LIFE02 ENV/FIN/000329: Kukkia Circlet

REPORT ON TECHNICAL AND ENVIRONMENTAL FOLLOW-UP OF PILOTS 2002 AND 2003

2002 – 2004

ANNEX (1) of the Final Report

FINNISH ROAD ENTERPRISE

RAMBOLL FINLAND LTD

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CONTENTS

1. INTRODUCTION

The objective of the Life-Environment project, Kukkia Circlet, has been to test and demonstrate sustainable, environmentally, technically and economically sound methods for the recycling of high-volume waste streams from the industry for the improvement and renovation of secondary road networks in Europe. Kukkia Circlet has focussed on the recycling of the most potential and interesting types of waste or “idle by-products” from the paper and chemical industry, the fly ashes, fibre sludge and filter cake, that represent the behaviour of the different types of industrial waste in Europe. The objects where these materials have been used are existing and badly damaged gravel roads, groundwater protection structure, and new types of light traffic lanes in Luopioinen that represents a typical rural region of Europe.

The project is composed of two pilots. Pilot 2002 involves renovation of several long sections of a secondary gravel road in Luopioinen by stabilising the existing road with help of stabilisers based on industrial by-products. The reference sections have been treated with different types of conventional maintenance and renovation methods.

Pilot 2003 involves renovation of sections of a gravel road and construction of different types of light traffic lanes with help of fibre-ash (a mixture of fibre sludge with fly ash) structural courses Pilot 2003 also involves testing of a groundwater protection structure the sealing course of which is made of fibre sludge. Also Pilot 2003 structures are located in Luopioinen.

This report is the final report of the technical and environmental follow-up studies carried out for the Pilot 2002 and the Pilot 2003. Material testing and the construction of the pilot structures are reported in detail in the earlier Progress and Interim Reports and available in the project’s website. A technical description of the processes and methods implemented in the pilots is also found in the DVD format.

2. Follow-up programme

The follow-up programme is shown in the following table (1). Some of the follow-up studies at the project sites will continue after the end of the project period. The follow-up involves sampling for environmental and geotechnical analysis and tests.

Table 1. Follow-up programme of the Pilot 2002 and the Pilot 2003.

PILOT 2002	**Method**	**Responsible**	**Year / quarter**												
			02	03				04				05 (after project)			
			4	1	2	3	4	1	2	3	4	1	2	3	4
Quality check	visual	FRE	x		x				x				x		
Bearing capacity	falling weight	FRE					x		x						
Studies of structures	Testing of drilled samples	Ramboll				x				x					
Water samples	Analysis of inorganics	Ramboll				x				x				x	
Soil samples						x				x				x	
PILOT 2003	**Method**	**Responsible**	**Year / quarter**												
			03					04				05 (after project)			
			1		2	3	4	1	2	3	4	1	2	3	4
Quality check	visual	FRE,			E		x		x				x		
Bearing capacity	falling weight	FRE					x		x						
Studies of structures	Testing of drilled samples	Ramboll					x			x					
Water samples	Analysis of inorganics	Ramboll				E				x				x	
Soil samples						E				x				x	

E = reference before Pilot construction

3. MATERIALS

Pilot 2002

The binder components (by-products) were supplied by UPM-Kymmene Ltd from Jämsänjokilaakso, the mills of Jämsänkoski and Kaipola (fly ash), Helsinki Energy power plant (fly gas desulphurisation residue) and Kemira Chemicals Ltd Kokkola (filter cake). Also commercial mixtures like cement and FTC were used in the binder admixtures. FTC is a product of Nordkalk Ltd, and also it origins from industrial by-products: it is composed of Finnstabi®[1] (by-product from TiO_2-production), fine lime and cement in proportion of 1:1:1.

In order to compose the best recipes for admixtures, the effect of different admixtures and amount of admixtures were tested in the laboratory of SCC Viatek Ltd in Luopioinen (1.4.2004– Ramboll Finland Ltd) according to the plan for material tests.

Pilot 2003

Fly ash used as a binder component came from UPM-Kymmene Ltd's power stations in Jämsänjokilaakso and fibre sludge from Georgia-Pacific Finland Oy's paper mill in Nokia. The fibre sludge chosen for the groundwater protection was of quality class U1, which was the most homogeneous type available. This U1 is based on the de-inking of high quality paper waste collected from the offices. Also ordinary cement was used in mixtures.

3. PILOT 2002

3.1. In general

The site for Pilot 2002 is located in Luopioinen, Finland, in the road 3201 between Kuohijoki and Kyynärö. The main problems of this road section were frost damages and especially the weak bearing capacity caused by the thawing of frost during the spring. The renovation process was prepared by testing the effect of different binder admixtures in the geotechnical laboratory, and by planning in details the process from the acquisition of materials, their storage and mixing to the finishing of the stabilisation. The preparations involved also the required formal application process for the environmental permit to use industrial by-products (waste) as construction materials (the permitting authority being the municipality of Luopioinen, under the guidance of the Regional Environment Centre).

The old road had been suffering of significant damage because of the freezing- thawing cycles of the arctic climate. The bearing capacity of the road was weak, there were chasms, cracks and holes in the road, the road’s materials were of inferior quality, and the structure was damaged and spread out covering the ditches and any other drainage system. Before the construction process could start, the ditches of the existing road had to be dug again, and the road surface had to be harrowed in order to remove the biggest stones (emerged on the surface as the road’s structural aggregates had been pushed downwards because of erosion and the increase of the share of fines). The harrowing had to be repeated at certain sections also during the construction process because of still emerging big stones that could break the cutter plates of the milling machine.

Pilot 2002 involved also testing of new types of covering courses based on the crushed aggregates mixed with filter cake that is generated during the manufacturing of salts. This mixture was tested as a new method to stabilise the covering course and to prevent the gravel roads from dusting.

3.2. Structures

The Pilot 2002 consists of reference sections of conventional renovation methods and the new types of stabilised sections, as described in the following table (2).

Table 2. Pilot 2002. Structures.

Pole distance	Structure	Note
0-1400	Reference 2 + covering with crushed aggregate material	"pot-hole renovation"; geotextile and 300 mm of crushed aggregates (0-32 mm); a covering course of 20 mm crushed aggregates (0-16 mm)
1400-2850	Reference 1 + covering with crushed aggregate material	"autumn renovation"; a new covering course of 20 mm crushed aggregates (0-16 mm); in autumn salt will be spread on the covering course (dust prevention)
2850-4350	Stabilisation A + covering with crushed aggregate material	200 mm of the existing road course was stabilised by 10 % of binder composed of fly ash and cement in proportion of 3:2
4350-5800	Covering with crushed aggregate material/filter cake only	50 mm of crushed aggregates and above it 50 mm of the aggregate mixed with 3…5 % of filter cake
5800-7640	Stabilisation B + covering with crushed aggregate material/filter cake	200 mm of the existing road was stabilised by 10 % of binder composed of fly ash and FTC (made by Nordkalk Ltd) in proportion of 3:2.
7640-8690	Stabilisation A + covering with crushed aggregate material/filter cake	See above
8690-9150	Stabilisation B + covering with crushed aggregate material/filter cake	See above
9150-9320	Covering with crushed aggregate material/ filter cake only	See above
9320-10340	Stabilisation E + covering with crushed aggregate material/filter cake	200 mm of the existing road course was stabilised by 10 % of binder composed of fly ash, fly gas desulphurisation residue and cement in proportion of 3:3:4..
10340-12180	Stabilisation A + covering with crushed aggregate material/filter cake	See above

The covering courses was made either of crushed aggregate material (0-16 mm) (poles 0 - 4350) or crushed aggregate material mixed with 3 … 5 % of filter cake (poles 4350 - 12180). Topmost between poles 2850 – 12180 came "stone-ash", i.e. fines from production of aggregates or from the crushing of rocks. In the Pilot 2002 filter cake was granulated with lime.

3.3. Follow-up studies

Before the renovation in 2002 the pilot road was in a bad shape and in springtime occasionally unsuitable for cars or at least heavy traffic. Now the road is in a good shape in the stabilised sections and usable around the year. The bearing capacity has improved, partly because of the stabilisation and partly because of the opening of the ditches. Strength development in samples taken from the road equals or exceeds the expectations. Structures are in good conditions and seem to work according to plans.

By looking at Figure (1) and Table (3) one can see that the bearing capacities of stabilised sections have increased considerably. In Reference 1 ("autumn renovation") the increase has been slight and in Reference 2 and “Filter cake” cover sections the average bearing capacities have stayed at the same level.

Due to the short-term results the range of bearing capacity is wide especially in the stabilised sections, but as a whole the Pilot 2002 has been a success. In springtime 2003 and 2004 there were no load limits for the traffic at the road while in past years the load limit has been required every other year. Of course the follow-up time of two years is too short for the further conclusions and the follow-up should be continued.

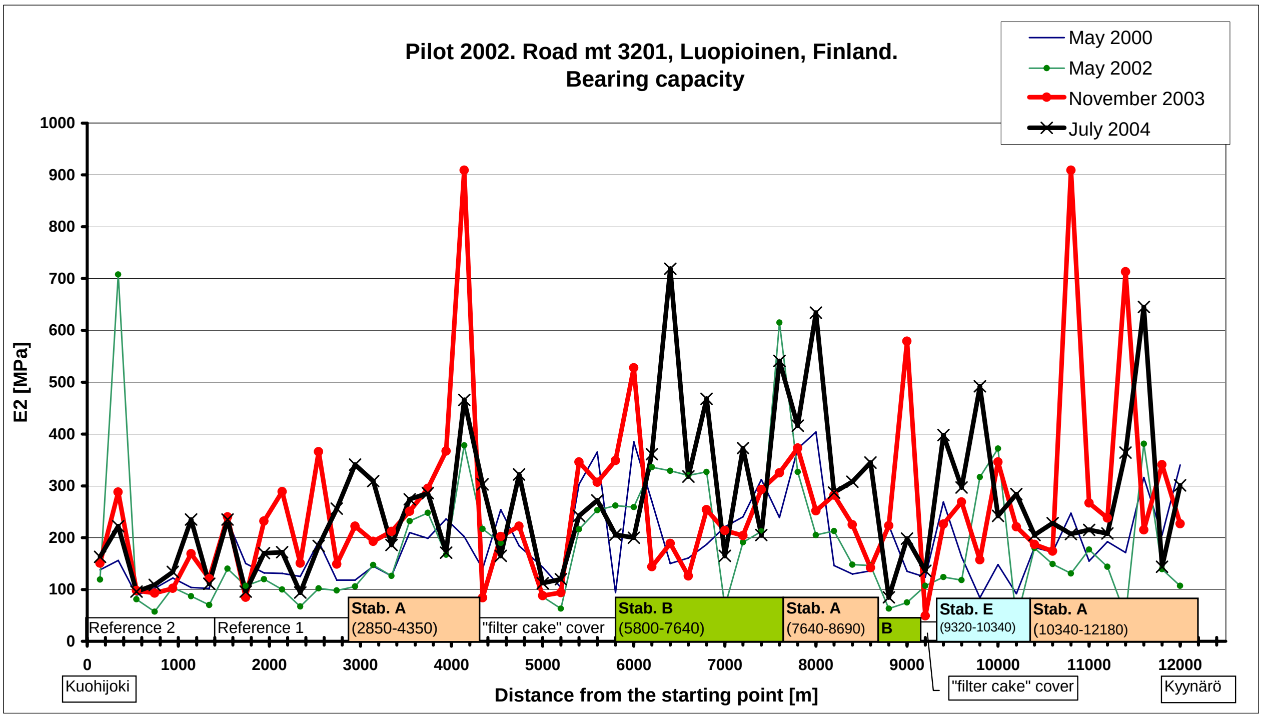


Figure 1. Pilot 2002. Bearing capacity between years 2000 and 2004.

