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Preliminary relationship between deflection and rut depth propagation for flexible pavement using ALT

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ABSTRACT
This paper presents an attempt to find a relationship between pavement response and pavement performance. The aim of the study was to investigate the effect of increasing pavement strength on pavement performance by accelerated load testing (ALT). Accelerated load testing has been carried out at the test facility at VTI, Sweden, using the HVS-Nordic ALT-machine (Heavy Vehicle Simulator, Mk IV). In concrete test pits three different test structures were constructed on 2,5 metres of subgrade. Two of the test structures were constructed on fine sand subgrade and in the third test the upper part of the fine sand subgrade was replaced by a layer, (1,0 m), of silty sand subgrade material. The performance of these pavement structures were studied during the accelerated loading by measuring cross profiles at five fixed longitudinal positions. From these cross profile measurements, the average rut depths and rut depth propagations were calculated. Before the accelerated loading test, falling weight deflectometer (FWD) measurements were carried out to get an indication of the structural strength of the test structures. One preliminary conclusion is that there seems to be a rather strong relationship between the rut depth propagation and surface deflections from FWD measurements. The rut depth propagation during the first phase, in dry condition, for these tests showed a good fit with exponential regression lines, ($y = Ax^B$), between rut depth propagation and number of loadings. In an attempt to find a relationship between pavement response and pavement performance, the relationship between surface deflections from FWD and the exponents in the rut depth propagation regression lines was used. The exponents were related to the sum of surface curvature index SCI 300 and D_{900} from the FWD measurement. A strong linear relationship was found between the exponent B and the surface deflections ($SCI_{300}+D_{900}$).

INTRODUCTION

In 1997, Finland and Sweden jointly invested in a Heavy Vehicle Simulator, HVS Mark IV, manufactured in South Africa. The HVS-Nordic machine is a mobile equipment for accelerated load testing and has been used in the two countries in periods of about two year in each country. In this paper, some results are presented from tests on low volume road structures carried out during the first and the second period in Sweden, 1999 and 2003-2005. Three tests on pavement structures with increasing bearing capacity are included in the study.

OBJECTIVE

The aim of the study was to investigate the effect of increasing pavement strength on pavement performance by accelerated load testing.

METHOD

All three tests have been carried out at the test site at Swedish National Road and Transport Research Institute, VTI, in Linköping, Sweden.
The rut depth propagation during the first phase, in dry condition, for these three tests have been compared using exponential regression lines ($y = Ax^B$), where the exponent B was taken as a function of surface curvature index SCI 300 and D_{900} from FWD measurements before starting the tests.

Test site

At VTI there is an indoor full-scale pavement test facility, where pavements can be constructed by ordinary road construction machines. This facility comprises three test pits and two of these are used for the accelerated loading tests. The size of the concrete test pits are 3 m in depth, 5 m in width and 15 m in length. The use of two test pits means that one test section can be constructed while the test is running on the other.

Test Machine

The HVS-NORDIC is a mobile linear full-scale accelerated load testing machine. If the HVS should be moved, the machine can run by itself over a short distance at walking speed and for longer distances, the HVS can be moved as a semi-trailer.
The HVS-NORDIC has a heating/cooling system and the temperature can therefore be held constant. The air inside the insulating box is heated or cooled and controlled in order to keep the pavement temperature constant. The standard pavement temperature is selected at +10°C.
The HVS can be run by diesel or by electric power. The diesel engine also provides power for the heating/cooling system and thus it is independent of external power.
The main technical characteristics are as follows:

- Loading wheels, dual or single
- Loading can be carried out in one or both directions
- Number of loading are 22,000 in 24 hours (including daily maintenance)
- Loading wheel lateral movement is up to 0,70 m.

In total, the length is 23 m, width 3.5 m, height 4.2 m and weight 47 000 kg. The wheel load can be varied from 30 kN to 110 kN (corresponding axle loads 60 to 220 kN) at speeds up to 12 km/h. The machine can be run 24 hours a day, during the nights and weekends without any staff present. If there is any problem with the machine when no one in the staff is present, the machine has a control system that automatically shuts it down and send a message to the operator.

Test method

Before the accelerated loading test, a pre-loading and a comprehensive response measurement program were performed.

