LIFE02 ENV/FIN/000329: Kukkia Circlet

REPORT ON TECHNICAL PROGRESS

1.12.2001 – 31.12.2002

ANNEX 1 of the Interim Report

FINNISH ROAD ENTERPRISE

SCC VIATEK LTD

19.3.2003

CONTENTS

1. INTRODUCTION

The objective of the Life-Environment project, Kukkia Circlet, is 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 will focus 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 will be–used are existing and badly damaged gravel roads, groundwater protection structure, and new types of light traffic paths in Luopioinen, representing a typical rural region of Europe.

The project is composed of four separate structures and two pilots. Pilot 2002 involves renovation of a secondary gravel road in Luopioinen by stabilising the existing road courses with help of stabilisers based on industrial by-products.

Pilot 2003 will involve construction of different types of light traffic paths and another renovation system by using mixtures of fibre sludge with fly ash as structural course materials. Pilot 2003 also involves testing of a groundwater protection structure based on a water permeable sealing course of fibre sludge. Also Pilot 2003 will take place in Luopioinen.

This report is mainly dealing with the Pilot 2002, but also the activities which has been carried out for the Pilot 2003 during the period of 1.12.2001 – 31.12.2002.

2. PILOT 2002

2.1. In general

Pilot 2002 will demonstrate that, in comparison with conventional renovation methods, ecologically and economically better renovation results could be obtained by using industrial by-products as binders for the stabilisation of existing gravel road courses. The pilot involves also testing of new types of covering courses on the gravel roads based on the crushed aggregates mixed with filter cake which is being generated during the manufacturing of salts to prevent the gravel roads from dusting.

The site for Pilot 2002 is locating in Luopioinen, the road 3201 between Kuohijoki and Kyynärö. The main problems of this road section (see Annex 1) have been the frost damage and weak bearing capacity caused by the thawing of frost during the spring. The renovation process was being prepared by testing the effect of different binder admixtures in the geotechnical laboratory (SCC Viatek Oy, Luopioinen), by planning in detail 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).

2.2. Structures

Pilot 2002 site starts at Kipparila (see pole 0 in the map of Annex 1). The Pilot consists of reference sections of conventional renovation methods and the new types of stabilised sections, as described in the following table (1) and figures 1 - 5:

Table 1: Sections of Pilot 2002

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.

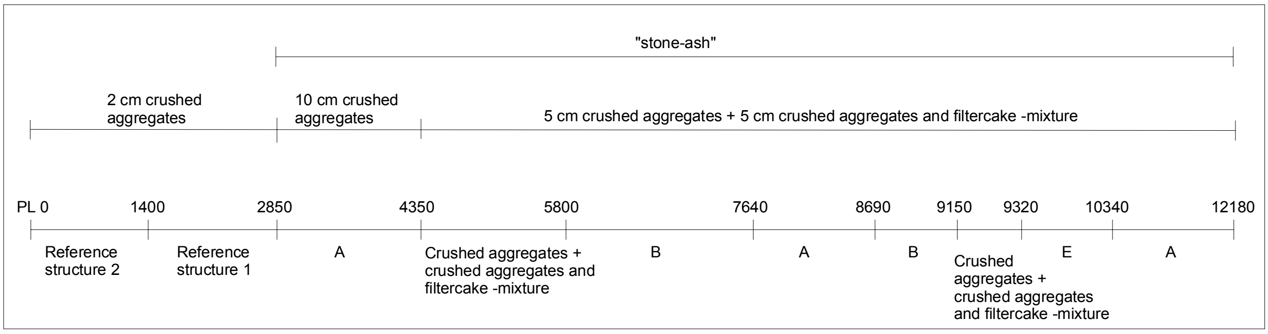

Figure 1. Pilot 2002 Structures of different road sections.

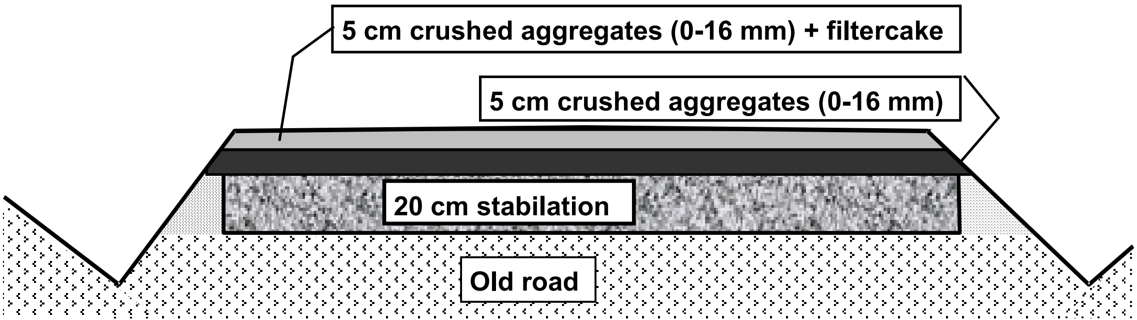

Figure 2. Principle of Stabilisation A-E.