Table 3. Pilot 2002. Average bearing capacities and standard deviations.

Structure		**Ref. 2**	**Ref. 1**	**Stab. A**	**Filter cake cover**	**Stab. B**	**Stab. A**	**Stab. B**	**Filter cake cover**	**Stab. E**	**Stab. A**
Starting pole		0-	1400-	2850-	4350-	5800-	7640-	8690-	9150-	9320-	10340-
Average	v.2000	116	154	172	226	226	238	180		151	220
	v.2002	175	105	203	162	292	208	69		194	162
	v.2003	146	216	317	210	263	255	401		244	363
	v.2004	153	172	292	206	356	398	142		343	280
Std. deviation	v.2000	22	39	42	91	80	123			66	63
	v.2002	218	21	82	74	134	66			127	86
	v.2003	64	88	237	97	113	75			62	248
	v.2004	52	57	86	79	169	126			91	142

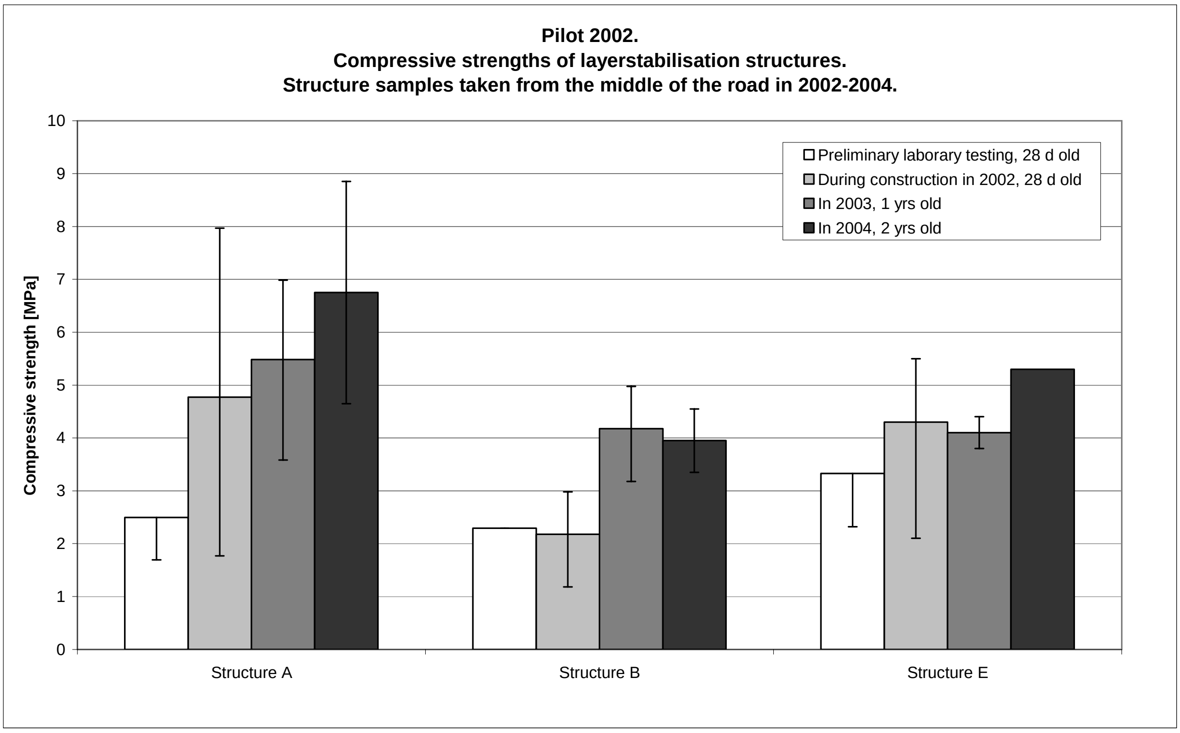


Figure 2. Pilot 2002. Strength development in structure samples taken from the middle of the road in 2002-2004.

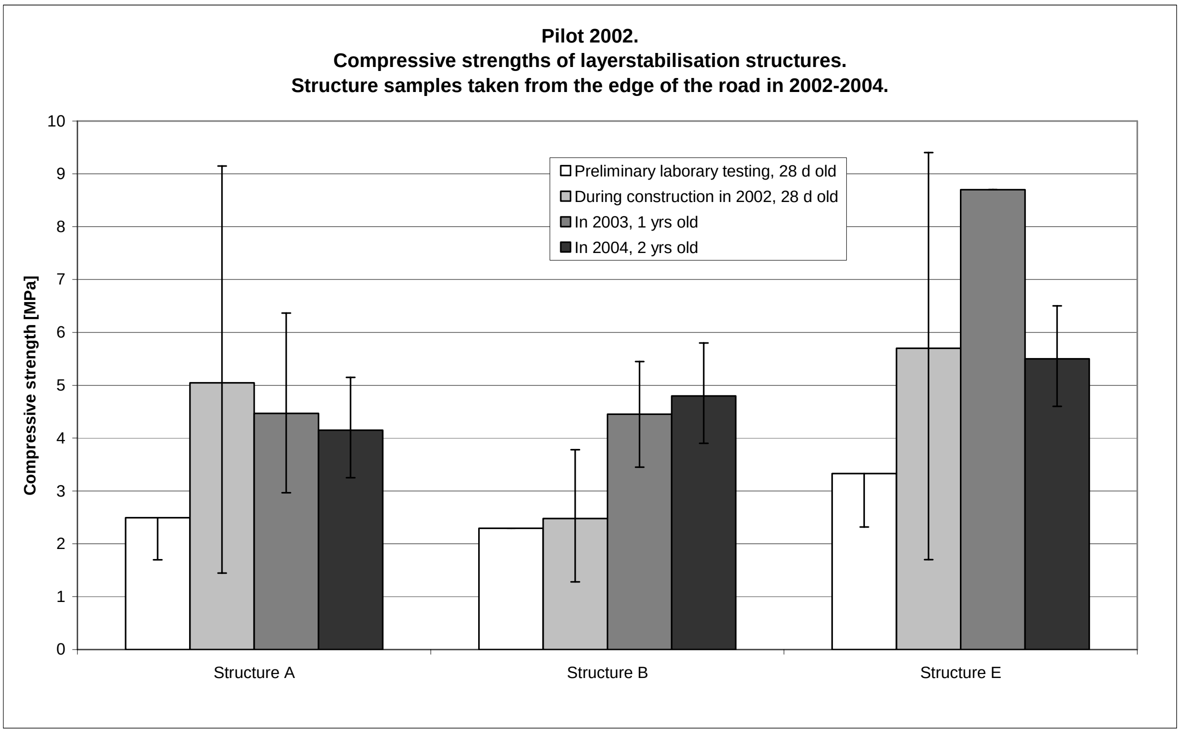


Figure 3. Pilot 2002. Strength development. Strength development in structure samples taken from the edge of the road in 2002-2004.

In Figure (2) there is no downward trend of strength development and based on that fact the structures should be functioning as planned. In Figure (3) the lower strength of the road edge as well as the wide range of values might be result of some problems during the construction (too light compaction, mixing of stabilisation and subsoil at the roadside). The strengths of structure samples have been around 4-5 MPa and noticeable better than reached in preliminary laboratory tests (tests before construction).

The capillarity and in the other hand the permeability through the stabilised structure is weaker than on the ordinary road material. Small capillarity might cause drying of the road surface, which leads to pothole and dusting problems. During rainy season the low permeability leads to softening of the surface where inclination of the road is too small. If crushed aggregate and filter cake mixture is used as covering material, the grain size distribution curve of the aggregate and possible usage of extra filler material should be considered.

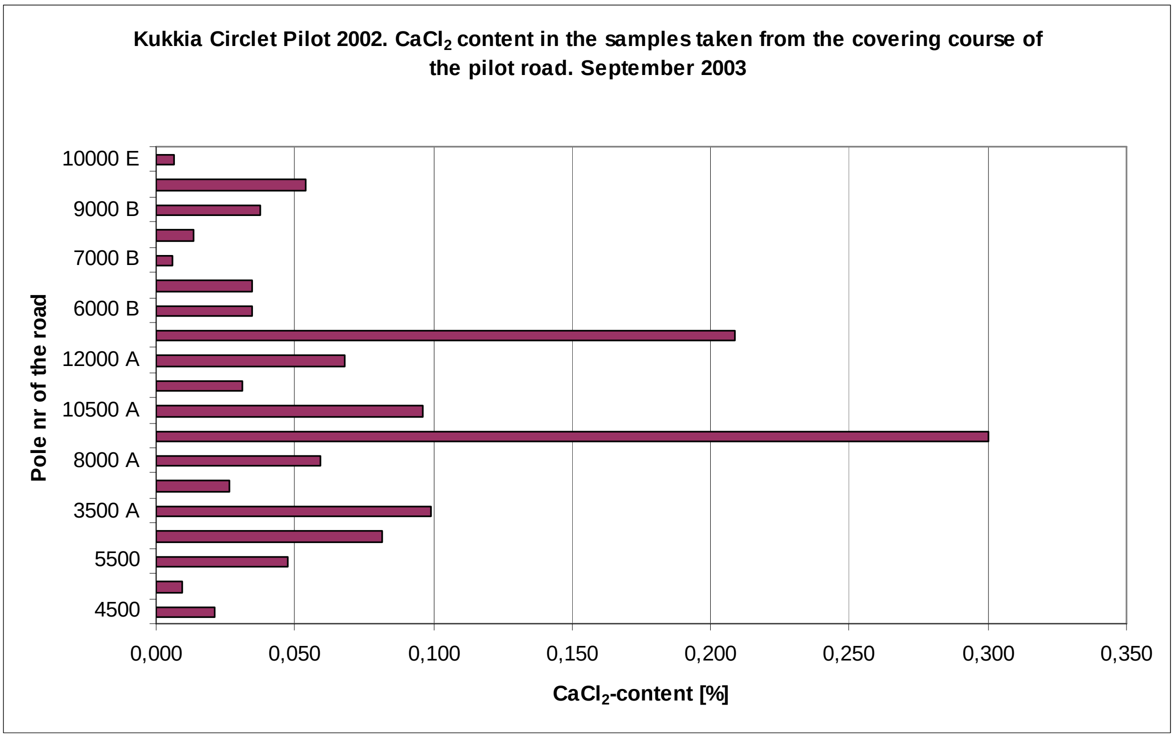


Figure 4. Pilot 2002. Calcium chloride concentrations in samples taken from the covering course.

The $CaCl_2$ content of covering course samples was measured one year after the construction. The target level was 0,6 % in 2002 (21 % of $CaCl_2$ in filter cake, 3 % of filter cake in covering course material) and in 2003 the levels varied between 0,004 % and 0,314 % (average 0,06 %). According to the TIEL2230013 (Maintenance and renovation of gravel roads, FinnRA; in Finnish) the needed amount of $CaCl_2$ is 0,15 % in springtime; so there might be need for extra $CaCl_2$ in the spring 2005. Covering course samples were taken also in 2004, but the results have not been available for the final report.