The pre-loading was performed in order to relax possible residual stresses and cause some post-compaction. This was done by 20 000 passes during one day with a lower wheel load (30 kN single wheel load), which was evenly lateral distributed on the test section. The size of the single wheel was 425/65R22.5.

The response measurement program embrace a considerable amount of measurement of stresses, strains and deflections at different positions in the test structures and at different test-loads, test-wheels, tyre pressures, lateral positions, speeds and temperatures.

After the response measurement program, the accelerated loading test was started. Normal running was day and night, five days a week, with interruptions only for daily service of the machine, which means about 22,000 loading per day including both directions. Pavement performance has been studied by visual inspections and measurements of cross profiles at five fixed locations on the test structures for rut depth calculations.

The following standard set of test parameters have been used in the main tests:

- Dual wheel load 60 kN
- Tyre pressure 800 kPa
- Wheel size 295/80R22.5
- Wheel speed 12 km/h
- Bidirectional loading
- Pavement temperature +10 °C
- Lateral wheel load distribution

Test structures
Three test structures with increasing bearing capacity are included in this study. Materials and layer thickness for these three structures are shown in figure 1.

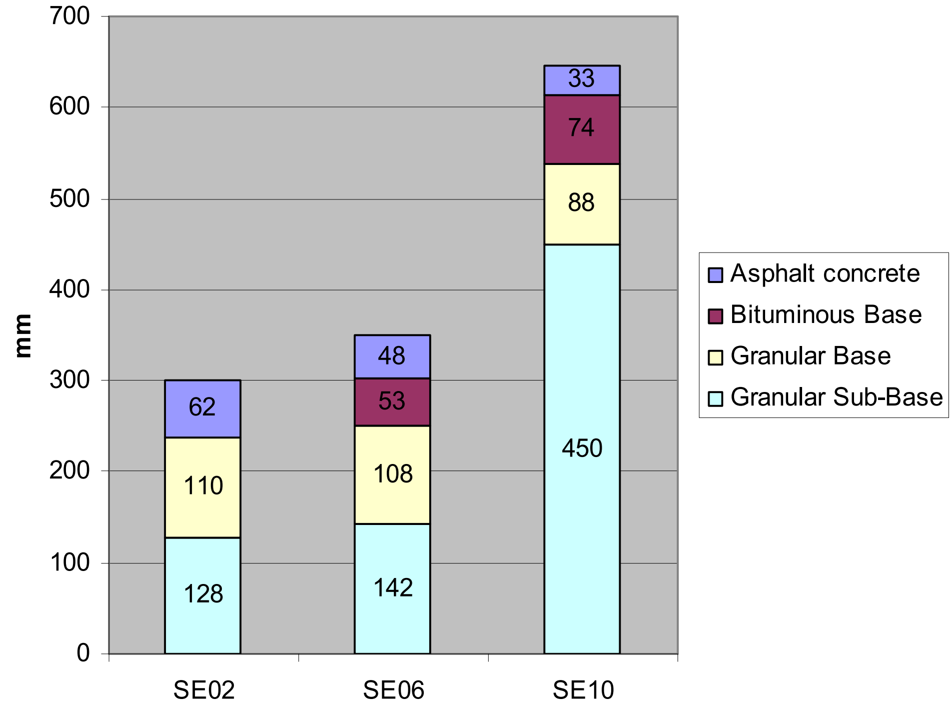

FIGURE 1: Pavement test structures with increasing bearing capacity

Two of the test sections (SE02 and SE06) were constructed on fine sand subgrade material and at the third test section (SE10) the upper part of the fine sand subgrade was replaced by a layer, (1,0 m), of silty sand subgrade material. The particle size distribution for the fine sand and the silty sand are shown in figure 2.

