BEHAVIOUR OF AN OLD EPS LIGHT-WEIGHT FILL AT VAMMALA, FINLAND

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ABSTRACT

Characteristics of a pavement and its EPS compensation fill were investigated in the fall of 1999. The pavement had been constructed in 1987, and no visible defects were found. The pavement was on a main street leading to an industrial area. The pavement was underlain by peat, soft clay and silt. To prevent excessive settlements within the peat deposit, the pavement loading was compensated applying a 400-600mm thick layer of EPS. The overlay consisted of about 600mm thick layer of crusher-run base/subbase that was separated from EPS with geotextile. The surface layers consisted of bitumen-bound base of 100mm and asphalt surface, about 50mm thick.

To monitor the actual condition of the pavement, Falling Weight Deflectometer (FWD) tests were carried out to measure the surface modulus. The pavement surface was monitored using Finnish road surface monitoring system for longitudinal roughness (IRI) measurements, and transverse rutting was measured, too.

To investigate the conditions in EPS-fill, the fill was opened in a test pit, excavated across the other half of the street. Ground water level was during excavation at the top of EPS. The exposed surface of EPS was intact and undamaged. Large samples of fill blocks were taken for further laboratory testing. They were later tested in the laboratory using the standard testing and applying for creep testing and for cyclic triaxial testing large uniaxial specimens.

Thus, it will be possible in later phase to compare the characteristics obtained in standard testing and advanced testing to the back-calculated and estimated characteristics in full scale. This site investigation was a part of the research program "EPStress 2001", started in the year of 2000. The main focus of this program was to develop criteria and design models for the mechanical design of thick EPS-fills in pavement construction.

Keywords: EPS light-weight fill, non-reinforced, old EPS

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INTRODUCTION

Within the Finnish "EPStress" research program, it was decided to carry out site investigations on an older road to study the long-term behaviour of EPS light-weight fill in pavements. In Finland, documented data on the behaviour of geofoam fills under traffic loading, has been scarcely available. The street, named Pesurinkatu was located in the town of Vammala in western Finland. The pavement had been constructed in 1987. It was a main street connected to an industrial area.

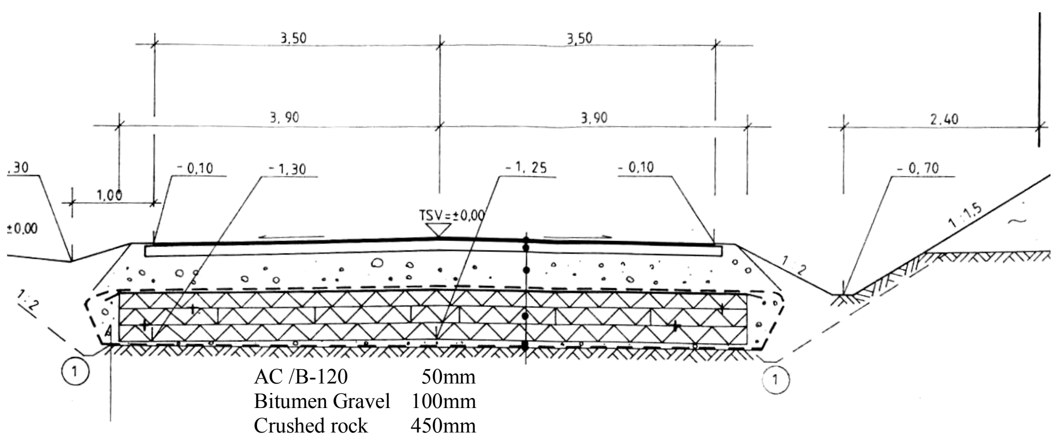
The aim of the study was to investigate the mechanical behaviour of EPS and deterioration in the pavement to get data for further development of the mechanical design of pavements containing thick EPS-layers. The EPS fill consisted of low density EPS (17kg/m^3) without strengthening (concrete slab, steel mesh reinforcement etc.). The investigation was carried out by Technical Research Centre of Finland (VTT) together with the town of Vammala and ThermiSol Finland Oy (VTT 1999).

