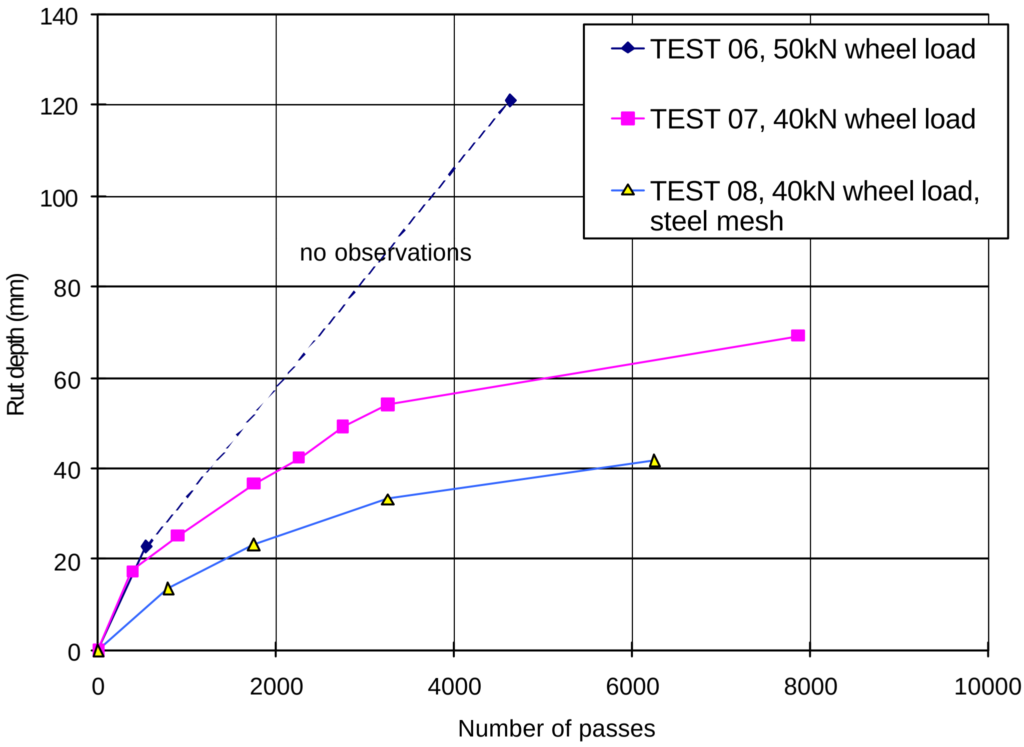

Figure 28. Rut depths vs. number of passes, test 06 (50 kN dual wheel load uni-directionally), test 07(40 kN dual wheel load uni-directionally) and test 08 (steel reinforced structure, 40 kN dual wheel load uni-directionally).

The steel mesh reinforced section also exhibited better resistance against cracking. The cracks appeared on road surface later than in the case without steel reinforcement in the base layer (Figure 29).

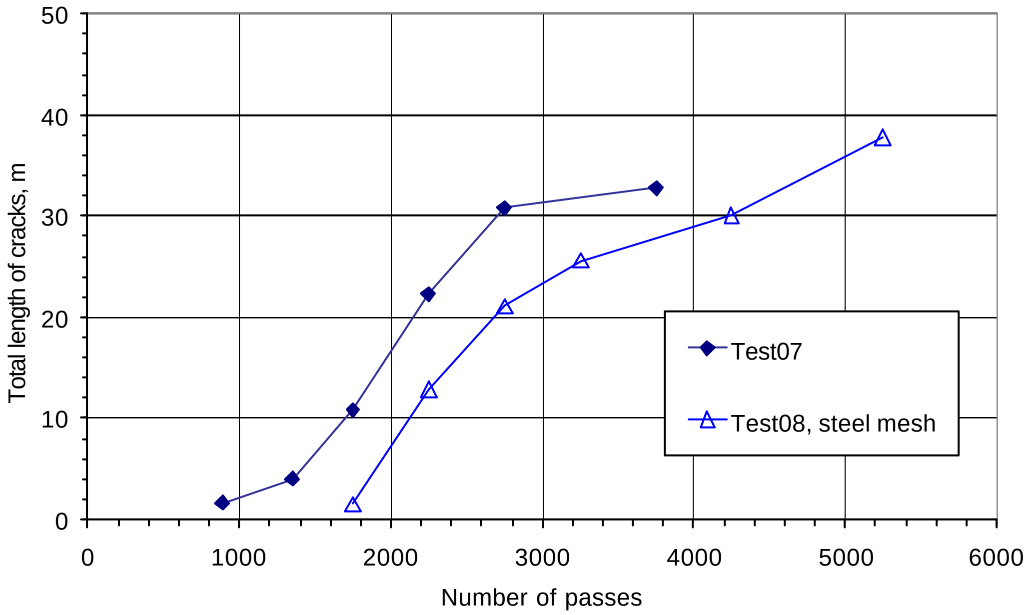

Figure 29. Crack length vs. number of passes, test 07(40 kN dual wheel load uni-directionally) and test 08 (steel-reinforced structure, 40 kN dual wheel load uni-directionally).

3.4 Highway pavements, high resistance to fatigue

Test 10 was done on Ring Road II in Espoo, 5 km from VTT. The structures of tests 09 and 10 were ones for heavy-traffic highways. One was conventional, and the other a so-called innovative structure. The aim was to study the effect of different materials and different location of bituminous layers on the pavement performance.

The research idea was that the lowest bound layer is a conventional asphalt concrete (with soft bitumen, B-200), which has high resistance to fatigue but is not very stiff. Above this layer is an asphalt concrete binder coarse, which is made with Gilsonite and is very stiff, three times stiffer compared to conventional asphalt concrete. This layer spreads the traffic load, thus reducing strains in subsequent layers and offering very good resistance to rutting (Table 5).

Table 5. Test parameters of tests 09 and 10.

Test	Objective	Pavement structure	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed
FIN09	Reference structure for heavy-traffic road	40 mm SMA 70 mm Asphalt in base 250 mm Crushed rock 700 mm blasted rock Rock	60 kN, bi-directional 800 kPa Dual 10 °C 12 km/h
FIN10	Innovative (high resistance to fatigue) structure for heavy-traffic road	60 mm ACBi 50 mm Asphalt (B-200) 250 mm Crushed rock 700 mm blasted rock Rock	60 kN, bi-directional 800 kPa Dual 10 °C 12 km/h

After initial response measurements only 0.14 million loadings were made on the test 09 because of HVS chain break. Very little rutting could be seen on road surface and naturally no cracks.