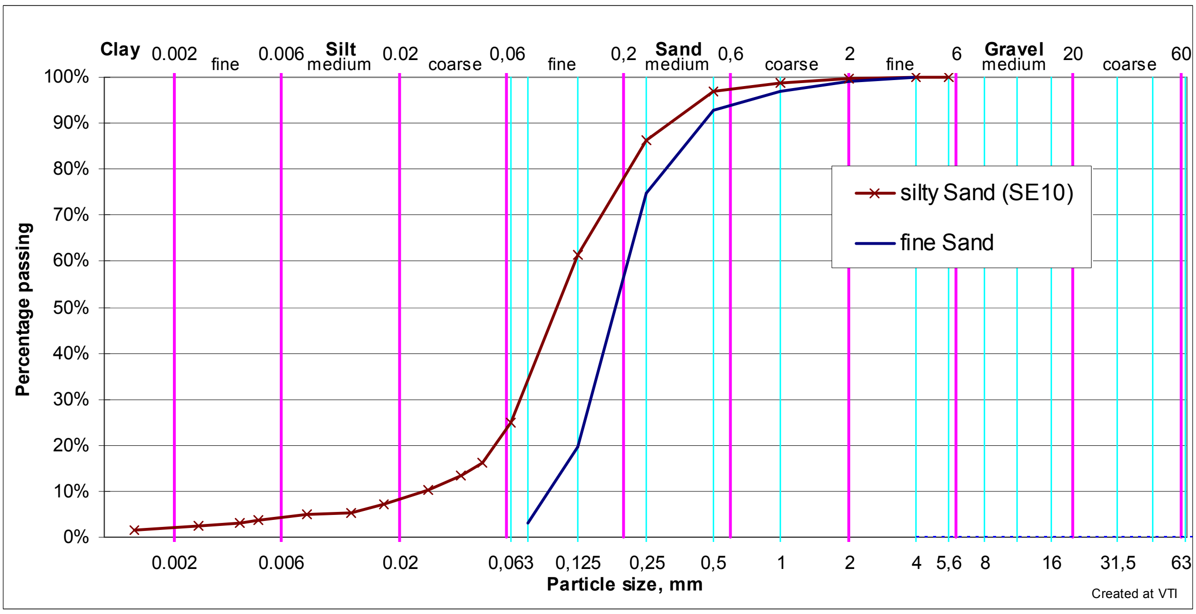

FIGURE 2: Particle size distribution for subgrade materials

RESULTS

The results used in this study are limited to the pavement performance at dry condition, phase 1 of the accelerated load testing. Normally phase 2 of the tests is carried out at wet condition with water table 300 mm below subgrade surface. This situation will be analyzed later and reported on later.

Surface rutting is used as performance indicator and cross profiles have been measured by a reference beam and a moving laser. Rut depth is defined as the maximum difference between the first measured profile, (before test), and the actual. Rut depth propagation during the first phase in these tests is presented below, figure 3, as the average of maximum rut depths from five fixed cross profiles.