In the EPStress program, the mechanical behaviour of EPS materials were studied, and the mechanical design concepts of pavements containing EPS fill were developed and tested. The research program was sponsored by the Finnish EPS industry.

PAVEMENT STRUCTURE

Pavement

The street had been constructed in 1987 by the town of Vammala. The pavement was underlain by peat and soft clay and silt. To prevent excessive settlements, the pavement was compensated using 400-600mm thick layer of EPS. The overlay consisted of about 600mm thick layer of crusher-run base/subbase that was separated from EPS with a geotextile. The maximum grain size of subbase was 70mm, that means the base material was quite coarse. The surface layers consisted of bitumen-bound base (bitumen gravel) of 80mm and asphalt surface, about 50mm thick (Fig. 1). The total length of EPS-fill was about 440 meters and the thickness was from 400 to 600mm. The street was about 1,6km long. Since the construction of EPS-fill in 1987, a vehicle weight limit of 48 tons had been in force.



AC /B-120	50mm
Bitumen Gravel	100mm
Crushed rock	450mm
geotextile	
plastic foil	0.2mm
EPS fill	400..600mm
sand	0..100mm
geotextile	
TOTAL	1000..1300mm

Figure 1. The design of EPS-filled street section of Pesurinkatu-street in Vammala (1986).

Surface monitoring

To monitor the actual condition of the pavement, Falling Weight Deflectometer tests were carried out to measure the surface modulus. The measurements were carried out along the whole street with an interval of 20m and in both directions. The measurements were carried out along the outer wheel path, nearer shoulders.

The pavement surface was monitored using longitudinal roughness (IRI – International Roughness Index) measurements, and transverse rutting was measured, too. Measurements were carried out with the Finnish road surface monitoring vehicle (PTM).

Layer thicknesses and properties

To investigate the conditions in EPS-fill, the fill was opened in a test pit. Large samples of fill blocks were taken for further laboratory testing. They will be tested using the standard testing, and applying for creep testing and for cyclic triaxial testing large uniaxial specimens.

The pit was excavated across the other half of the pavement. According to the measurements, the total thickness of top layer (bituminous, base/subbase) was on the average 210mm thicker than designed. At the surface, bituminous layers had a thickness of 170mm (the design thickness of 150mm). The thickness of the crusher-run base/subbase was about 640mm thick (design 45mm).

During the excavation, the ground water level was at near the top of EPS. The pit was excavated early in autumn, when the water table was relatively low. The exposed surface of EPS was visually intact and undamaged. Some local dents were detected, caused by crusher-run stones (Figs 2, 3a and 3b**)**. Large samples of fill blocks were taken for further laboratory testing.

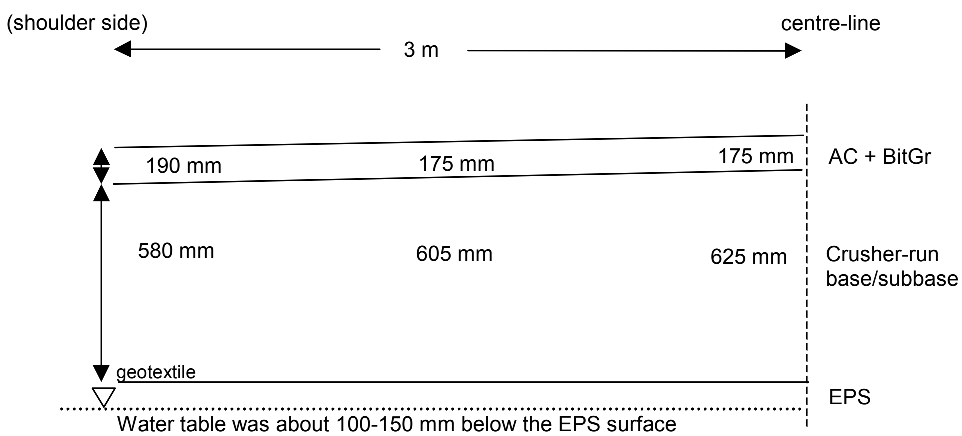


Figure 2. The measured thickness of layers in the trial pit.