After the initial response measurements, only 0.50 million loadings were done in test 10. Less than 4-mm rutting could be seen on the road surface (Figure 30) and naturally no cracks. These tests were interrupted because the HVS was transported to Sweden.

However, the structures could be compared to each other. Based on the response measurements and laboratory fatigue criteria, the innovative structure had 30 times better resistance to traffic loading. However, the construction costs of the bituminous layers were only 10 % higher for the innovative structure.

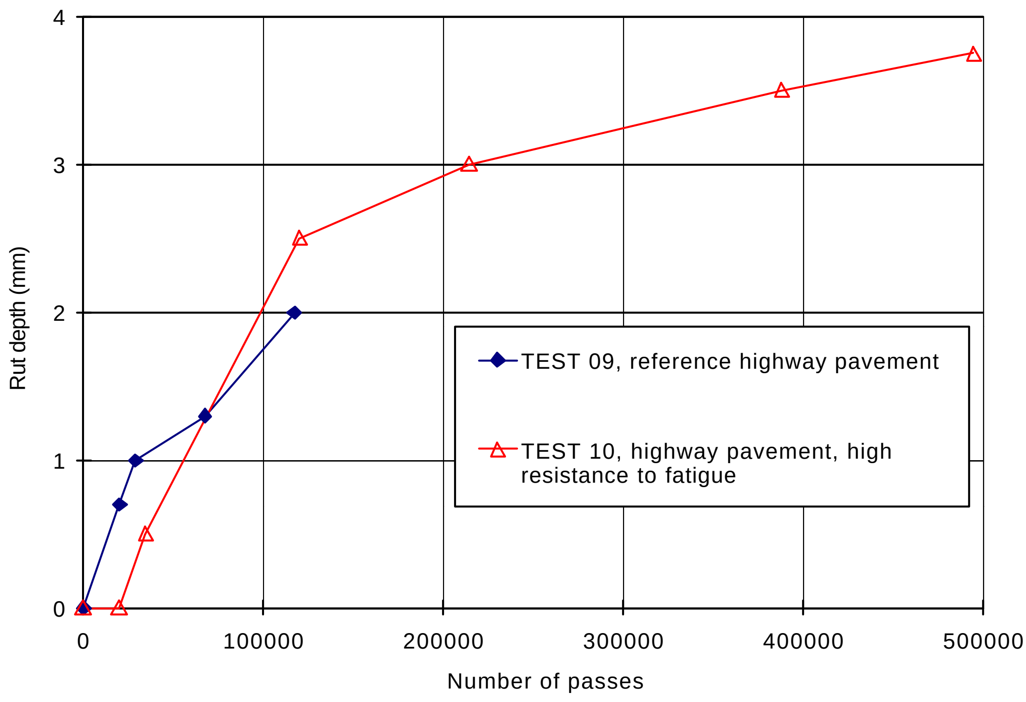

Figure 30. Rut depths vs. number of passes, test 09 (conventional structure) and test 10 (innovative structure, high resistance to fatigue), 60 kN dual wheel load for both tests.

3.5 The effect of wheel type and load

Figure 31 presents the rutting of the two tests. The road structures are similar but test 01 was loaded with 60 kN dual wheel, and test 03 with 70 kN single-wheel (Table 6). In the latter case, rutting is about double compared to the former. In test 03, also a few cracks were found after 0.8 million loadings.

Table 6. Test parameters of tests 01 and 03.

Test	Objective	Pavement structure	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed
FIN01	Reference pavement, low-quality base material wheel type and load	50 mm, Asphalt 250 mm, Crushed rock 2300 mm Sand	60 kN, bi-directional 800 kPa Dual 10 °C 10 km/h
FIN03	Reference pavement, high-quality base material wheel type and load	50 mm, Asphalt 250 mm, Crushed rock 1300 mm Sand	70 kN, bi-directional 800 kPa Single 10 °C 12 km/h

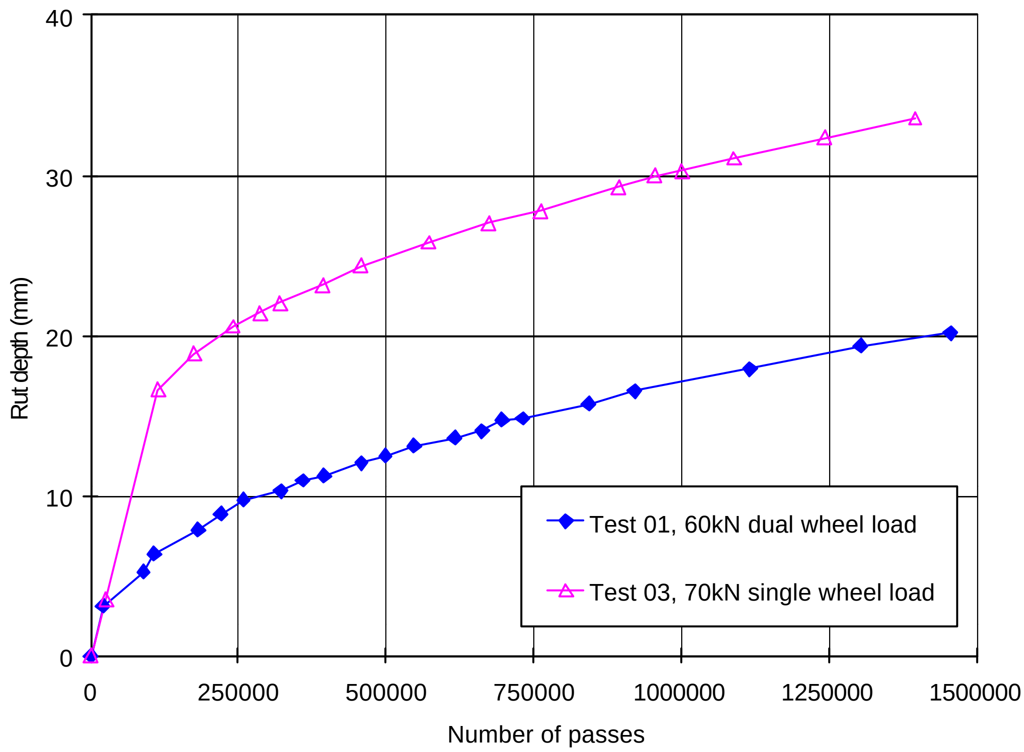

Figure 31. Rut depths vs. number of passes, test 01 (60 kN dual wheel load) and test 03 (70 kN single-wheel load).

3.6 The effect of pavement structure

Figure 32 shows a comparison of the effect of bituminous layer thickness on rutting (Table 7). In test 10, which has 110-mm bituminous layers, rutting is about one third compared to that of test 01, which has only a 50-mm bituminous layer.

Table 7. Test parameters of tests 01 and 10.