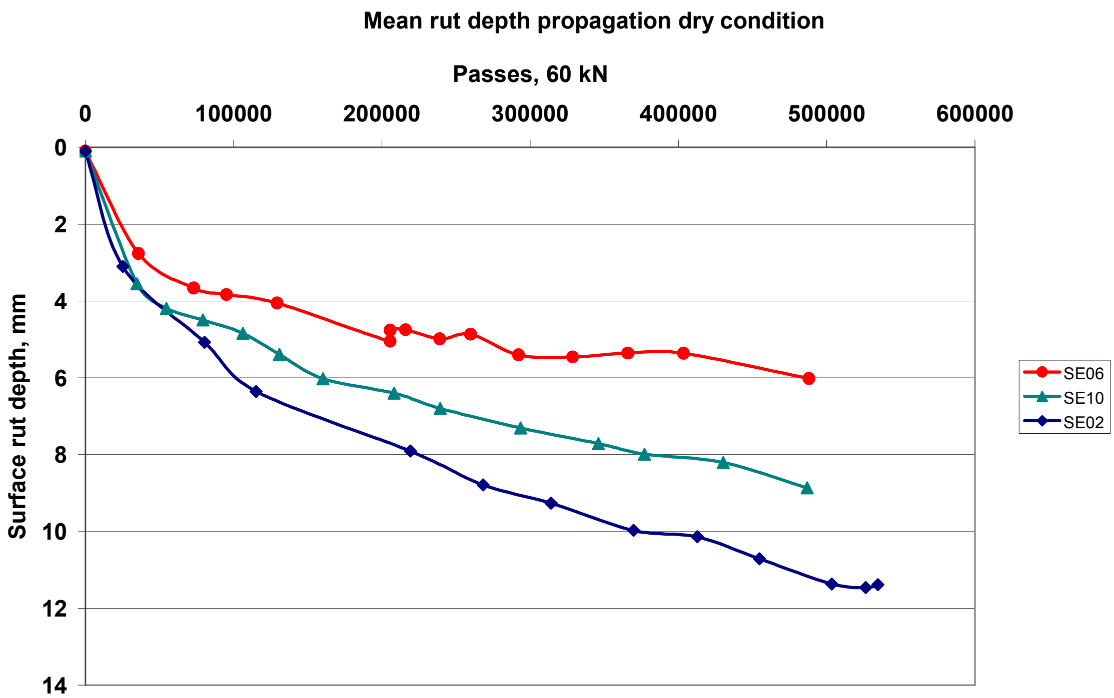

FIGURE 3: Rut depth propagation in dry conditions

Surface deflections measured by falling weight deflectometer, FWD, have been used as indicator of structural strength of the test pavements. The results from the FWD measurements before the tests are shown below, figure 4, as the average surface deflections on each structure, (14 loading positions).

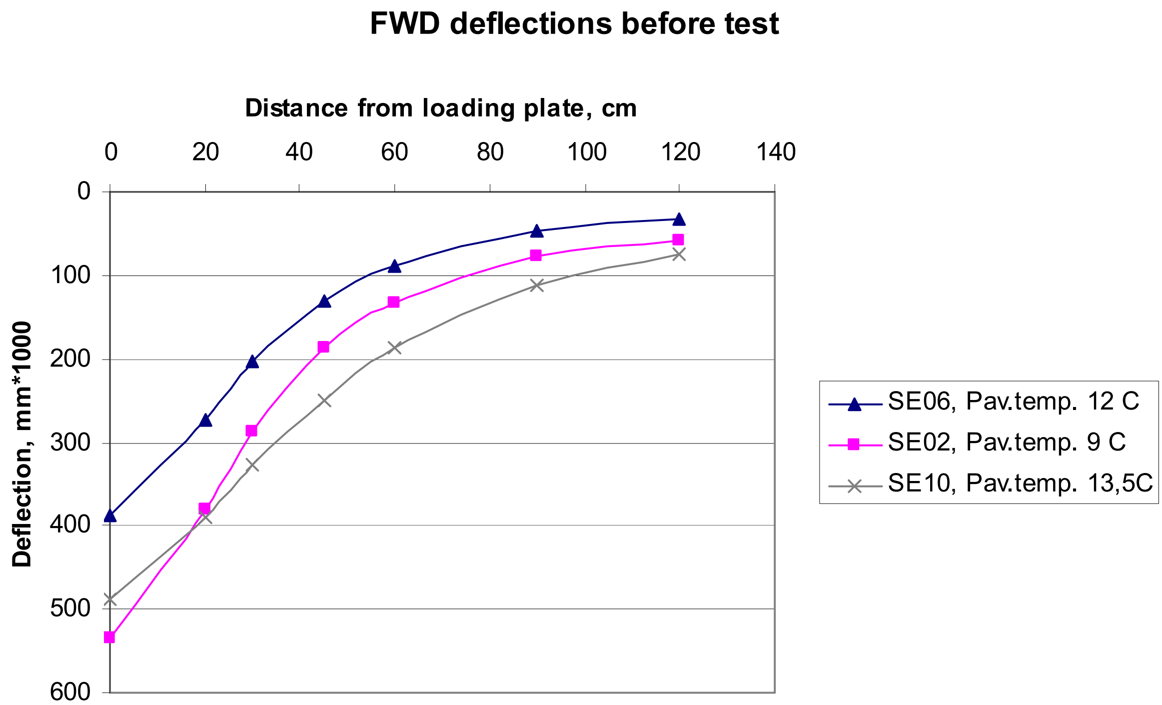

FIGURE 4: Average surface deflections before tests

FINDINGS AND CONCLUSION

The performance of these pavement structures during the accelerated load tests will be analyzed in more detail in the future. One preliminary conclusion is that there seems to be a rather strong relationship between the rut depth propagation in dry condition and surface deflections from falling weight deflectometer (FWD) measurement.