EPS properties

Properties of the sampled EPS were investigated in the laboratory. The wet density of EPS was 130-200kg/m^3 in surface block and 130-162kg/m^3 in deeper-lain blocks. Dry density was 17kg/m^3 . Moisture content was 11-18vol.%, which was a considerably high value for EPS. The high moisture content indicated that EPS-layer had been under water for long periods.

Fig. 3a. The test site.

Figures 3b. Exposed EPS-surface in the test pit on Pesurinkatu.

SITE TESTING AND MEASUREMENTS

Surface modulus

The variation of surface modulus was measured using Falling Weight Deflectometer (Dynatest M8000) along the street. The measurements were carried out along the centreline of the outer (shoulder side) wheel paths. Deflections were measured at 20m intervals.

The measured surface modulus for the different points are illustrated in Fig. 4. The modulus can be seen to decrease in EPS filled area.

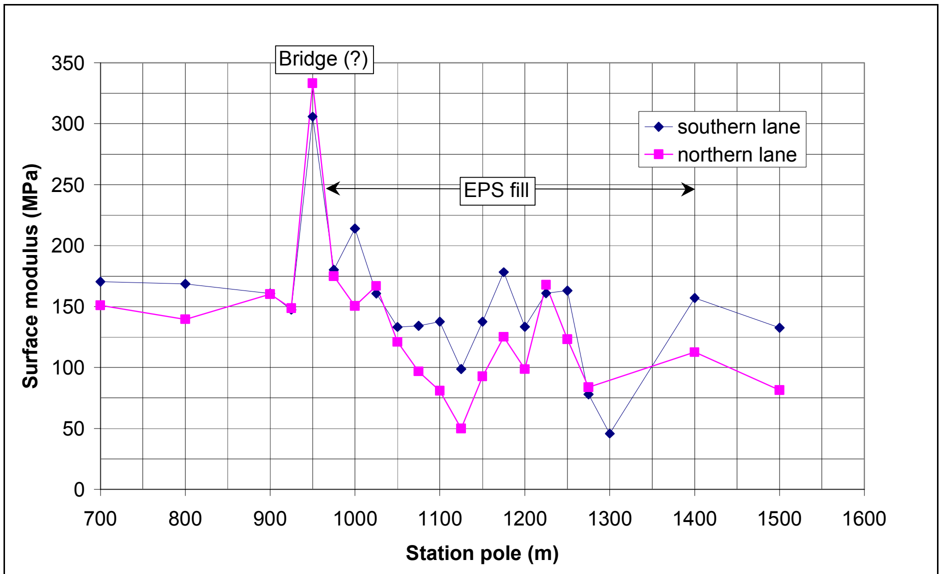


Figure 4. Measured surface modulus on Pesurinkatu in 28 October the 28th, 1999.

According to the measurements, the surface modulus within the EPS-fill stretch was as great as or smaller than the surface modulus on the surrounding pavement on the soft ground. The surface modulus on EPS fill was at the lowest about 50 MPa. It could be considered as a low value for an industrial street. In spite of low surface modulus, rutting measurements did not indicate any clearly higher deformations within the EPS-filled area compared to the adjoining street sections.

Roughness and rutting

Measured values of the longitudinal roughness IRI (mm/m) are illustrated in Figs. 5 and 6. Both 5-meter and 100-meter roughness indices are presented. With the exception of some local, higher IRI values, the roughness differed only slightly between the EPS filled area and the surrounding street. Measured rutting (roughness in transverse profile) is illustrated in Fig. 7.