Test	Objective	Pavement structure	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed
FIN01	Reference pavement, low-quality base material	50 mm, Asphalt 250 mm, Crushed rock 2300 mm Sand	60 kN, bi-directional 800 kPa Dual 10 °C 10 km/h
FIN10	Innovative (high resistance to fatigue) structure for heavy-traffic road	60 mm ACBi 50 mm Asphalt (B-200) 250 mm Crushed rock 700 mm blasted rock Rock	60 kN, bi-directional 800 kPa Dual 10 °C 12 km/h

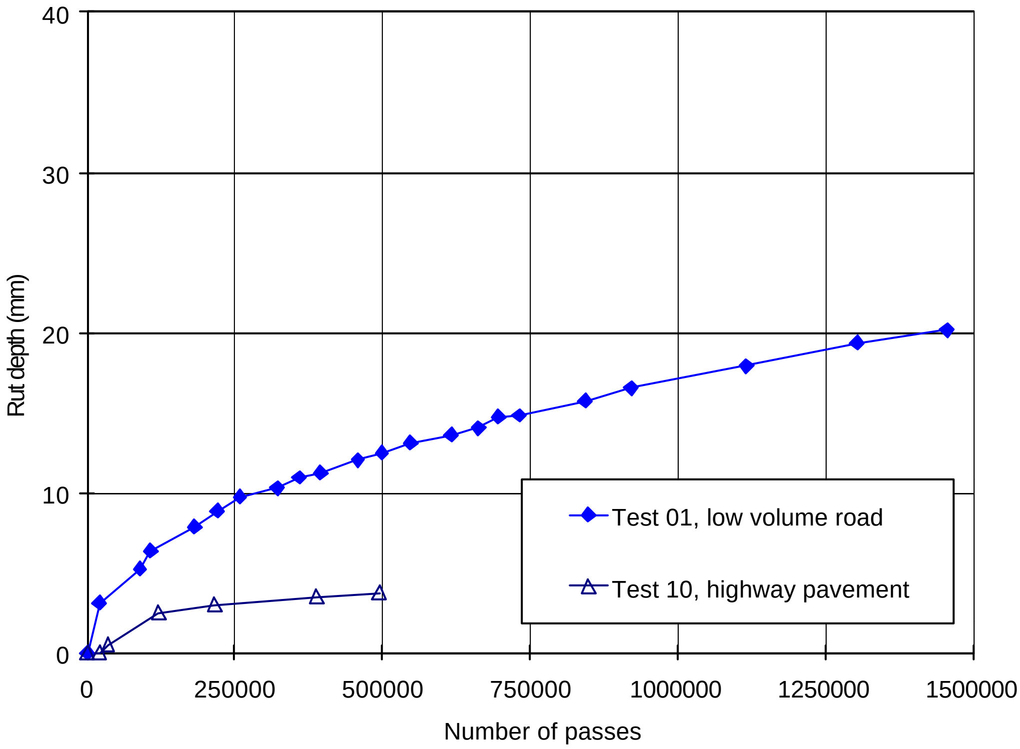

Figure 32. Rut depths vs. number of passes, test 01 (50-mm bituminous layers, 60 kN dual wheel load) and test 10 (110-mm bituminous layers, 60 kN dual wheel load).

4 DISCUSSION

4.1 HVS-NORDIC as a testing tool

It was expected that there are always teething problems with a new facility and it would take some time for the research team to learn to work efficiently. The use of time can be seen in Figure 33. Please note that time is calculated from the point of view of the machine, or 24 hours a day, even though the research team basically worked 8 hours a day, sometimes longer, and in two shifts, and during emergency situations at any time, even at night.

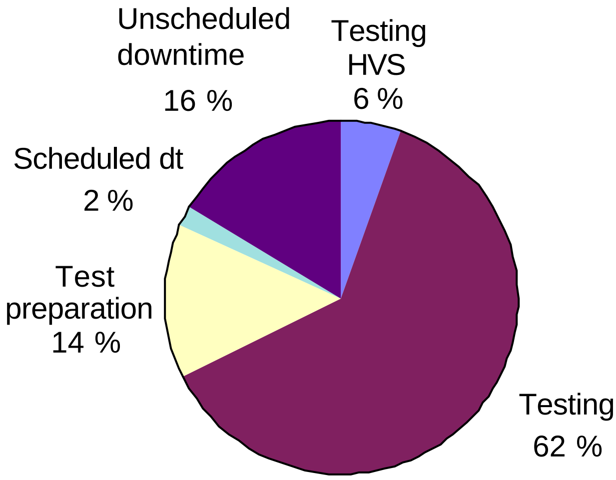

Figure 33. Use of HVS-NORDIC during the first year.

It was found very practical that the personnel could check the basic information with their mobile phones. They could read by the mobile phone the pavement temperature, ambient temperature (may be very important during a very cold period) and the number of loadings. Other information is considered. HVS-NORDIC alerts by mobile phone if it stops or the pavement temperature is outside preset limits.

Even though we were prepared for some unexpected problems, there were too many teething and other technical difficulties with the HVS-NORDIC. It made effective running-time shorter and occupied too much of the HVS-NORDIC personnel's time. However, unscheduled down time was 16 %, which is not very high for this kind facility in the first year.

4.2 Interpretation of the results

This periodic report is a summary of the tests during the first year in Finland. This interpretation of tests is based mainly on observations and rut measurements and only on a few response measurements. The real interpretations will be presented in the following research reports (tentative names):

- HVS-NORDIC Test report 1: Accelerated pavement tests on thawing, frost-susceptible subgrade.
- HVS-NORDIC Test report 2: Field tests on ring road II with high trafficed pavements
- HVS-NORDIC Test report 3: Tests on Otaniemi test pit, base course and loading mode tests

They will be published during summer 2000.

The pavements lasted longer than expected (excluding tests with frost-susceptible subgrade). It is quite common and for instance VTT has its own experience, that during the dynamic axle load test at CAPTIF in New Zealand /8/ the pavements lasted much longer than expected. No special reasons were found for good pavement performance at CAPTIF.

VTT also has its own experience from the Manége de fatigue of LCPC in Nantes /2/, where pavements lasted roughly according to expectations. Both were circular, the first one with a relatively small radius (7 m) and speed (45 km/h) and sheltered from rain and sunshine but no temperature control, and the second one with greater speed (72 km/h) and radius (40 m) and without any protection against rain or sunshine.

The water content was during the tests 01 - 05 the optimum water content as no water was added nor removed in the watertight pool where the pavements were constructed. The case was the same during the test at CAPTIF. As the Manége de Fatigue at LCPC is outside the water content follows the natural situation and was relatively high during the winter season.