The rut depth propagation during the first phase, in dry condition, for these three tests showed a good fit with exponential regression lines, $y=A*x^B$, figure 5.

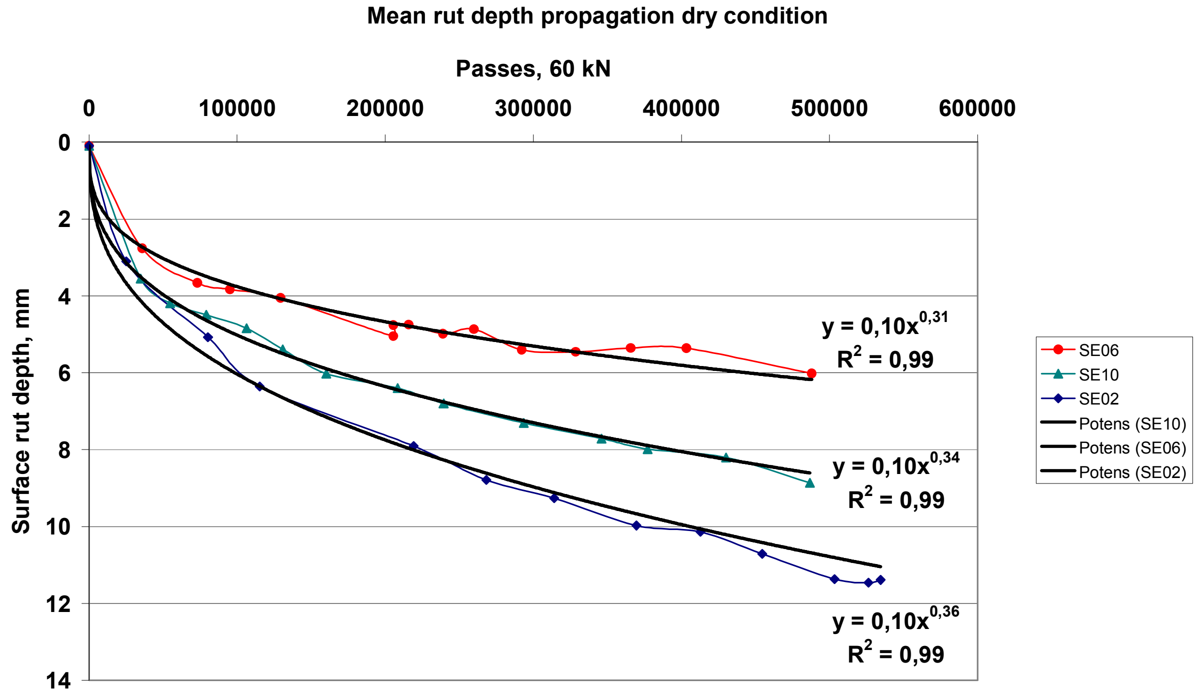

FIGURE 5: Rut depth propagation in dry condition and regression lines for the pavement test structures with increasing bearing capacity

In an attempt to find a relationship between pavement response and pavement performance the relationship between surface deflections from FWD and the exponents in the rut depth propagation regression lines was used as the A-factor were the same in the three tests. The exponents were related to the sum of surface curvature index SCI 300 and D_{900} from FWD, measured before the tests. SCI_{300} was chosen as an indicator of the properties of the pavements and D_{900} as an indicator of the properties of the sub grades.

SCI_{300} is the deflection at the centre of the loading plate minus deflection 300 mm from the loading plate and D_{900} is the deflection 900 mm from the loading plate.

A good linear relationship was found between (SCI_{300} + D_{900}) and the exponent B as can be seen in figure 6.