Figure 5. Pilot 2002. Drilled samples from a stabilised section.

4. PILOT 2003

4.1. In general

The Pilot 2003 consists of three different kinds of subprojects. The renovation of gravel road with fibre ash structure was carried out in the local road Pt 13981 (Pihtisalmentie) in Luopioinen. Two badly frost damaged sections of 400 m and 500 m were selected and renovated during summer 2003. The second pilot site was a groundwater protection structure made from fibre clay and located in the roadside of the road Pt 13981. The protection structure was about 30 meters long and extended 5 meters away from the road. The third pilot site was a new 4 kilometres long light traffic lane along the main connecting road Kt 322 passing by the central village of Luopioinen municipality and consisting of three different kinds of structures. Construction materials for the light traffic lane were fibre-ash and geotextiles. Filtercake used in the covering course mixtures of Pilot 2003 was not granulated with lime like in the Pilot 2002.

4.2. Fibre-ash structural course for renovation

4.2.1 Structures

The renovation process started by levelling the old road surface and by piling these surface materials on the road edges (edge supports for the fibre-ash). A 200 mm course of fibre ash was spread and compacted on the surface, and was covered by 50 mm of crushed aggregates and 50 mm of aggregate mixed with 3…5 % of filter cake.

Figure 6. Pilot 2003. The pilot road before and after renovation in 2003.

4.2.2 Follow-up studies

The renovation was done to the most damaged parts of the pilot road. The stabilised sections have stayed in good conditions and the road as a whole has now been usable without load restrictions around the year. Inhabitants are satisfied with result and have hoped that the other parts of the road could be renovated as well.

The surface of the renovated sections was in good condition in 2004 while there were some potholes outside the stabilisation. Fibre-ash layer was firm and was not mixed with covering course material. In 2003 there were some soft spots in the road, which were caused by non-stabilised fibre clay. The sides of the road were slightly soft, because the deepness of ramps affected to the compaction work.

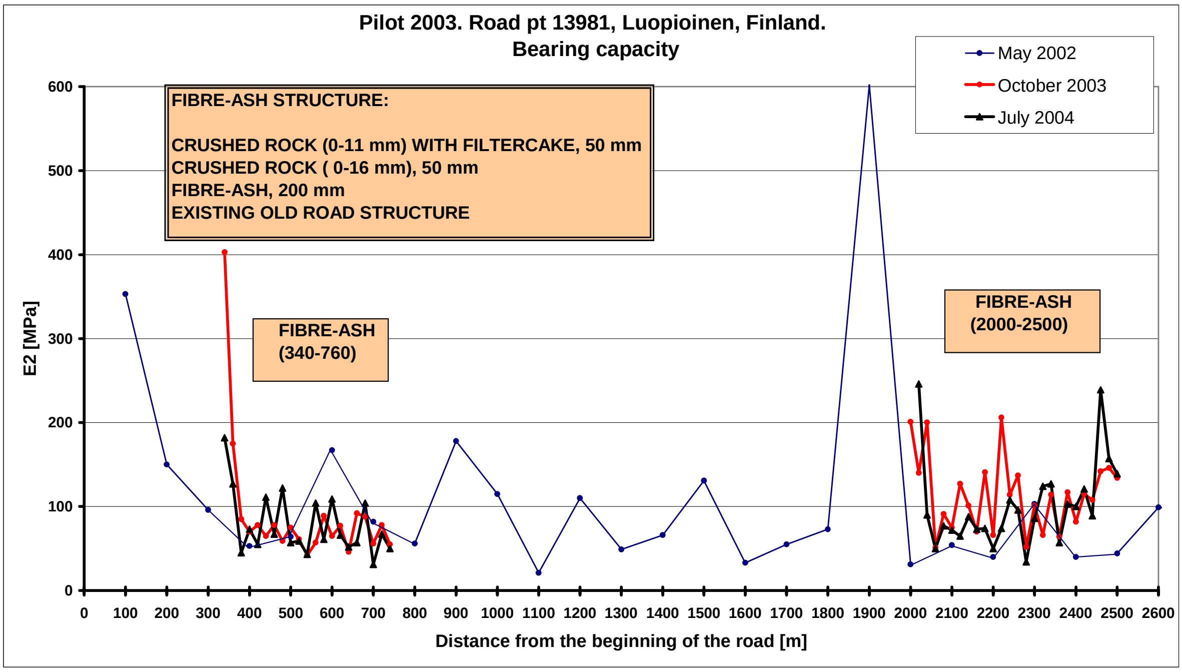


Figure 7. Pilot 2003. Bearing capacity between years 2002 and 2004.

The bearing capacity has remained about the same or improved a little. The main point of using fibre clay is not the increasing of bearing capacity but to prevent the damaging frost heave. The fibre clay forms an insulating, separating, and elastic layer, which reduces frost penetration, prevents mixing of subsoil and covering course, and diminishes frost heaving.

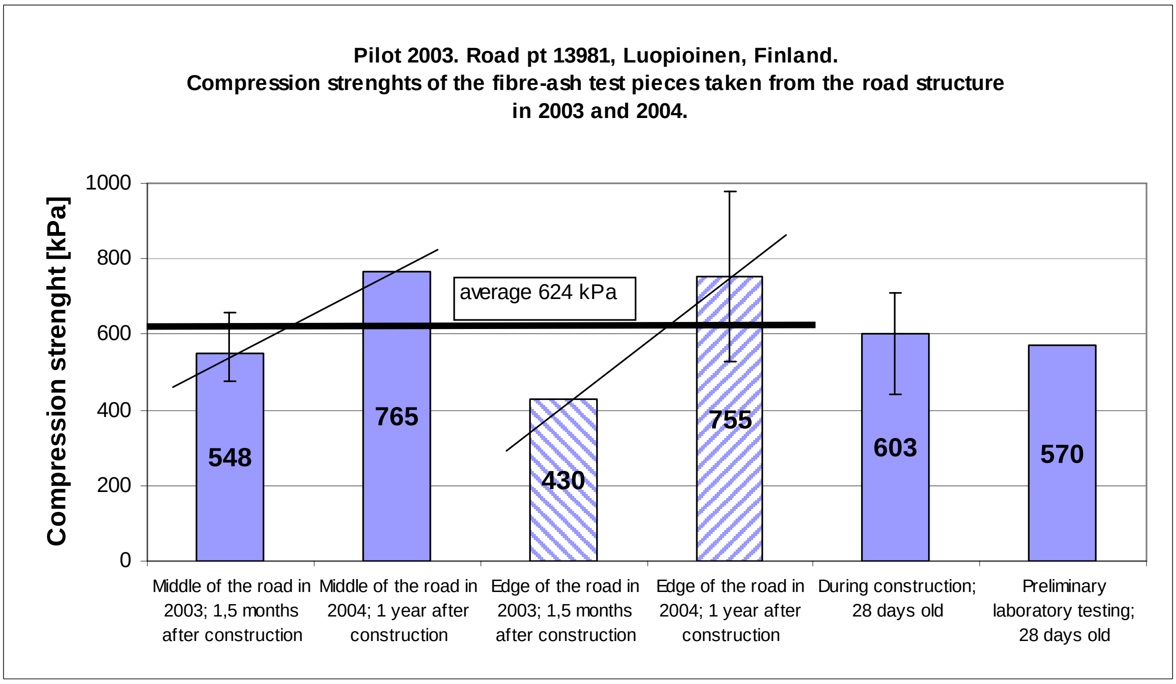


Figure 8. Pilot 2003. Strength development in structure samples taken from the road in 2003 and 2004.

The strength values fulfil the expectations and the strength development has continued in the samples taken from the pilot road. Structures are in good condition (firm, not mixed with covering course) and seem to work according to expectations and plans.

The insulation of fibre-ash affects the frost penetration under the fibre-ash structures. This phenomenon was inspected by placing thermo-measuring elements under the fibre ash and reference (non-renovated) structures and taking daily temperature measurements via GSM link. Thermo-measuring elements were placed also above and under the fibre clay ground-water protection structure.

According to the temperature measurements done in fibre ash section and in reference section, it seems that fibre ash structure has both reduced frost penetration and delayed the melting of frost. Temperature curves are shown in Figures 9, 10, and 11.

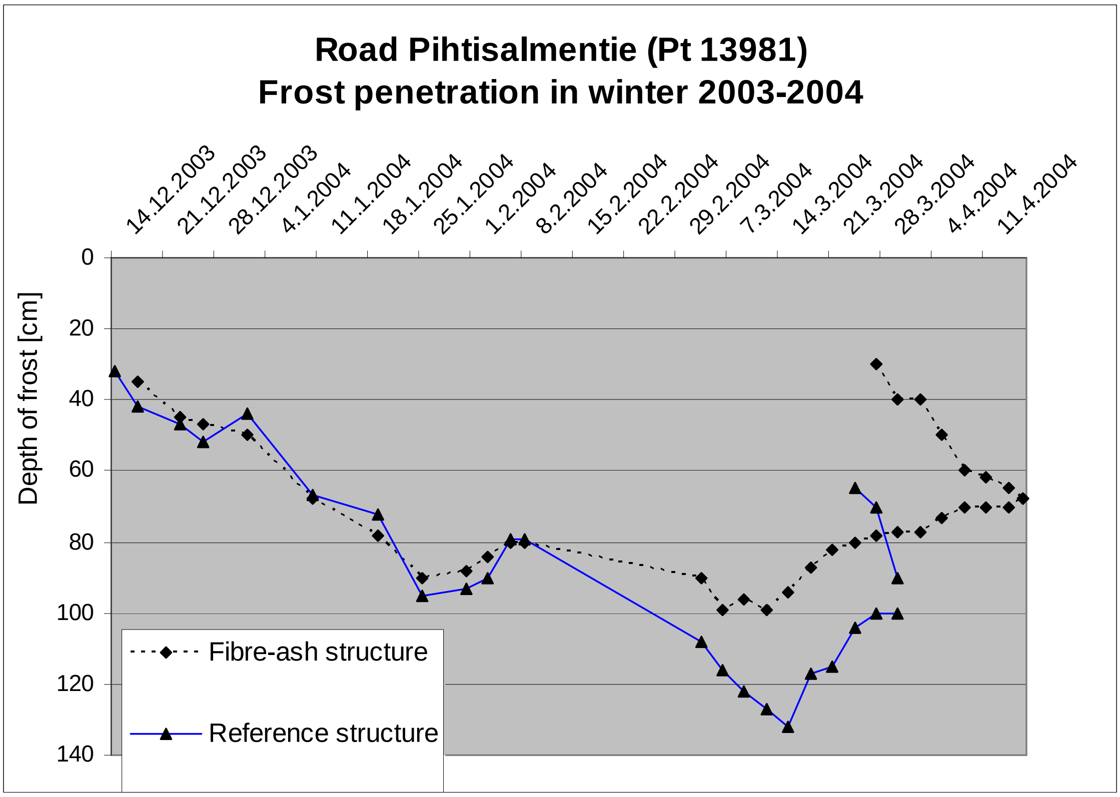


Figure 9. Pilot 2003. Frost penetration in road Pt 13981 in winter 2003-2004. During few weeks of spring there are two frost penetration depths, because the melting of frost starts also from the top after snow has melted.