As the water-table was raised up to the bottom of the base course in the end of test 01 the accelerating effect was dramatic. The effect of moisture will be further discussed in chapter 4.3 Testing parameters.

The accelerating effect can be attained by

- a greater number of loadings in a time period,
- increasing wheel load,
- making the pavement weaker
- in certain cases using high temperature.

If the wheel load is increased or the pavement is made weaker the stresses are greater in the pavement and on the materials, and the pavement may even behave in a different way than in reality.

The pavements that were used in the tests are typical for minor roads in Finland. They were selected to be weak enough in order to avoid the first tests lasting for too long. Thus, in our case, the bituminous courses were thin, only 50 mm.

Horizontal strains at the bottom of the bituminous layers were relatively small because the length of the contact interface between the tyre and the pavement is relatively long compared to the thickness of the layer. They revealed, too, that horizontal strains at the bottom of thin bituminous layers do not only increase with load but may also decrease. The reason is that the length of the contact interface increases as the load increases at the same tyre inflation pressure. In this case tyre inflation pressure was constant. This phenomenon has been found earlier at our response measurements at Virttaa test site /8, 9/.

Normally the tyre inflation pressures should be increased as the load increases and it is very important to have a correct tyre inflation pressure. It is especially important if overloads are used. Even in that case the strains at the bottom of the bituminous layers behave in different way if the bituminous layer is relatively thin; the strains do not increase in direct relation to the wheel load.

The performance of bituminous layers was found to be much better than expected in present thinking concerning bituminous pavement design. The design is mainly based on horizontal strains at the bottom of the bituminous layers (fatigue) and vertical strains on the subgrade (rutting).

This phenomenon seems to set limits on the testing of thin bituminous mixtures and the test must be carefully planned. Therefore, the value of the response measurements increases.

The effect of thin bituminous layers means that, if the pavement is made weaker in order to accelerate failure and make the test shorter, the bituminous mixture itself cannot be part of the test, but only a protective layer. The tests concerning unbound layers may be, however, at the same time realistic.

The mode of failure seemed to be different than in reality, since there was more rutting but much less cracking. The cracks that appeared were very thin and did not widen during the test. The possible reasons may be

- speed
- bi-directional loading
- no additional water
- strains are smaller than expected in thin bituminous layers
- no ageing.

The moduli of bituminous materials depend on the speed, or the effective moduli are smaller than on the roads. This may increase rutting but should not affect cracking too much. This phenomenon could perhaps be avoided by using harder bitumen, which has been considered, but not used.

As the speed is slower than on the road, the change in strain from compression to tension occurs slower than on the road or the strain gradient is smaller. The fatigue properties may depend on this but the authors have not found any research results.

If the loading is uni-directional, there may be an accumulation of residual stresses and cracking may occur earlier than in the bi-directional loading, where opposite loading may relax the stresses during every load pass. The comparison was to be made in tests 03 and 04, but unfortunately test 04 had to be finished too early because of thawing tests.

Uni-directional loading is natural, but if bi-directional loadings are used, the number of loadings is double compared to uni-directional and thus the work is more efficient.

The cracks that appeared were very thin and they did not widen later during the test. This may be due to the lack of water and dirt. It has also been found that thin cracks seem to disappear or there are healing effects.

The pavements were new and in some cases were protected from rain and sunshine before the test. As the facility is mobile, in principle it is possible to construct pavements early, but that is seldom possible. Some ageing possibilities have been considered, but no tests have been carried out up to the present time. Another possibility is to use harder bitumen, which would simulate hardening.

4.3 Testing parameters

The number of loadings is now about 25 000 in 24 hours and cannot be increased.

One possibility to accelerate testing is to increase the load stepwise, as has been done at certain accelerated testing facilities. It may be a good solution if rutting is the failure mode, but not very realistic if the failure mode is cracking.

Normally the tire inflation pressure should be increased as the wheel load increases, and it is very important to have the correct tire inflation pressure. This is especially important if overloads are used. Initial response measurements were made at several loads and tire inflation pressures.

It is possible with the HVS-NORDIC to keep all the essential test parameters constant, which is important for reliable comparisons between all the tests and between the tests in Finland and in Sweden as well. However, the parameters are not constant on the road, but especially the following are variable:

- traffic loads
- temperature
- water content
- sunshine (UV).

The traffic loads vary in magnitude and in time (effect of rest periods), which may not be a serious disadvantage for accelerated pavement testing.

Temperature has a great effect on bituminous materials. In our case, it would be possible to change temperature periodically during the test, but it would be rather difficult to do. At the present time, the temperature must be selected according to the test. If permanent deformation is the failure mode the temperature must be high, in our case 30°... 40° C, and if cracking is the failure mode the temperature should be a close weighted mean value. The constant temperature has not been found to be a serious problem.

There is a very important seasonal variation in water content in the road and it has a dramatic effect on the performance, as is seen in test 01 (Figure 6). This means that the cracking and rutting will occur because the unbound materials and/or subgrade have high water content. The water content is usually, in accelerated pavement tests, the optimum water content, which has been used during the construction or in most cases, the change of water content has been prevented.

VTT has the possibility to change the water-table level in test area 1. What should be the best water-table level, should it be a spring, summer or fall situation? Should there be changes during the test? How can the effect be kept constant from test to test? These are very important factors and will be seriously considered before the HVS-NORDIC is back in Finland.

The test pavements are protected from rain. This means that, if there are cracks, no water will penetrate the cracks to the pavement. Water is likely to affect the healing properties of bituminous materials and there is always some kind of pumping effect of very fine materials.

Surface watering has been considered. There are certain problems in how to make it constant from one test to another, what kind of corrosion (rust) may occur, and with the electrical components that are not protected well enough. Therefore, surface watering is likely not possible.

4.4 Recommendations

The planning of the tests must be done very carefully. Even though the personnel of VTT have experience from several APT facilities, this has not really been understood. It means, for instance, that the goal of each test must be carefully studied. The previous experience of VTT is from circular tracks, and thus both smaller speed and total environmental control are new.

According to first results, the test parameters and circumstances have to be thought out once again. Study different deterioration mode, rutting instead of fatigue, and planning structures to be tested in that way could be good idea.

It would be reasonable to test the effect of water content in structural layers as well as the quality of the unbound base layer material especially.

5 CONCLUSIONS

This periodic report is a summary of the tests during the first year in Finland. This report presents only main results, which are based on observations and rut measurements and only on a few response measurements. Final conclusions will be presented in the following research reports (tentative names):

- HVS-NORDIC Test report 1: Accelerated pavement tests on thawing, frost-susceptible subgrade.
- HVS-NORDIC Test report 2: Field tests on ring road II with high trafficed pavements
- HVS-NORDIC Test report 3: Tests on Otaniemi test pit, base course and loading mode tests

They will be published during summer 2000.