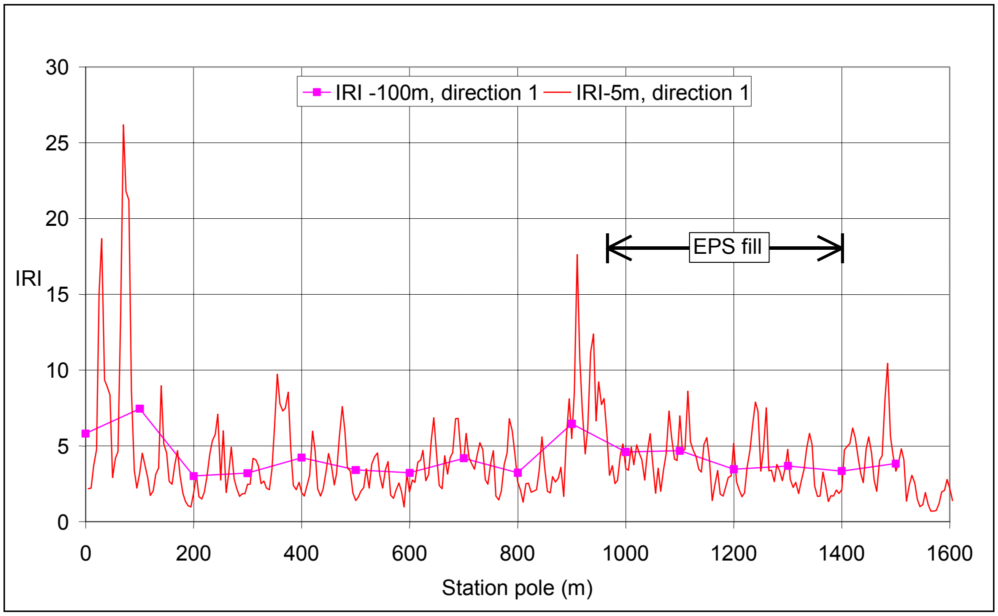


Figure 5. Measured IRI-100m and IRI-5m values, direction 1 (Northern lane).

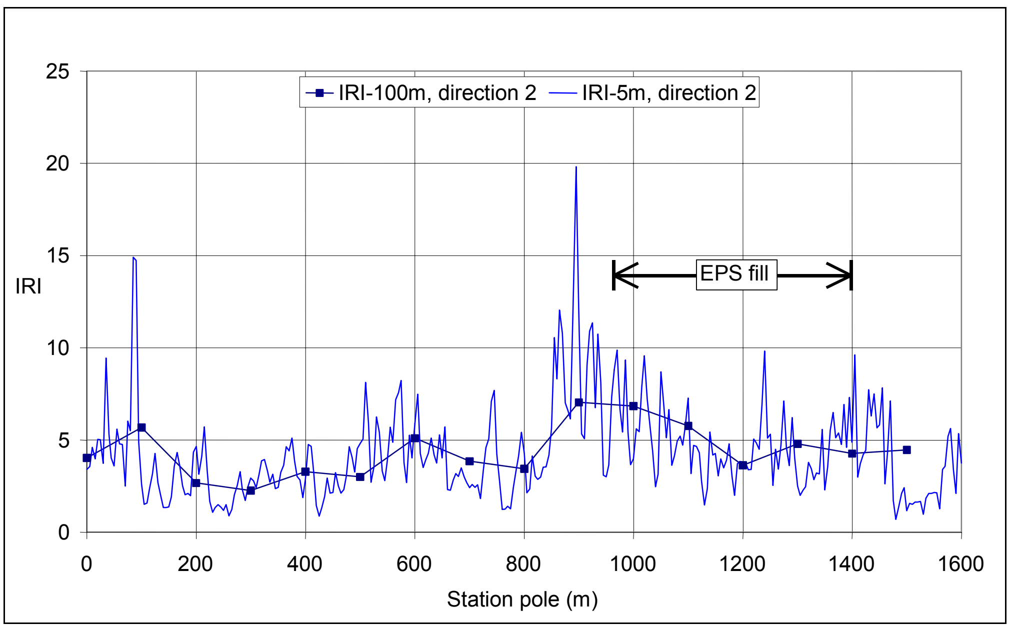


Figure 6. Measured IRI-100m and IRI-5m values, direction 2 (southern lane).