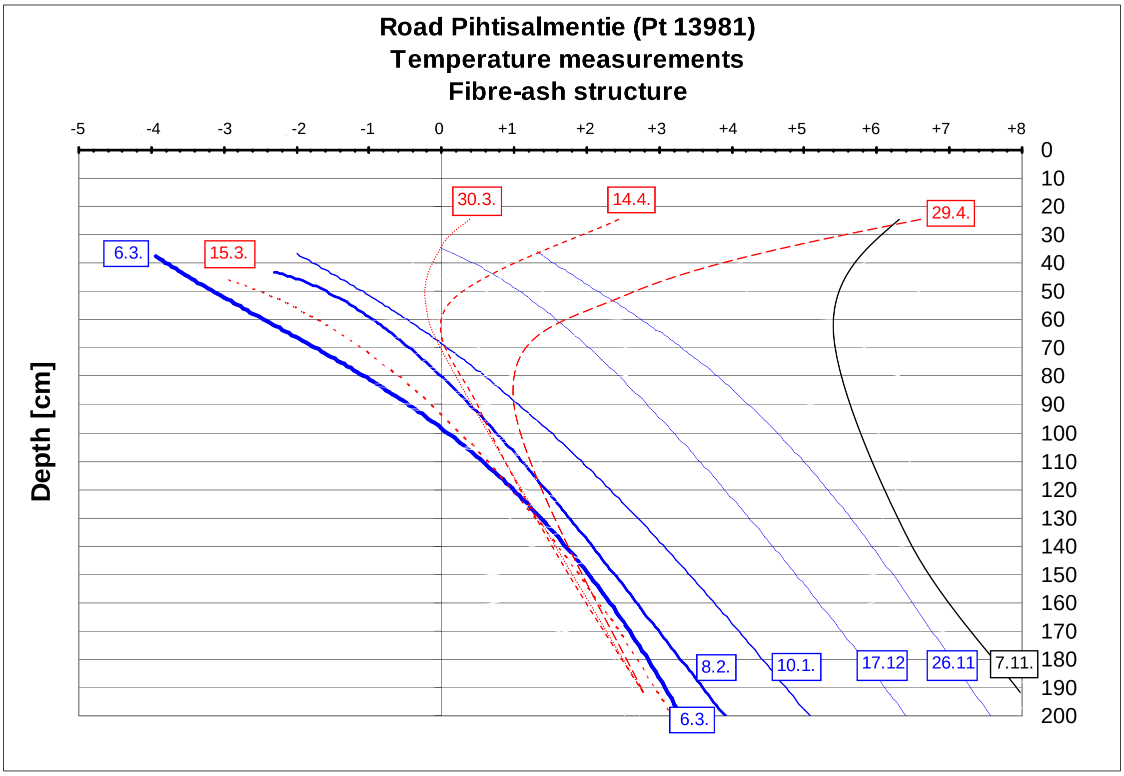


Figure 10. Pilot 2003. Temperature measurement curves at the fibre ash structure of the pilot road.

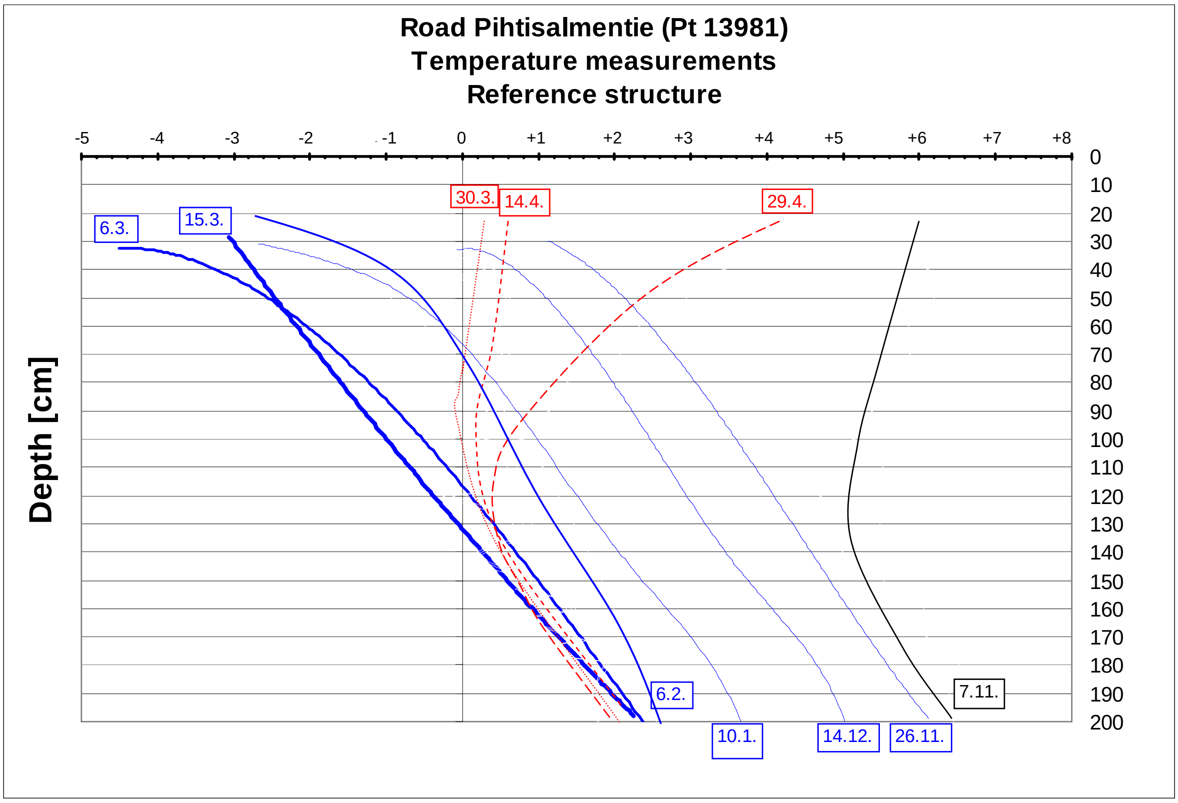


Figure 11. Pilot 2003. Temperature measurement curves at the reference structure of the pilot road.

4.3. Groundwater protection structure

4.3.1 Structures

The groundwater protection structure runs along the edge of the local road Pt 13981(Pihtisalmentie) for about 30 meters with a width of 5 meters. It covers the ditch on both sides. The structure is about 0.5 meters thick and made of fibre clay.

4.3.2 Follow-up studies

Fibre clay has been used as covering material for closing dumping sites. With a careful compaction the water permeability (k-value) of a fibre clay layer could be even lower than 10^{-10} m/s. In this pilot project the measured k-values were too high, about 10^{-7} m/s, which was probably due to feeble and too light compaction work. Also the top soil layer was too thin and, thus, too light to generate any longer term loading embankment for the fibre clay layer. The permeability was determined with help of a infiltrometer (Figure 12).

Thermo-measuring elements were placed above and under the fibre clay groundwater protection structure. Daily temperature measurements were taken via GSM link. As seen in Figure (13) the insulation of fibre clay and snow cover prevented the subsoil from freezing.

Figure 12. Pilot 2003. Infiltrometer measurement done in the fibre clay groundwater structure.

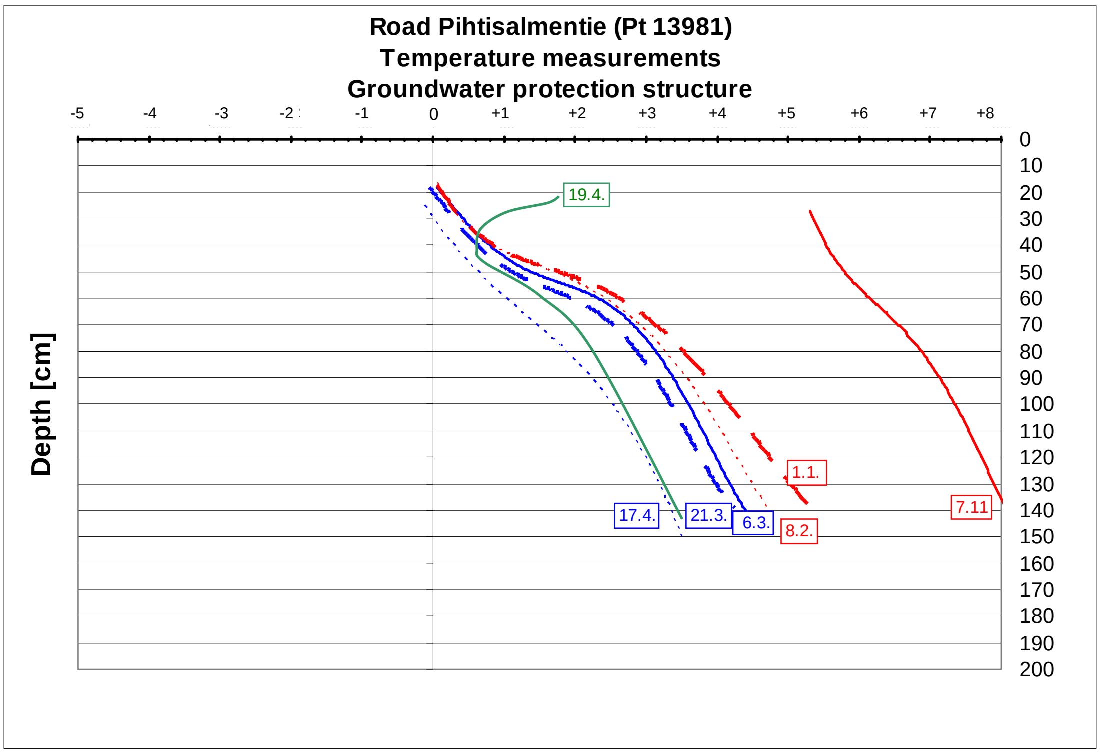


Figure 13. Pilot 2003. Temperature measurement curves at the fibre clay groundwater protection structure.

4.4. Light Traffic Lanes

4.4.1 Structures

The third pilot site was a new, totally 4 kilometres long light traffic lane system on the side of the main road Kt 322. The light traffic lane's system consists of three structures: 1) a light-weight floating structure on a soft soil (running close to the lake Kukkia), 2) a structure on an firm embankment (running partly near the lake Kukkia and partly close to the village), and 3) an one metre wide safety lane on the sides of Kt 322.

Construction materials for the light traffic lanes were fibre ash and geotextiles.

Figure 14. Pilot 2003. Safety lane in connection to the main road Kt 322, during construction in 2003.

4.4.2 Follow-up studies

One year after the construction the light traffic lane running close to the lake Kukkia was in good condition and there were no visible cracks or holes. The lane nearby the village suffered from some long cracks in the spring time because of the occasionally too thin fibre-ash layers. In one point the layer thickness was even only 100 mm, though the target was 200-300 mm. The cracks closed during the summer time. The fibre ash layer itself was firm and homogeneous.

The bearing capacity was low in both sections (about 50 MPa), but that was like expected. The fibre clay works as an insulating, separating, and elastic layer and therefore the high bearing capacity is not necessary for a satisfactory result. Strengths of the samples taken from the road were lower than the strengths measured in preliminary laboratory testing (tests before construction), but the strength development has been satisfactory.

Safety lanes were monitored already about one and a half months after the construction in the autumn 2003. The fibre ash structure was softer than expected. The structure was harder close to the driveway than closer to the roadside or in the middle of the structure which is caused by problems in compaction. Strengths in samples taken from the road were noticeable lower than the strengths measured in the preliminary laboratory testing. Also the bearing capacity was low (about 90 MPa).