Ten pavement sections were tested during the first year. These had to include also the testing of the HVS-NORDIC, which had effect on the choice of the tests and the original research program could not be exactly followed. Even there were quite a few teething problems the unscheduled downtime was only 16% and real testing time was 62%, both calculated on the basis of 24 hours a day and 7 days a week.

The first result was that the pavements lasted for much longer than expected, except for the thawing structures.

No difference was found in rutting when the loading mode was uni- or bi-directional. Consequently, bi-directional loading mode can be used to give HVS double efficiency compared to the uni-directional loading mode.

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The pavement structure for heavy–traffic roads that had high resistance to fatigue was very good. The research idea was that the lowest bound layer is a conventional asphalt concrete one (with bitumen B-200), which has high resistance to fatigue but is not very stiff. Above this layer is an asphalt concrete binder course with Gilsonite, which is very stiff, three times stiffer compared to conventional asphalt concrete. This layer spreads the traffic load, thus also reducing strains in subsequent layers.

Based on the response measurements and laboratory fatigue criteria, the innovative pavement structure (high resistance to fatigue) gave 30 times better resistance to traffic loading compared to the conventional one. However, the construction costs of bituminous layers were only 10 % higher for the innovative structure.

Each test produces a considerable amount of data. The APT is neither simply a performance test, nor are only the life-times of different pavements compared. The other measurements, especially the response measurements, are very important. The final comparison of test structures can be made only after careful analysis of that data.

6 FUTURE PLANS

This report describes the activity of the first period in Finland 1997-1999. After that HVS-NORDIC was moved to Sweden, where eight typical Swedish road structures are tested. Two of the first tests have thin (50 mm) asphalt layers and the next two are rehabilitated structures. The first tests in Sweden are conventional Swedish structures with well-documented and well-known performance from studies in the field, e.g. survey and test sections on the road network. These eight test sections will be as follows:

- Structure 1: 40-mm AC wearing course and 110-mm granular base.
- Structure 2: As structure 1 but complemented with a 150-mm granular sub-base.
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- Structure 5: 20 mm Surface dressing + 200 mm granular base + 200 mm granular sub base (Icelandic structure).
- Structure 6: Same as structure 5 but the upper half of base (100 mm) stabilised with bitumen emulsion.
- Structure 7: Reference to structure 8. Thick AC-layers and high temperature (as a part of EC project REFLEX).
- Structure 8: As structure 7 but reinforced with steel mesh (as apart of EC project REFLEX).

Tests 5 and 6 are made for Iceland Road Administration. The road materials are brought from Iceland and the tests are done under Icelandic supervision.

A European consortium from Sweden, Germany, Italy and Finland consisting of steel industry companies, road administrations and research institutes has agreed with the European Commission on an RTD project, REFLEX (Reinforcement of Flexible Road structures with steel Fabrics to Prolong Service Life). The co-ordinator of the project is Kent Gustafson from VTI, who is one of the key persons in HVS-NORDIC.

All test sections will be built on fine-sand subgrade of the same type as was used in the first test runs in Finland. In Figure 34 below, these sections are shown.

After these eight tests, the HVS-NORDIC will be moved back to Finland in October 2000.

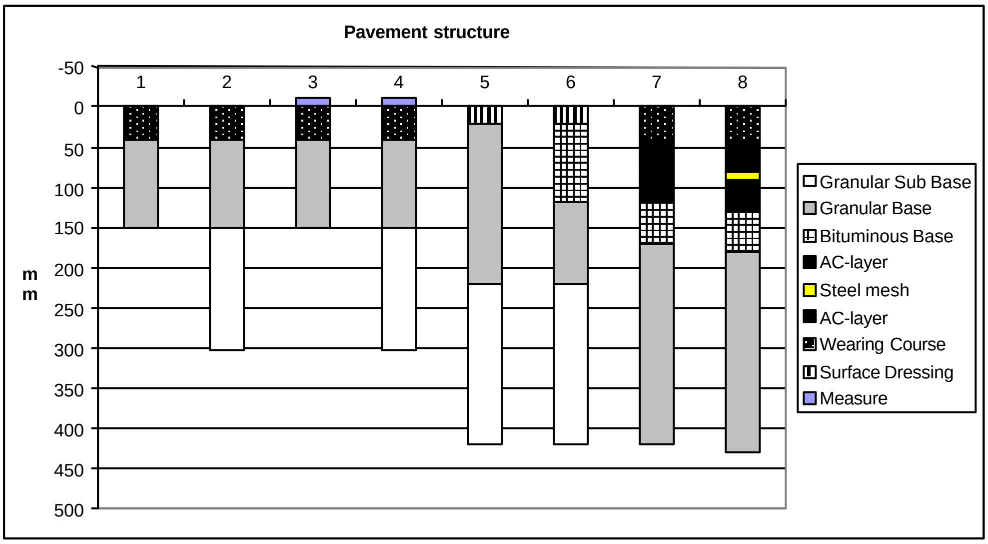

Figure 34. HVS pavement structures in Sweden 1998- 2000.

In the second period in Finland, one reinforced (in unbound layer) structure (as apart of EC project REFLEX) will be constructed and tested. A similar structure without steel reinforcement is planned for testing. The third planned pavement structure in the same test pool includes also light weight material (expanded polystyrene, EPS). These three pavements have thin bituminous layers and are for low-volume roads.

The next three pavements to be tested are also for low-volume roads. The aim is to study the importance of the road cross section to the structural properties. Two different slopes are built and as a reference "horisontal slope". The pavement response due to moving wheel load with severaloffsets are measured and finally the pavement performance is evaluated with accelerated testing (Figure 35).

It is considered to take HVS-NORDIC to an old road with aged and fatigued pavement. However, it is not easy to find suitable road section where the test can be performed.