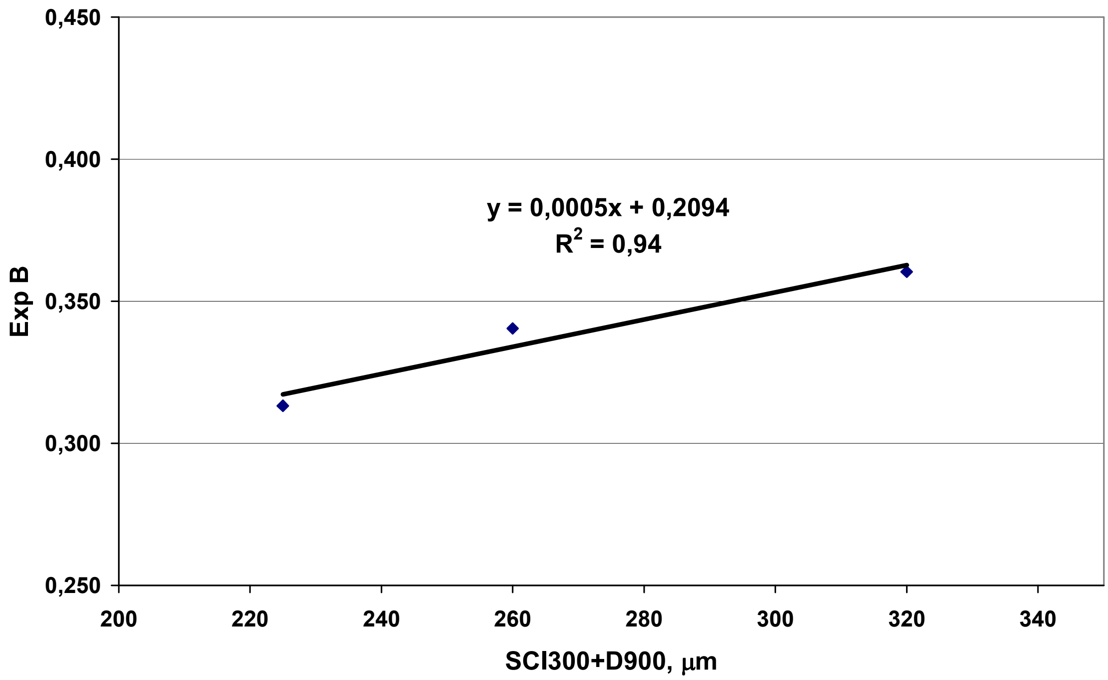

FIGURE 6: Relationship between exponents in regression lines and SCI 300+D_{900} from FWD measurements before tests

The relationship is based on mean values from each test and the standard error in these mean values are calculated as the standard deviation divided by the square rot of the number of readings. The results of these calculations are given in table 1.

TABLE 1: Mean values and standard errors for exponent B and deflection parameter (SCI_{300}+D_{900})

Exp. B		SCI_{300}+D_{900}	
Mean (-)	Std error (-)	Mean (µm)	Std error (µm)
0,313	0,004	233	3
0,340	0,002	264	6
0,360	0,002	320	4

The standard error is less than 3 % in all cases. The rut depth propagation (pavement performance) can then be described as a function of the number of loadings and surface deflections from FWD (pavement response) as follows:

$$R = 0{,}10 * N^B$$

where:
R = Rut depth (mm)
N = number of wheel loadings (60 kN)
$B = 5*10^{-4}(SCI_{300}+D_{900}) + 0{,}2094$
SCI_{300} = FWD(50kN)-deflection at the centre of the loading plate minus deflection 300 mm from the loading plate (µm)
D_{900} = FWD(50kN)-deflection 900 mm from the loading plate (µm)

These results and findings will be complemented and studied further with other and future tests. Furthermore a similar relationship was found with data from the Swedish LTPP sections which indicates that this can be a link between ALT and RLT (real-time load testing).

References

Wiman, L. G. (1999). " *Accelerated Load Testing of Pavements – HVS Nordic tests in Sweden 1999". * VTI report 477A, Swedish National Road and Transport Research Institute, Linköping, Sweden, 2001

Wiman, L. G. (2005). "*Accelerated Load Testing of Pavements - HVS-Nordic tests at VTI Sweden 2003-2004",* VTI report 544A, Swedish National Road and Transport Research Institute, Linköping, Sweden, 2006

Wiman, L. G. (2008). "*Accelerated Load Testing of Pavements - HVS-Nordic tests at VTI Sweden 2004-2005",* VTI report 576, Swedish National Road and Transport Research Institute, Linköping, Sweden, 2008 (working document in Swedish, summary in English)