In 2004, only the visual checking was done to the safety lanes. There were no signs of damages. Despite the structural problems after construction the final results have been satisfactory and structures are believed to perform well.

The surface of the safety lanes has been paved; otherwise there could be problems with surface erosion or weak road sides. The wider road might tempt car drivers to cut in road curves and vibrating (serrated) lines were painted to prevent that happening. Some erosion occurred in the slopes one year after the construction and therefore it is recommended to cover slopes with grass or other plants/material immediately after construction.

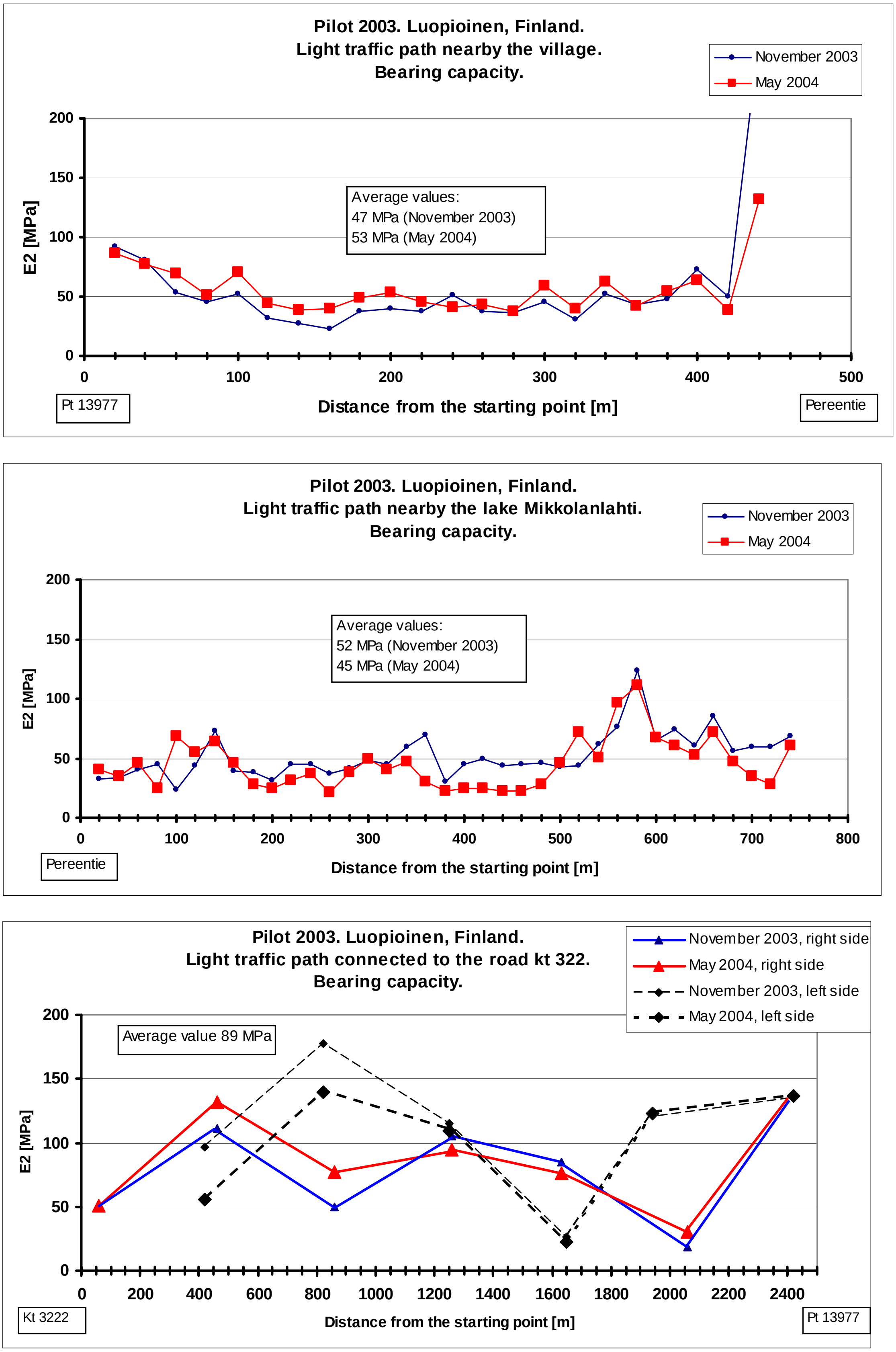


Figure 15. Pilot 2003. Bearing capacities of the light traffic lanes in 2003 and 2004. Above and middle the results of the separate light traffic lanes and below the results of the safety lanes.

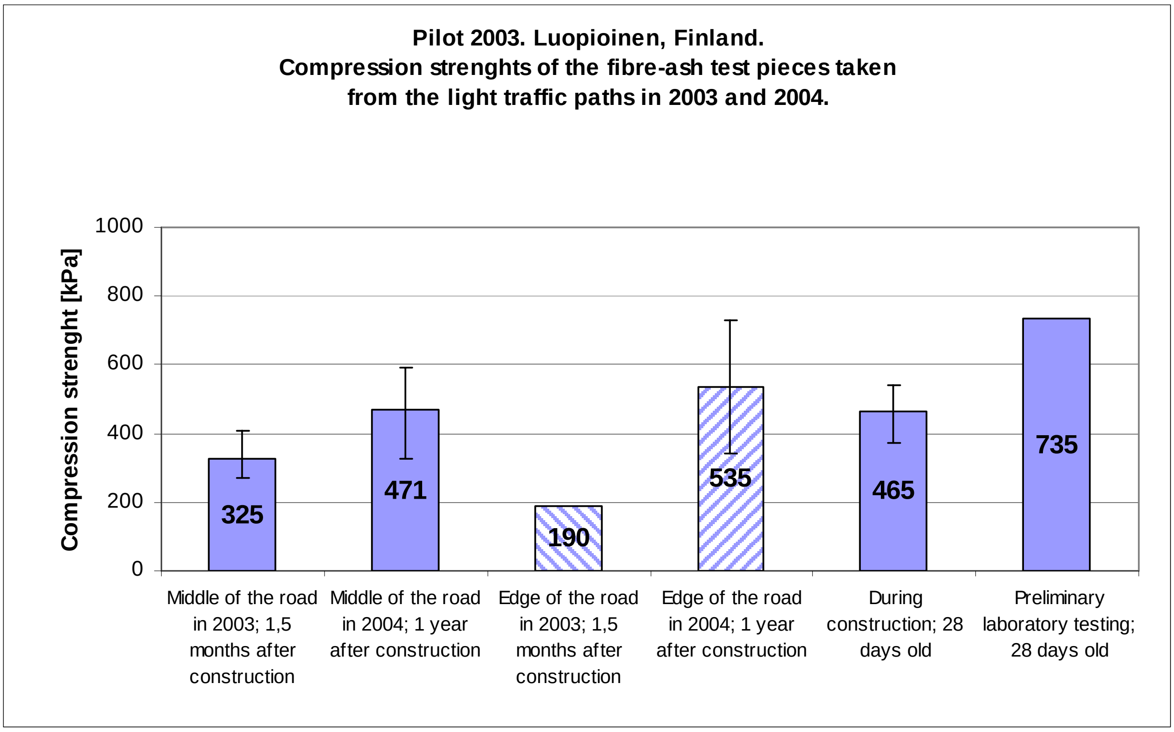


Figure 16. Pilot 2003. Strength development in structure samples taken from the light traffic lanes running nearby the Kukkia Lake and the village in 2003 and 2004.

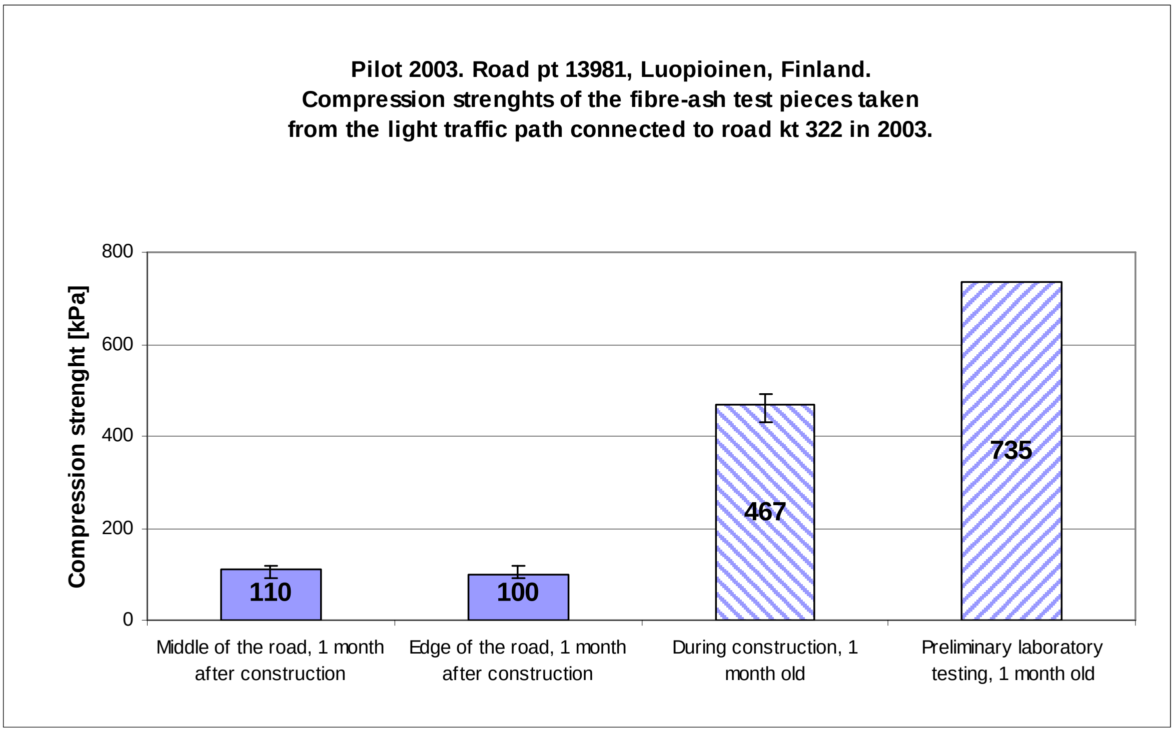


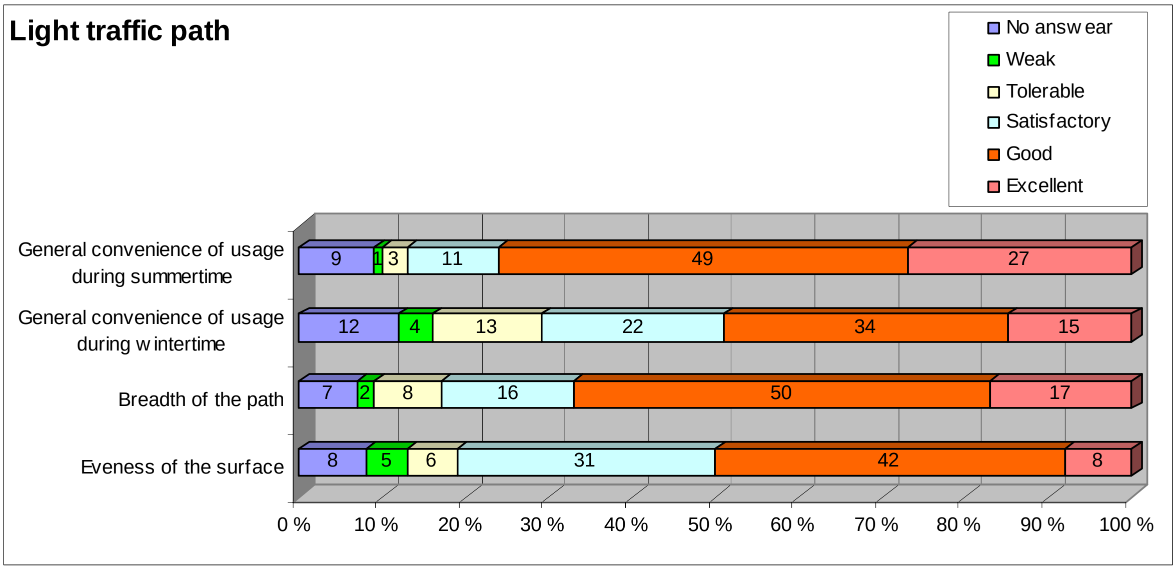
Figure 17. Pilot 2003. Strength development in structure samples taken from the safety lane connected to Kt 322 in 2003 and 2004.