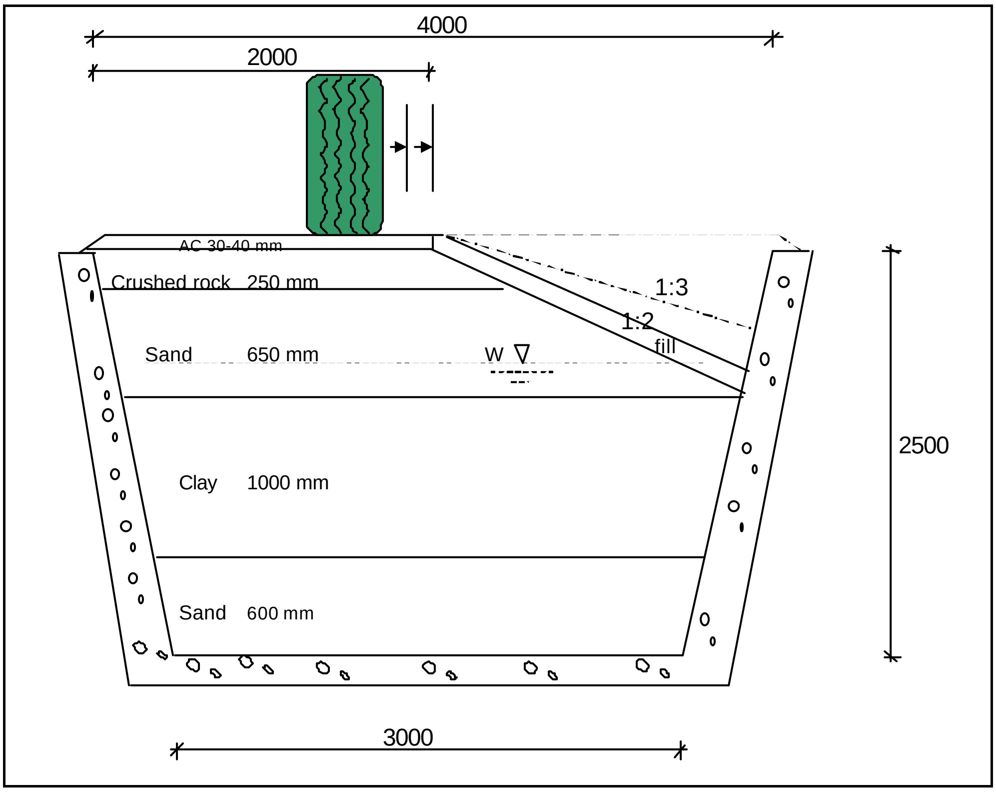

Figure 35. HVS pavement structures in Low volume road research project in Finland 2000 - 2001.

Around APT, there is international co-operation. The first international conference on APT was held in October 1999 at Reno, Nevada. It included two presentations from Finland and one presentation from Sweden concerning the HVS studies. The TRB Task Group is well-known within countries that have APT facilities. FEHRL (Forum of European National Highway Research Laboratories) has proposed a new group on accelerated pavement testing in Transport Research in COST (European Co-operation in the Field of Scientific and Technical Research). COST is an organization of the European Commission but may have members in its groups also from non-EU European countries like the eastern European countries. All the countries that have APT facilities, including Finland and Sweden, will participate in this action. This COST 347 action will probably start in late 2000.

The first research programme /1/ will be modified. The next pavement structures will be constructed according to experience of the first periods in Finland and Sweden. In addition, input from international connections will be taken into account.

7 EXECUTIVE SUMMARY

This is the first report of **HVS-NORDIC, the six-year joint Finnish-Swedish Research Programme on accelerated pavement testing.** This report describes the activity of the first period in Finland.

HVS-NORDIC research is a part of the Finnish National Road Structures Research Programme, TPPT, which is sponsored by the Finnish National Road Administration (Finnra). The HVS-NORDIC research is being carried out in co-operation with the Swedish National Road and Transport Research Institute (VTI), and the Swedish National Road Administration (SNRA).

HVS-NORDIC is **owned on a 50/50 basis by Sweden (VTI) and Finland (VTT and Finnra)**. It was used in Finland during 1997 98 and in Sweden, 1998 2000. A six-year period of research collaboration between 1997 and 2003 has been agreed /1/. The co-operation is **organized on three levels** with steering, programme and operative groups.

HVS-NORDIC is a **mobile** full-scale accelerated pavement-testing facility (Figure 1), whose loading is **linear**. HVS-NORDIC has a **heating/cooling system** and thus temperature can be held constant. The air temperature inside the heating/cooling box is controlled in order to keep the pavement **temperature constant**. The standard temperature of bituminous layers is selected to be +10 °C.

The main technical characteristics are: length 23 m, width 3.5 m, height 4.2 m and weight 46 t. The loading wheels are dual or single; standard dual wheel type is 295/80R22.5 and wide base wheel type is 425/65R22.5. Loading can be uni- or bi-directional, and lateral movement is 0.75 m. The wheel load is from 20 kN to 110 kN (corresponding axle loads 40...220 kN) at speeds up to 15 km/h. The loading of the HVS-NORDIC can be varied dynamically +/- 20 %. The number of loadings is 25 000 in 24 hours (including daily maintenance).

The test site is located a few hundred metres from the office of VTT’s personnel. The site is smaller than planned because of the problems with the city planning office. The site includes two test pits. One test pit is made of concrete, the walls have thermal insulation and there is complete water table regulation. Its length is 36 m including a 16-m-long slope. Its depth is 2.5 m and its width 4 m at the top and 3 m at the bottom. Two or three test pavements can be constructed in a test pit. The second test pit is parallel to the first one. It is excavated mainly in rock and it has no water table regulation. It is roughly of the same size as test pit no. 1.

The instrumentation for the response measurements is mainly based on experience that has been gained at the Virttaa test site during the last 15 years /2, 8, 9/.

The basic instrumentation is based on strain gauges installed at the bottom and on the surface of the bituminous layers. VTT uses retrofit strain gauges. The most common set of gauges comprises four longitudinal and four transverse gauges at the bottom and three longitudinal and three transverse gauges on the surface.

Stress in unbound layers is measured with stress sensors that have been bought from the University of Nottingham. These are installed three at the same level (triplicates because the installation may sometimes cause some problems). The height levels are in the middle of the base course and 100 mm and 350 mm in the subgrade.

Deflection under the moving wheel load is measured by a deflection rod anchored at the bottom of the subgrade near the concrete or rock bottom.

The temperature of bituminous layers is measured at three depths.

Test procedure is determined. Test is started first with a pre-run in order to relax possible residual stresses and cause some post-compaction. After the pre-run, so-called zero measurements are made. They include a considerable amount of response measurements: strain, stress and deflection measurements at different wheel loads, tyre inflation pressures, lateral positions and temperatures. Both wide-base tyre and dual tyres are used. The same measurements are repeated later during the test but not so comprehensively. The initial measurement programme is presented in chapter 1.5 (Table 1).

Table 1. Variables in the initial measurement programme (nearly all combinations are used).

Wheel load	(kN)	40	50	60	70	80
Tyre pressure	(kPa)	500	600	700	800	900
Speed	(km/h)	1	4	7	10	12
Pavement temperature	(°C)	0	5	10	15	20

Basically the same programme is followed later during the test, but in a much simplified fashion.

Transverse profiles are measured at five locations with a laser profilograph constructed at VTI for the HVS-NORDIC. Rutting is expressed as a mean value of those rut depths.