RESILIENT ANALYSIS OF THE PAVEMENT STRUCTURE

Calculation model and layer moduli

The modelling of pavement was based on in-situ measurement results. The measured FWD deflection bowl was modelled with the 'Modcomp3' computer program, Modcomp3 (1994). The thickness of pavement layers was determined from test pit measurements. A linear elastic model was applied for all the layers. The FWD deflection bowl, applied in the analysis, was measured at the pit location. The program back-calculated corresponding elastic material moduli for different layers. Back-calculated moduli are presented in Table 1.

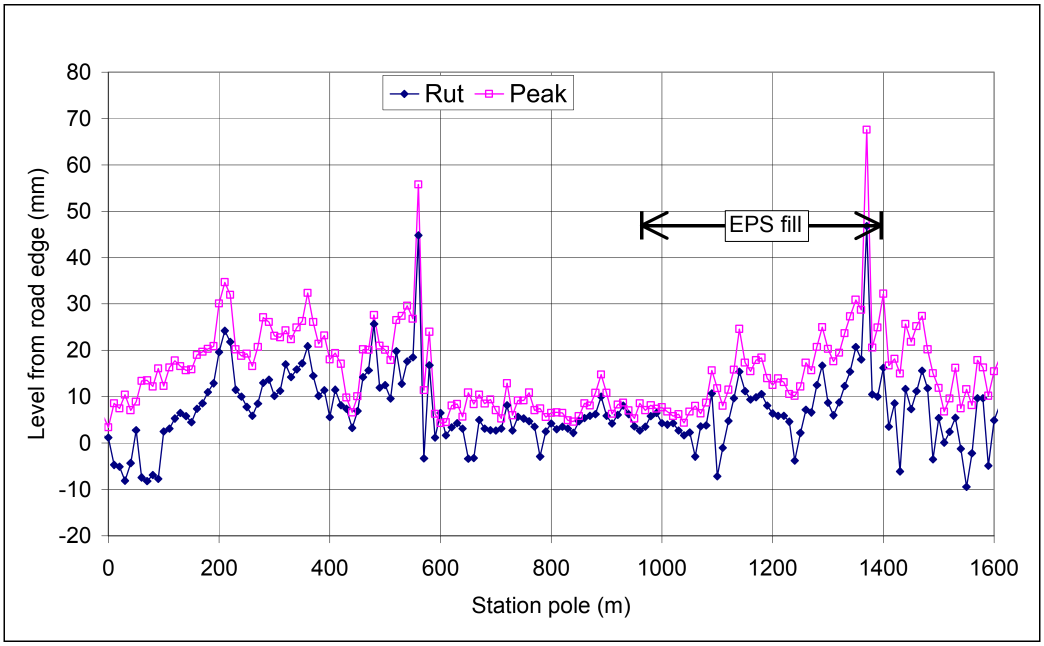


Figure 7. Rut and peak values on Pesurinkatu. Values were measured with the Finnish road surface monitoring system (PTM). The differences between measured peak and rut describe transverse unevenness of road profile.

The linear-elastic model seemed to work quite well in this case, although the program was based on the conventional multi-layered elastic theory, which may not be so realistic for this kind of a structure. Back-calculation resulted in a low material modulus of the unbound base layer. It is evident, that the crusher-run aggregate could not be so well compacted on the soft EPS layer than on a stiffer underlay. In the computer analysis, a modulus value of 6,9 MPa was determined for the EPS-layer. The result was quite comparable to the values presented in the literature.