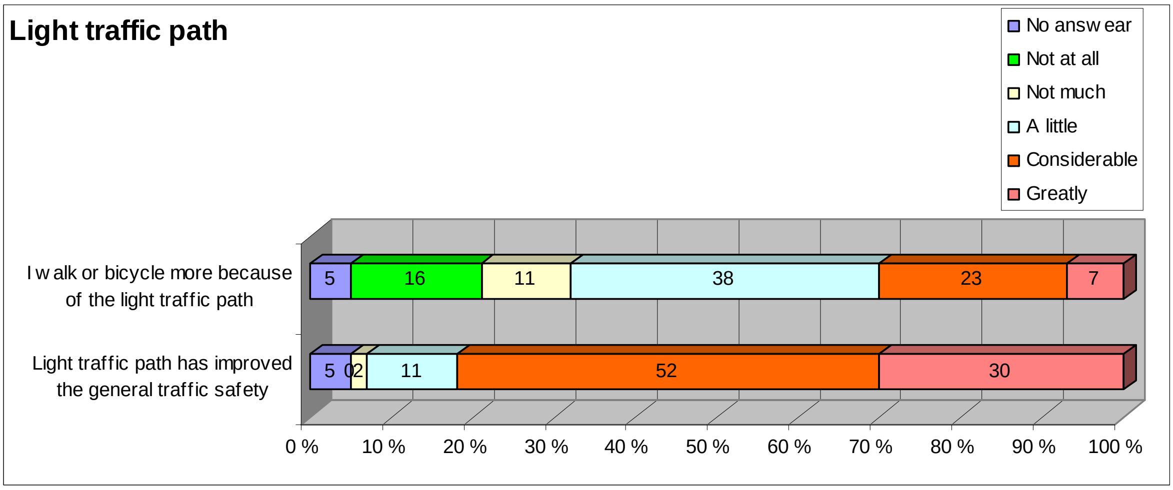
4.5. Survey of the users' opinions

The project conducted a local opinion poll about the new types of light-traffic lanes of the Pilot 2003. A questionnaire was send to the local inhabitants and the answering percentage was 20 %.

Like expected, the light-traffic lanes are considered to give additional safety and more convenient walking and cycling possibilities for the local inhabitants. Also the safety lane is an improvement though considered too narrow (a wider structure was impossible to construct). The main criticism was on the safety lane. The lane was unpaved until the summer 2004 and this unpaved lane was found too soft and not usable during the wintertime. Also the maintenance of the safety lane during winter was neglected which caused a lot of negative opinions. The improvement was taking place during 2004: In the summer the safety lane was paved, and the serrated lines were painted.

Figure 18. Pilot 2003. Light traffic lane passing by the village in spring 2004.





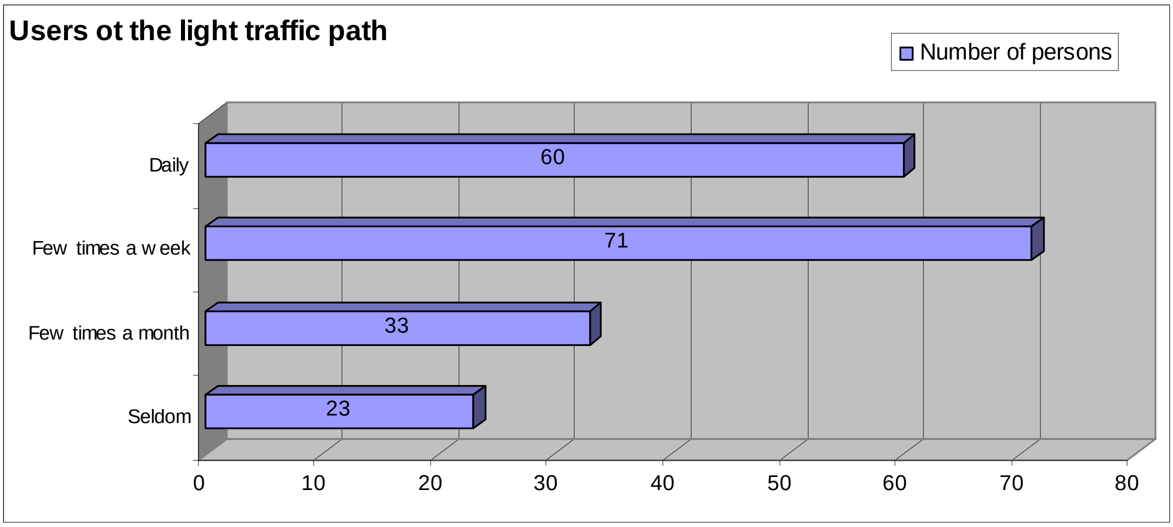
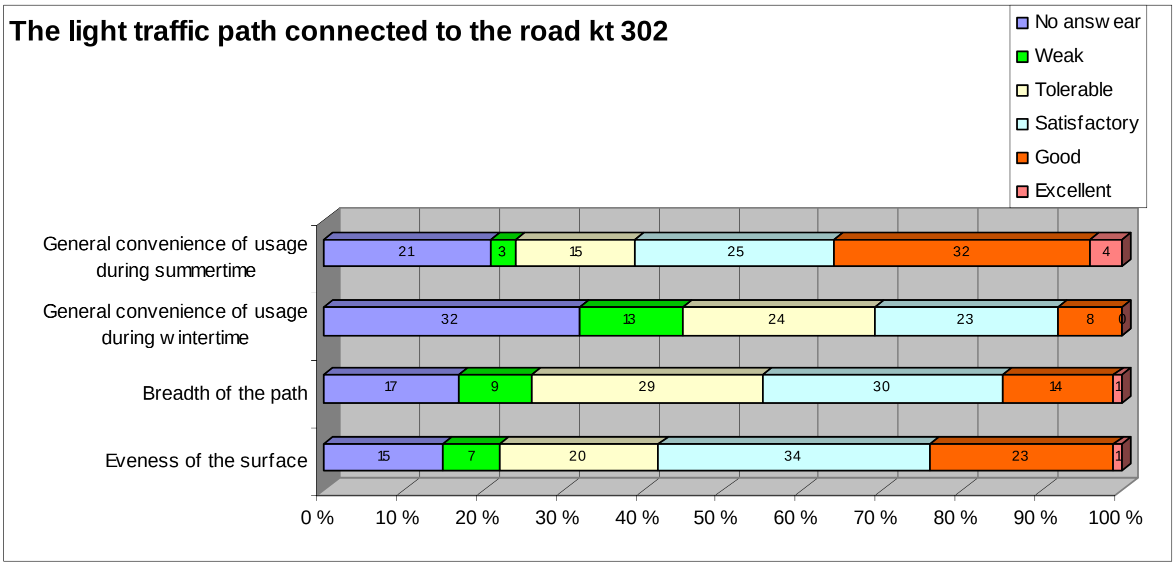
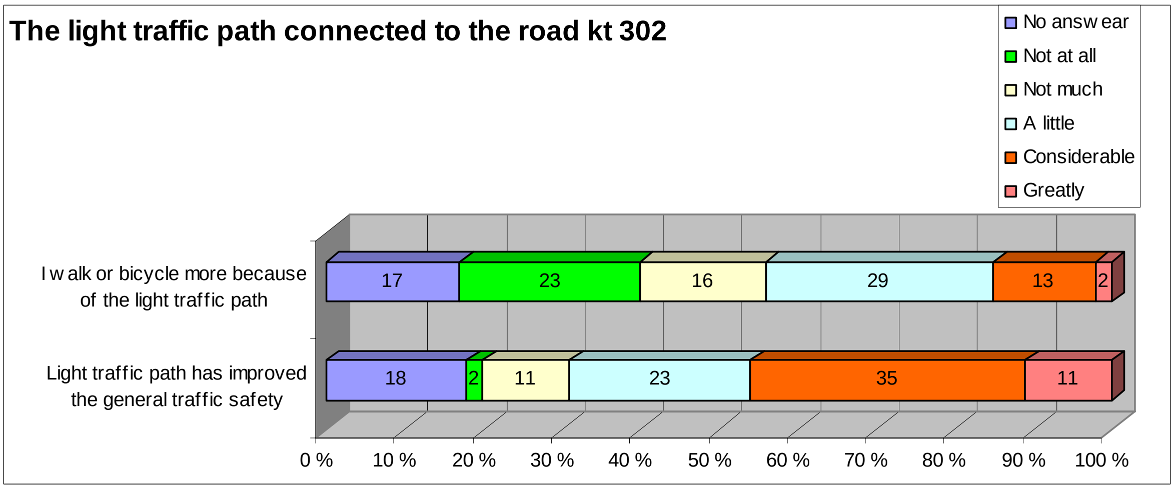


Figure 19. Pilot 2003. Survey of the light traffic lanes, users' opinions about the light traffic lanes running close to the lake and the village.





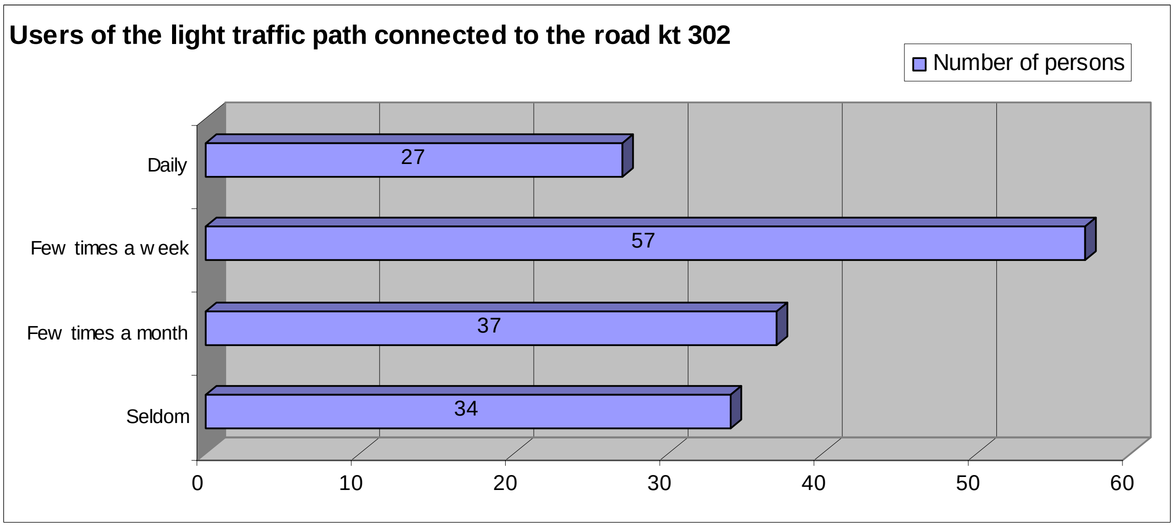


Figure 20. Pilot 2003. Survey of the light traffic lanes, users' opinions about the safety lane connected to the main road.