Cracks are drawn on paper with the aid of a 1x1 m grid that is divided into 100x100 mm squares.

All the data is collected in a **common database**. Tables include all the information on test fields, pavement structures, sensors and materials. Environment data as well as profile and FWD results are in their own tables. The driving history is complete only in the HVS files, and only selected information that is relevant to research is saved in the common database.

Measurement signals are saved in their own signal files and only top values, etc. that will be used in data analysis are stored in the common database.

The test programme is defined. The test sections for the first period in Finland are described in chapter 1.7 (Figure 3). The test programme, its background and principles are described in the joint Finnish-Swedish Research Programme /1/.

The goals for evaluating different pavement structures through tests with the HVS are:

- to clarify the performance and durability of various pavement structures and differences between pavement structures in these respects;
- to evaluate different design methods and to estimate the usability of results obtained with different laboratory methods when designing pavements;
- to develop performance models for different pavements.

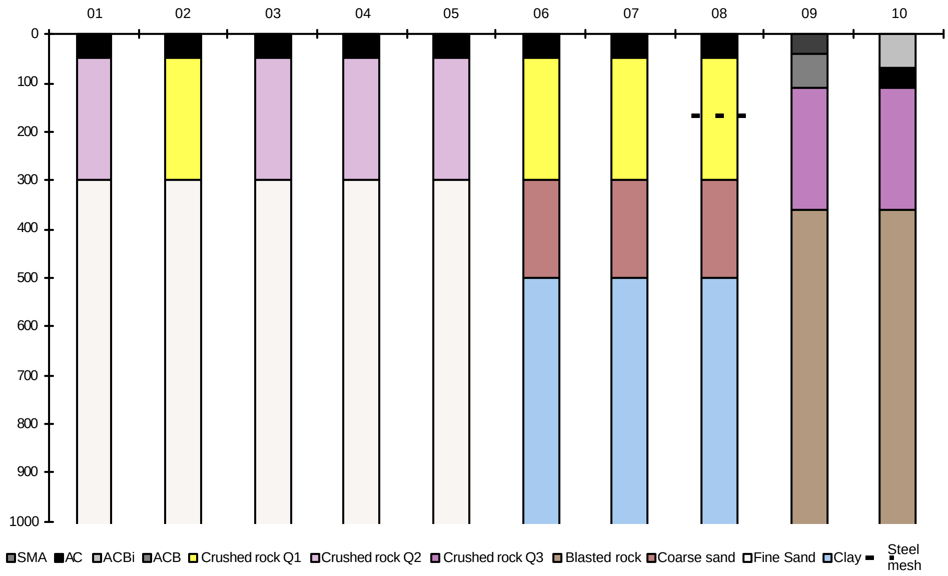

Figure 4. Test sections in Finland for the years 1997-1998. The abbreviations are described on page 3.

The reporting of the research programme will be made at six different levels. The reporting is focused for different reasons. The types of report are: **Test chart, Weekly report, Test report, Periodic report, Research report** and **Conference papers**.

This periodic report is a **summary of the tests** during the first year in Finland. This report presents only main results, which are based on observations and rut measurements and only on a few response measurements. Final conclusions will be presented in the following research reports (tentative names):

- HVS-NORDIC Test report 1: Accelerated pavement tests on thawing, frost-susceptible subgrade.
- HVS-NORDIC Test report 2: Field tests on ring road II with high trafficed pavements
- HVS-NORDIC Test report 3: Tests on Otaniemi test pit, base course and loading mode tests

They will be published during summer 2000.

Ten pavement sections were tested during the first year. These had to include also the testing of the HVS-NORDIC, which had effect on the choice of the tests and the original research program could not be exactly followed. Even there were quite a few teething problems the unscheduled downtime was only 16% and real **testing time was 62 %**, both calculated on the basis of 24 hours a day and 7 days a week.

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No difference was found in rutting when the loading mode was uni- or bi-directional. Consequently, bi-directional loading mode can be used to give HVS double efficiency compared to the uni-directional loading mode.

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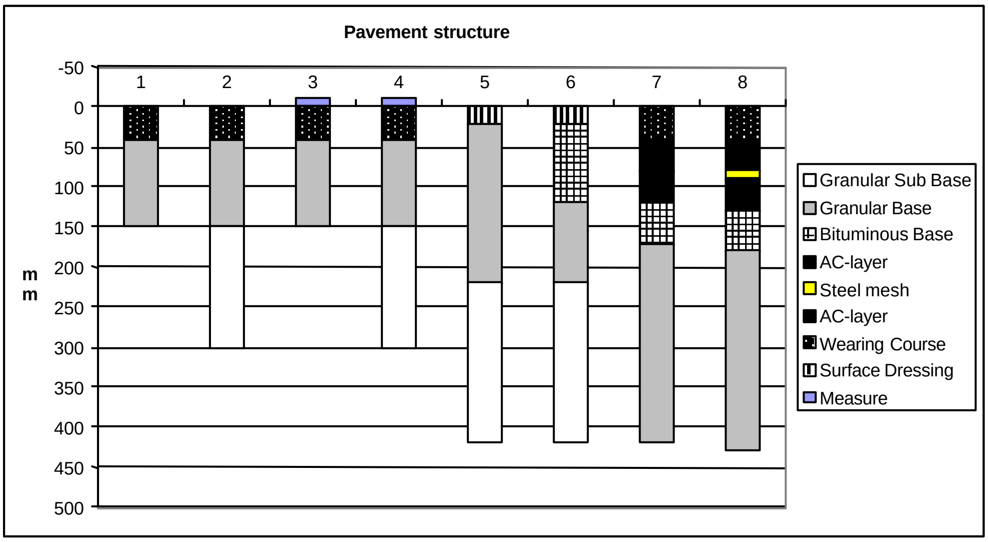