Table 1. Back-calculated layer moduli of the pavement with EPS-fill on Pesurinkatu.

Layer	Thickness[1] [mm]	Modulus[2] [MPa]	Poisson ratio[3]
AC+Bit. Gravel (temp. +5°C)	180	6600	0.35
Crushed rock	590	104.0	0.35
EPS	600	6.9	0.10
subgrade	∞	46.5	0.40

1) Measured from test pit
2) Back-calculated using the Modcomp3 program. The FWD deflection bowl was measured at the test pit location
3) Values taken from literature

Stresses and resilient strains in pavement layers

Resilient deformations under applied load were modelled with Bisar computer program, Bisar (1998). The applied layer characteristics were the same as determined in the FWD analysis. The strains and pressures under overburden load and with a 50kN circle-shaped surface load (diameter 0.3m) are presented in Table 2.

The wheel-type can vary in normal traffic, but if the aim was to investigate the response of EPS, the shape and size of the loaded surface do not have so much of an effect. A vehicle weight limit of 48 (metric) tons had been applied on Pesurinkatu since the construction, and no information about the annual traffic was available. Thus, it was not possible to estimate the equivalent number of standard axles.

Table 2. Computed stresses and strains at the surface of the EPS layer.

	Vertical stress kN/m^2	Vertical elastic strain %
Pavement surcharge	16.1	0.32
Surface (wheel) load, 50kN	5.3	0.11
Total	21.4	0.43

Permanent deformations in EPS

EPS is deformed elastically if the compression deformation is less than 0,4 a' 0,5% (Duškov 1997). According to the modelling, the strains in EPS due to overburden pressure were below the elastic limit of the EPS material. Creep might also have been a risk, if the overburden stresses from the pavement overlay had been higher than 20-25% of the nominal strength of the actual EPS-product (corresponding to the 10% strain). In this case, the load should have been lower than $20kN/m^2$. The estimated development of creep strains in EPS at Pesurinkatu is illustrated in Table 3. The applied creep equation was for an EPS-geofoam with a density of $20kg/m^3$, Horvath (1998).

Table 3. Estimated creep in EPS layer in Pesurinkatu (static load effect).

Level of total (resilient+creep) strain %	time to reach the creep level (years)
0.32	0.0
0.33	0.0
0.34	0.0
0.36	0.1
0.40	1.1
0.46	11.4
0.55	114.2

DISCUSSION AND CONCLUSIONS

The wet density of the investigated EPS varied between $130\text{-}200kg/m^3$. Dry density was $17kg/m^3$. The observed moisture content, 11.18vol-%, could be considered as high value for an EPS-material. The high moisture content indicated that the EPS fill had been under water for long periods. Despite the high moisture content, the mechanical properties of EPS did not seem to differ from those typical for dry conditions.

According to the road surface monitoring, the roughness was slightly higher in EPS filled area in comparison with the surrounding pavement. Anyhow, the condition of the pavement varied greatly along the investigated street line, and the roughness of the pavement containing EPS fill was not significantly different.

The surface modulus was lower in EPS filled area than in other street sections. The lowest value was about 50MPa. This must not be interpreted in a wrong way. Although the modulus of EPS was low, the deformations can stayed at the elastic range, resulting minor plastic deformations. EPS materials can not be compared to natural soft soils or subgrades, although the resilient modulus is the same.

Possible rutting and fatigue damage may also result from the layers of unbound crusher-run aggregates or bitumen-bound materials. Within a pavement containing EPS, the critical layers may be the unbound base and bitumen-bound layers. If the resilient deformations of EPS are below the maximum elastic deformation (less than 0.4 a' 0.5%), EPS behaves as an elastic material, without excess accumulation of creep and cyclic strains.

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