5. Environmental studies

5.1. Pilot 2002

Before the construction started water samples were collected from neighbourhood wells and from ditches which run from the site towards Lake Kukkia and towards Lake Kyynärö. Soil samples were also collected close to the road. Samples were analysed in laboratory to determine the heavy metal contents with ICP-MS. Also pH and electric conductivity were analysed. These results are the reference results to the results of the follow-up samples that have been collected every autumn but only for three years after the pilot construction work. The results are given in table (4).

By looking at soil samples taken in 2004 it is noticed that the total content of As (arsenic), Cr (chromium), Cu (copper) and Zn (zinc) are in most samples higher than the Finnish target values for clean soil which is typical variation in Finland. Concentration values of Al (aluminium) and Mn (manganese) varies also in different years which is typical in Finnish soil. Especially in the reference structure and in the stabilised section A (PL 11675) the concentration of Mn is higher than in earlier samples.

Total contents of the analysed substances have not increased in the water samples taken in 2004. The concentrations in wells are below the maximal chemical quality standard values and recommendations given in the decree of Social and Health Ministry (STM 461/2000). The only exception can be noted in the a little increased concentration of Mn in the Well nr 10. Drainage ditches have high Al content values (due to clayey conditions), but the other results show “clean”. (Table 5, parts 1 - 3).

5.2. Pilot 2003

Before the construction the water and soil samples were collected for the reference purposes. Water samples have been taken from wells and drainage ditches close to the pilot sections. Soil samples have been collected close to the construction site about one to two meters from the roadside at the depth of soil layers below the by-product course. Corresponding samples have been taken in August-September 2004, one year after construction. In order to make any conclusions the environmental follow-up should be made for three years, at least. Therefore, the follow-up results may not yet be considered as final.

Samples are analysed to determine the heavy metal contents with ICP-MS. Also TOC (because of fibre sludge), pH, and electric conductivity are analysed. The results of the follow-up samples can be compared with the reference results. The results are found in tables (6) and (7).

Results of the soil samples show that the level of the total content has not changed due to the construction. All the results are within the natural variation. Some samples, like M2 and

M3, have higher concentrations of Cu, Ni (nickel), and Zn, but the results are still under the limit value for the polluted soil.

The total content values of water samples are about the same in the years 2003 and 2004. The concentrations of Mn and Al have increased, but are still within natural variation limits. Results are below maximal chemical quality standard values and recommendations given in STM 461/2000. Exceptions are the higher concentrations of Al and Mn which are mainly caused by the mixing of clayey subsoil to the well water in the rainy summer of 2004. The concentration of Ni has increased in Well 5 and the result is now over the maximal chemical quality standard value. That is explained by the local natural variation or by the leaching of Ni from the water pipes and other water supply fittings.

Table 4: Environmental follow-up results of soil samples from Pilot 2002

PILOT 2002				pH	EC	As	B	Ba	Cd	Cr	Cu	Mo	Ni	Sb	Se	Zn	Al	Mn
					mS/m 25°C	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Drafted guidelines 1997/ Sorvari 2000**			Target value, clean soil	-	-	4	5	600	0,15	37	18	5	19	5	1	23	-	-
			Limit value for the pollution	-	-	60	50	600	10	500	400	200	300	40	10	700	-	-
Soil PL 3600	Stab. A	PL2850-4350	REF 2002	5,2	2,4	**12,10**	<1	64,7	0,05	**40,5**	**28,1**	2,56	11,3	<0.02	0,81	**36,2**	9880	151
			2003	5,1	4,6	**9,41**	<1	26,2	0,06	**41,1**	**25,0**	1,08	**20,3**	<0.02	0,60	**37,1**	14300	105
			2004	5,2	1,7	**9,27**	1,20	36,4	0,11	**42,2**	**21,0**	1,30	15,5	0,02	0,64	**38,0**	17100	137
Soil PL 4600	Ref.	PL4350-5800	REF 2002	5,2	2,7	**9,61**	<1	70,5	0,05	**42,6**	**29,5**	2,18	11,6	<0.02	0,89	**39,6**	10700	173
			2003	5,5	1,7	**8,30**	<1	43,5	0,05	28,2	**20,4**	1,23	8,97	<0.02	0,72	**29,2**	7840	122
			2004	5,4	1,7	**9,94**	1,60	80,7	0,14	**48,9**	**30,3**	1,85	20,3	0,02	0,59	**60,7**	14300	308
Soil PL 6400	Stab. B	PL5800-7640	REF 2002	5,0	2,4	**5,15**	<1	42,2	0,03	26,1	**18,4**	1,38	7,48	<0.02	0,54	**25,8**	6780	121
			2003	4,9	6,0	**9,60**	1,5	66,2	0,15	**44,6**	**47,0**	1,67	18,1	<0.02	0,82	**103,0**	12800	272
			2004	5,6	0,9	**7,75**	1,20	42,6	0,07	20,5	**21,5**	1,37	8,73	<0.02	<0.5	**23,8**	7420	101
Soil PL 8230	Stab. A	PL7640-8690	REF 2002	4,7	3,1	**7,70**	<1	42,6	0,09	27,4	**21,1**	1,01	12,4	<0.02	<0.5	**34,1**	10100	129
			2003	5,2	1,8	**7,19**	<1	47,9	0,07	31,5	**23,4**	1,01	17,8	<0.02	0,68	**44,1**	12100	153
			2004	5,1	2,5	**8,34**	1,38	58,1	0,04	35,6	**19,7**	1,37	14,2	0,02	<0.5	**38,6**	13900	162
Soil PL 9010	Stab. B	PL8690-9150	REF 2002	5,0	5,7	**12,20**	<1	76,5	0,11	**46,0**	**36,8**	2,45	13,1	<0.02	**1,07**	**47,7**	11700	179
			2003	5,1	**26,3**	**8,11**	2,10	83,6	**0,69**	30,5	**29,0**	2,09	23,6	0,07	**2,04**	**57,4**	8540	112
			2004	4,9	2,3	**10,1**	1,19	72,5	0,06	**43,0**	**32,0**	2,41	14,8	0,02	0,71	**43,7**	11900	183
Soil PL 9885	Stab. E	PL9320-10340	REF 2002	4,6	7,8	**11,00**	<1	68,2	0,05	**41,4**	**32,4**	2,67	10,9	<0.02	0,96	**38,0**	11000	163
			2003	4,9	11	**11,50**	2,10	76,5	0,09	**59,6**	**72,1**	1,48	25,1	<0.02	**1,50**	**76,5**	22200	205
			2004	4,9	1,5	**6,36**	<1	42,2	0,07	33,5	**18,5**	0,59	15,8	<0.02	<0.5	**35,6**	18700	97
Soil PL 11675	Stab. A	PL10340-12180	REF 2002	4,9	9,9	**8,09**	<1	68,4	0,06	31,7	**29,6**	1,21	13,5	<0.02	0,52	**39,5**	11800	157
			2003	5,7	6,7	**6,66**	1,75	41,9	0,08	**39,1**	**22,9**	1,23	22,7	<0.02	**1,10**	**49,7**	17900	164
			2004	5,1	1,9	**5,35**	1,72	64,9	**0,17**	34,4	**20,4**	1,03	16,8	0,03	<0.5	**147,0**	14400	827

** Jaana Sorvari: Ympäristökriteerit mineraalisten teollisuusjätteiden käytölle maarakentamisessa. Suomen ympäristö 421/2000. Table 19 (p. 94): median content on soil having 4,9 % claye and 1,2 % organic substances.

Table 5(1): Environmental follow-up results of water samples of Pilot 2002

Criteria STM 461/2000 /FIN			Al	As	B	Ba	Cd	Cr	Cu	Mn	Mo	Ni	Sb	Se	Zn	pH	EC
			µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l		mS/m 25°C
Chemical quality standards (max)				10	1000		5	50	2000			20	5	10			
Recommendations (max target values)			200							50						6,5-9,5	250
Other (older criteria) of STM 1994						700					70				3000		
WELLS	nr 1	2002REF	<1	0,34	3,23	4,93	<0.02	<0.2	33,3	**59,7**	0,22	2,57	<0.02	<0.5	242	7,1	9,0
		2003	<1	0,20	2,52	3,85	<0.02	<0.2	36,4	37,7	0,27	1,46	<0.02	<0.5	157	6,8	8,3
		2004	1	0,18	4,65	4,53	<0.02	<0.2	44,8	**53,5**	0,22	2,42	<0.02	<0.5	201	6,5	8,5
	nr 2	2002REF	2	0,08	34	6,84	<0.02	<0.2	19,9	18,8	1,01	0,77	0,04	<0.5	99	7	26
		2003	DRY, NO SAMPLES														
		2004	5	0,12	52	8,18	0,02	<0.2	63,9	13,8	0,63	1,23	0,10	<0.5	147	6,8	27
	nr 3	2002REF	62	0,13	27,9	15,5	0,07	0,3	96,5	4,46	0,07	1,71	0,06	<0.5	113	6,5	9,6
		2003	DRY, NO SAMPLES														
		2004	187	0,18	36,1	19,2	0,07	0,5	12,9	7,78	0,06	2,86	0,05	<0.5	59	5,8	9,6
	nr 4	2002REF	30	0,09	7,60	11,3	0,07	<0.2	395	22,1	0,07	1,63	0,02	<0.5	79	6,6	10
		2003	4	0,07	7,71	12,3	0,06	<0.2	225	31,5	0,41	1,47	0,02	<0.5	86	6,6	13
		2004	105	0,16	8,86	12,3	0,07	0,3	16	18,4	0,17	2,88	0,03	<0.5	236	6,4	11
	nr 5	2002REF	36	0,23	20,1	9,1	<0.02	0,29	3,81	5,7	0,24	0,89	0,05	<0.5	5,0	6,8	10
		2003	DRY, NO SAMPLES														
		2004	15	0,42	27,7	6,2	0,03	0,44	9,42	6,1	0,20	5,74	0,04	<0.5	16,6	7,3	17
	nr 6	2002REF	22	0,38	31,4	17,5	0,02	0,31	19,7	2,7	0,20	0,94	0,08	<0.5	61,5	6,8	17
		2003	DRY, NO SAMPLES														
		2004	46	0,30	36,0	14,6	0,05	0,33	5,5	1,4	0,17	2,62	0,06	<0.5	5,2	7,1	16
	nr 7	2002REF	11	0,09	8,8	6,4	0,08	<0.2	123	18,0	0,15	1,40	0,05	<0.5	290	6,5	10
		2003	1	0,07	6,7	6,7	0,09	<0.2	62	**53,8**	0,12	1,41	0,20	<0.5	611	6,7	10
		2004	60	0,15	14,8	11,4	0,17	0,35	115	28,8	0,23	2,26	0,18	<0.5	909	6,7	13