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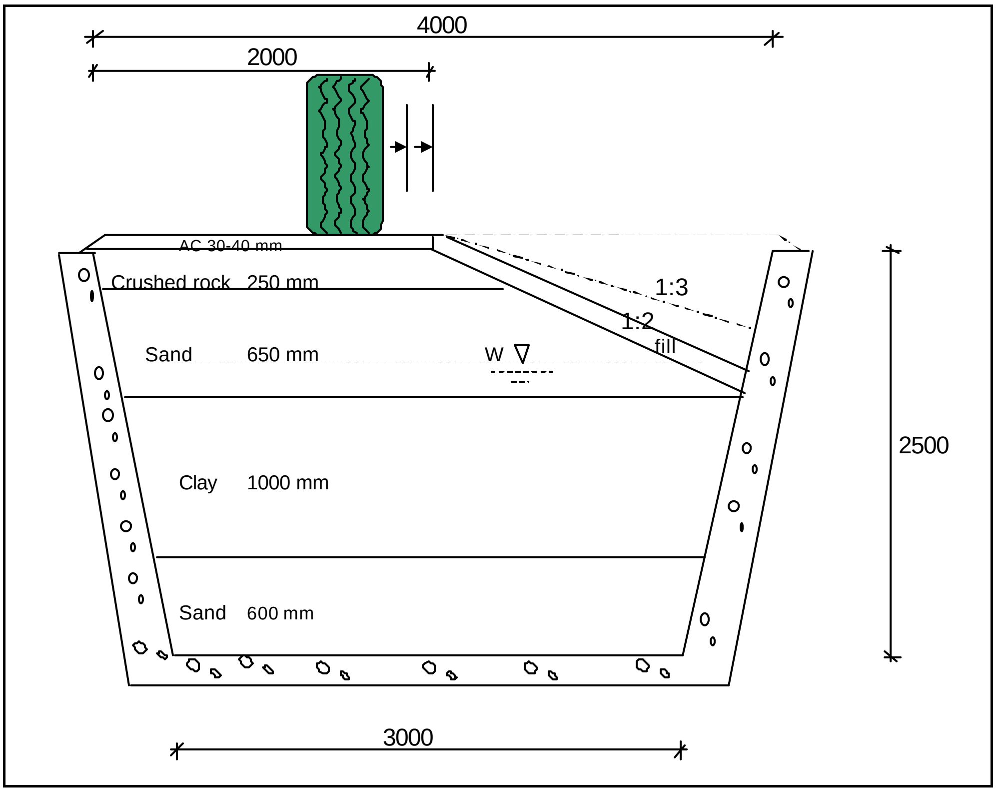

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8 REFERENCES

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Table 1. Overview of HVS tests and results.

Test	Objective	Structure	Pre-load parameters Passes Wheel load, kN Tyre type Temperature Speed	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed	Rut depth at		First crack at	Remarks
					Passes (pre-run included)	Rut, mm		
FIN01	Reference pavement, low-quality base material	50 mm, Asphalt 250 mm, Crushed rock 2300 mm Sand	0-72.000 40 kN, bi-directional Dual 10 °C 10 km/h	60 kN, bi-directional 800 kPa Dual 10 °C 10 km/h	100 000 200 000 400 000 800 000 1 200 000 1 700 000	6. 0 mm 8. 5 mm 11. 2 mm 15. 3 mm 18. 5 mm 62. 0 mm	-	GW in sand layer, N=1 510 000- 1 710 000
FIN02	Reference pavement, high-quality base material Wheel load	50 mm, Asphalt 250 mm, Crushed rock 2300 mm Sand	0-37.350 30 kN, bi-directional Single 10 °C 10 km/h	80 kN 800 kPa Dual 10 °C 10-12 km/h	20 000 40 000 100 000 140 000 170 000	2. 8 mm 5. 5 mm 13. 5 mm 16. 2 mm 17. 5 mm	-	
FIN03	Reference pavement, low-quality base material loading mode	50 mm, Asphalt 250 mm, Crushed rock 1300 mm Sand	0-25.000 30 kN, bi-directional Single 10 °C 10 km/h	70 kN, bi-directional 800 kPa, Single 10 °C 12 km/h	100 000 200 000 400 000 800 000 1 200 000 1 400 000	15. 0 mm 19. 5 mm 23. 0 mm 28. 0 mm 32. 0 mm 33. 5 mm	890 000	
FIN04	Reference pavement, low quality base material loading mode	50 mm, Asphalt 250 mm, Crushed rock 1300 mm Sand	0-17.400 50 kN, bi-directional Single 10 °C 10 km/h	70 kN, uni-directional 800 kPa Single 10 °C 12 km/h	100 000 200 000 318 000	15. 0 mm 18. 8 mm 21. 5 mm	-	unfinished
FIN05	Reference pavement, low-quality base material loading mode	50 mm, Asphalt 250 mm, Crushed rock 1300 mm Sand	-	-	0	-	-	not started

Test	Objective	Structure	Pre-load parameters Passes Wheel load, kN Tyre type Temperature Speed	Test parameters Wheel load, kN Tyre pressure, kPa Tyre type Temperature Speed	Rut depth at		First crack at	Remarks
					Passes (pre-run included)	Rut, mm		
FIN06	Thawing test, frost-susceptible subgrade	50 mm Asphalt 250 mm crushed rock 200 mm sand 1500 mm dry crust clay 600 fine sand	0-250 20 kN, uni-directional Dual 10 °C 12 km/h	50 kN, uni-directional 700 kPa Dual 10 °C 12 km/h	500 1 000 2 000 4 900	15. 0 mm 32. 0 mm 55. 0 mm 125. 0 mm	no observation	
FIN07	Thawing test, frost-susceptible subgrade	50 mm Asphalt 250 mm crushed rock 200 mm sand 1500 mm dry crust clay 600 fine sand	0-250 20 kN, uni-directional Dual 10 °C 12 km/h	40 kN, uni-directional 550 kPa Dual 10 °C 12 km/h	500 1 000 2 000 3 500 8 100	19. 0 mm 27. 8 mm 40. 0 mm 71.0 mm -	1 140	
FIN08	Thawing test, frost-susceptible subgrade, steel mesh reinforcement in crushed rock	50 mm Asphalt 250 mm crushed rock 200 mm sand 1500 mm dry crust clay 600 fine sand	0-250 20 kN, uni-directional Dual 10 °C 12 km/h	40 kN, uni-directional 550 kPa Dual 10 °C 12 km/h	500 1 000 2 000 3 500 6 500	7. 0 mm 17. 0 mm 27. 0 mm 37. 0 mm 45. 4 mm	2 000	
FIN09	Reference structure for heavy-traffic road	40 mm SMA 70 mm Asphalt in base 250 mm Crushed rock 700 mm blasted rock Rock	0-20.000 30 kN, bi-directional Single 10 °C 12 km/h	60 kN, bi-directional 800 kPa Dual 10 °C 12 km/h	20 000 40 000 80 000 100 000 130 000	0. 7 mm 1. 1 mm 1. 5 mm 1. 8 mm -	-	unfinished
FIN10	Innovative (high resistance to fatigue) structure for heavy-traffic road	60 mm ACBi 50 mm Asphalt (B-200) 250 mm Crushed rock 700 mm blasted rock Rock	0-20.000 30 kN, bi-directional Single 10 °C 12 km/h	60 kN, bi-directional 800 kPa Dual 10 °C 12 km/h	20 000 100 000 200 000 400 000 500 000	0. 0 mm 2. 1 mm 2. 9 mm 3. 5 mm 3. 8 mm	-	unfinished