Table 5(2): Environmental follow-up results of water samples of Pilot 2002

Criteria STM 461/2000 /FIN			Al	As	B	Ba	Cd	Cr	Cu	Mn	Mo	Ni	Sb	Se	Zn	pH	EC
			µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l		mS/m 25°C
Chemical quality standards (max)				10	1000		5	50	2000			20	5	10			
Recommendations (max target values)			200							50						6,5-9,5	250
Other (older criteria) of STM 1994						700					70				3000		
	nr 8	2002REF	6	0,13	5,6	8,2	0,03	<0.2	51	0,9	0,35	0,78	0,03	<0.5	68	6,5	10
		2003	4	0,12	5,1	8,2	0,03	<0.2	81	1,2	0,40	1,09	0,03	<0.5	87	6,7	10
		2004	15	0,13	7,2	8,8	0,04	<0.2	94	2,0	0,22	1,06	0,03	<0.5	97	6,6	12
	nr 10	2002REF	14	0,27	10,2	10,2	<0.02	<0.2	70	**84,4**	0,31	2,59	0,02	<0.5	25	6,4	12
		2003	1	0,18	10,7	11,0	<0.02	<0.2	35	**65,4**	0,34	3,85	0,02	<0.5	18	6,9	14
		2004	126	0,62	7,9	13,6	0,05	0,41	25	**141,0**	0,14	3,91	0,05	<0.5	24	6,3	11
	nr 15	2002REF	<1	**33,2**	84,7	0,49	<0.02	<0.2	0,21	4,8	2,99	0,35	0,66	<0.5	5	8,1	37,1
		2003	DRY, NO SAMPLES														
		2004	DRY, NO SAMPLES														
	nr 16	2002REF	<1	0,1	13,2	6,9	0,19	<0.2	127	21,0	0,35	15,1	0,02	0,9	65	6,3	16
		2003	<1	0,1	12,8	8,9	0,20	<0.2	109	24,4	0,27	18,4	0,02	0,8	86	6,5	17
		2004	<1	0,1	13,0	5,8	0,15	<0.2	126	12,0	0,50	7,3	0,03	0,8	111	6,6	15
	nr 19	2002REF	3	0,3	7,3	11,2	<0.02	0,30	3	2,7	0,13	0,3	0,05	<0.5	12	6,8	17
		2003	DRY, NO SAMPLES														
		2004	DRY, NO SAMPLES														
	nr 20	2002REF	17	0,4	8,0	5,7	0,05	0,27	5	0,7	0,16	1,0	0,04	<0.5	9	6,6	14
		2003	DRY, NO SAMPLES														
		2004	33	6,0	16,1	5,5	0,05	1,20	32	0,9	0,14	1,3	0,05	<0.5	20	6,4	13

Table 5(3): Environmental follow-up results of water samples of Pilot 2002 (Ditches)

Criteria STM 461/2000 /FIN			Al	As	B	Ba	Cd	Cr	Cu	Mn	Mo	Ni	Sb	Se	Zn	pH	EC
			µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l		mS/m 25°C
Chemical quality standards (max)				10	1000		5	50	2000			20	5	10			
Recommendations (max target values)			200							50						6,5-9,5	250
Other (older criteria) of STM 1994						700					70				3000		
DITCHES	Ditch nr 4830	2002REF	173	0,7	5,3	8,7	0,02	0,51	1	**66,1**	0,15	2,9	0,04	<0.5	5	6,3	6
		2003	DRY, NO SAMPLES														
		2004	**763**	0,7	7,5	11,6	0,10	1,20	5	**73,3**	0,15	6,3	0,06	<0.5	13	5,9	7
	Ditch nr 5060	2002REF	54	0,5	5,3	5,7	0,02	0,24	1	31,3	0,09	2,9	<0.02	<0.5	3	6,8	15
		2003	DRY, NO SAMPLES														
		2004	**424**	0,8	6,9	9,6	0,07	0,84	3	23,4	0,17	9,4	0,03	<0.5	12	6,4	10
	Ditch 8690	2002REF	**547**	3,2	3,6	8,0	0,10	0,85	2	38,9	0,16	3,3	0,04	<0.5	18	5	6
		2003	DRY, NO SAMPLES														
		2004	**469**	1,9	8,9	12,3	0,18	1,24	6	36,1	0,24	4,7	0,07	<0.5	16	4,4	6

Table 6: Environmental follow-up results of soil samples of Pilot 2003

PILOT 2003				pH	EC	TOC	As	B	Ba	Cd	Cr	Cu	Mo	Ni	Sb	Se	Al	Mn	Zn
					mS/m 25°C	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Target value, clean soil				-	-	-	*13*	*5*	*600*	*0,3*	*80*	*32*	*5*	*40*	*5*	*1*	-	-	*90*
Limit value for the pollution				-	-	-	*60*	*50*	*600*	*10*	*500*	*400*	*200*	*300*	*40*	*10*	-	-	*700*
Road Pt 13981	PL 420, right side, slope of ditch	M1	R	5,7	2,4	510	4,38	2,70	185	0,08	73,0	**32,5**	0,93	35,7	0,02	<0.5	26100	834	**114**
			04	5,4	1,2	170	3,65	2,11	*207*	*0,22*	72,4	19,4	1,07	***43,5***	*0,03*	<0.5	25700	*2020*	***179***
Road Pt 13981	PL 2320, right side, slope of ditch	M2	R	6,2	4,5	330	4,14	1,80	151	0,09	61,9	21,3	0,92	34,1	0,02	0,81	24600	925	**117**
			04	6,0	2,2	110	*5,18*	*2,03*	*203*	*0,15*	*79,3*	***32,9***	*1,00*	***47,4***	0,02	0,53	*28400*	*1270*	***184***
Light traffic lane	to the lake about 1,5 m	M3	R	5,6	17	6600	3,89	2,53	81,3	**1,03**	17,3	**108**	0,89	**96,8**	0,07	**1,69**	12400	206	**103**
Lake Kukkia			04	*5,9*	4	390	*5,10*	*2,79*	*153*	***1,23***	*56,9*	**39**	*1,19*	41,6	0,02	1,42	*19100*	*415*	**95**
Light traffic lane	to the lake about 1,5 m	M4	R	4,1	27	2400	2,01	1,27	27,0	**1,99**	4,96	14,1	0,61	**110**	0,18	0,77	9990	34,3	89,3
Lake Kukkia			04	*6,0*	3	98	*6,61*	*1,64*	*58,8*	0,07	*19,7*	*19,7*	*1,18*	8,58	0,02	<0.5	6690	*170*	30,3
Light traffic lane	between light traffic lane and road Mt 322	M5	R	5,3	23	2600	2,43	2,44	101	**0,93**	20,1	22,1	2,87	22,1	0,07	**2,13**	8580	1080	51,6
village side	lane running close to the office		04	*5,8*	3	210	*4,23*	2,33	*149*	0,16	*58,8*	*28,5*	0,89	*29,6*	0,02	<0.5	*19100*	689	***107***
Light traffic lane	between light traffic lane and road Mt 322	M6	R	5,9	5,6	700	5,65	1,53	191	0,18	66,2	**35,1**	0,78	**41,5**	0,03	0,69	22700	471	**101**
village side	close to the other end of the lane		04	5,5	4,5	300	4,86	*2,17*	147	*0,66*	64,7	**32,0**	*0,95*	38,1	*0,69*	*0,92*	19100	518	**100**
Safety lane	On the side of the Lake Kukkia	M7	R	5,9	2,4	250	5,82	1,42	113	0,06	51,9	27,5	0,95	26,2	0,02	<0.5	16600	498	72,8
			04	5,6	2,2	190	5,23	*1,52*	*132*	*0,09*	*76,2*	*29,2*	0,94	*29,0*	<0.02	<0.5	*18400*	455	*88,5*
Safety lane	On the side of the Lake Kukkia / Haltianselkä	M8	R	5,9	2,3	1400	4,69	1,87	91,5	0,11	44,5	24,6	0,86	18,8	0,02	0,54	15200	316	59,6
			04	4,9	2,0	320	4,09	1,53	83,5	0,06	59,6	28,3	0,79	25,1	0,02	<0.5	12700	172	*62,7*

R = Reference samples taken in 2003 before construction
04= Samples taken in 2004

Table 7: Environmental follow-up results of water samples of Pilot 2003

		TOC	Al	As	B	Ba	Cd	Cr	Cu	Mn	Mo	Ni	Sb	Se	Zn	pH	EC
		mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l		mS/m 25°C
STM 461/2000. Chemical quality standards(max)				*10*	*1000*		*5*	*50*	*2000*			*20*	*5*	*10*			
STM 461/2000. Recommendations (max target values)			*200*							*50*						*6,5-9,5*	*250*
Others/ STM 1994						*700*					*70*				*3000*		
Well nr 4 close to Safety lane connected to Mt 322, Haltianselkä	R	2,7	140	0,6	8,4	21,7	0,0	0,4	50,4	12,4	0,5	1,0	0,1	<0.5	408	7,5	28
	04	1,7	4	0,5	*10,0*	*40,0*	0,1	<0.2	30,8	*15,2*	0,4	*2,8*	0,1	<0.5	*554*	7,5	*61*
Well nr 5 close to Safety lane connected to Mt 322	R	5,7	31	1,3	22,8	21,1	0,0	0,5	7,4	14,3	0,3	14,7	0,6	<0.5	16	7,2	35
	04	3,7	*54*	0,3	21,8	*36,2*	*0,2*	0,3	6,9	*33,8*	0,1	***21,9***	0,1	<0.5	*31*	6,4	32
Well nr 8 close to Safety lane connected to Mt 322	R	4,9	**363**	0,8	7,9	19,8	0,1	0,9	10,4	7,6	0,5	3,6	0,1	<0.5	43	6,7	12
	04	4,4	***772***	*0,9*	*24,2*	*28,2*	0,1	*1,5*	*14,5*	**281,0**	0,4	*5,7*	0,1	<0.5	*74*	6,6	11
Well nr 10 close to the Light traffic lane and Lake Kukkia	R	3,1	106	0,6	6,0	12,3	<0.02	0,3	2,9	2,2	0,4	1,9	0,0	<0.5	5	7,0	14
	04	2,7	46	0,3	*10,3*	*17,6*	0,0	0,2	*3,2*	*4,5*	0,1	*4,7*	0,0	<0.5	*8*	6,5	*18*
Well nr 1, close to the renovated Road Pt 13981; problems to compare the R and O4 values because of change in wells	R	2,3	**605**	0,4	6,6	13,2	0,0	1,0	19,1	5,4	0,4	1,5	0,0	<0.5	33	6,9	12
	04	<1	3	0,2	147	7,41	<0.02	<0.2	1,5	4,8	1,1	0,2	<0.02	<0.5	2	8,2	28
Well nr 2, close to the renovated Road Pt 13981	R	2,5	**217**	0,1	3,6	20,5	0,0	0,4	9,2	18,5	0,2	1,5	0,0	<0.5	6	5,7	2
	04	3,5	***314***	0,1	8,0	19,1	0,0	0,5	*11,0*	*22,1*	0,3	1,5	0,0	<0.5	7	5,9	3,5

R= Reference water samples taken in wells in 2003
04= water samples taken in 2004