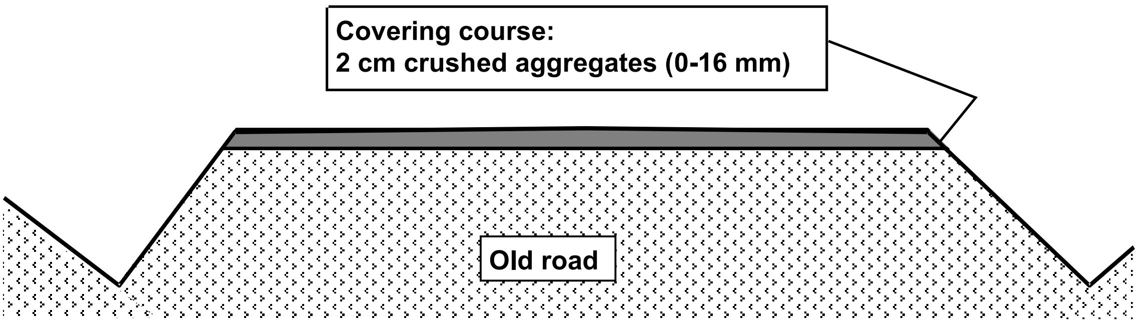

Figure 3. Principle of the reference structure 1.

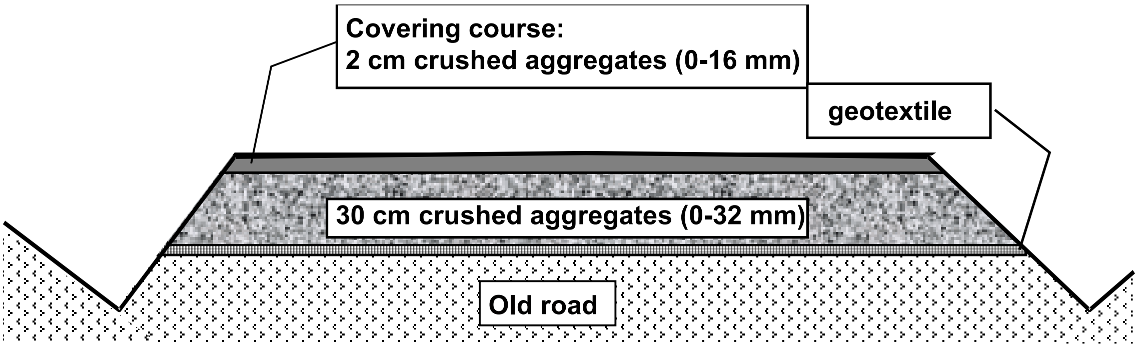

Figure 4. Principle of the reference structure 2, the “pot-hole” sections.

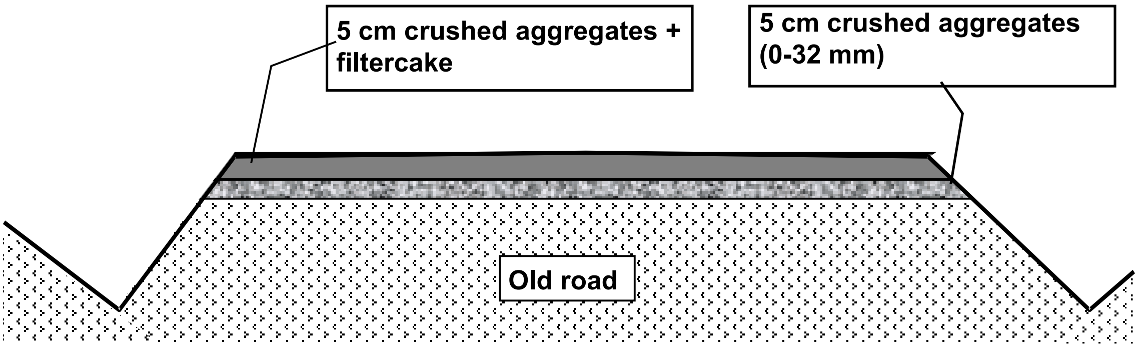

Figure 5. Principle of the “crushed aggregate material mixed with filter cake” –structure.

2.3. Materials

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], 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 according to the plan for material tests. Figure 6 gives the compression strengths of all those admixture recipes that were chosen to be used in the stabilisation: after stabilisation at ambient temperature for 28 days and after a freezing-thawing tests.

[1] Finnstabi is based on a by-product from TiO_2-production

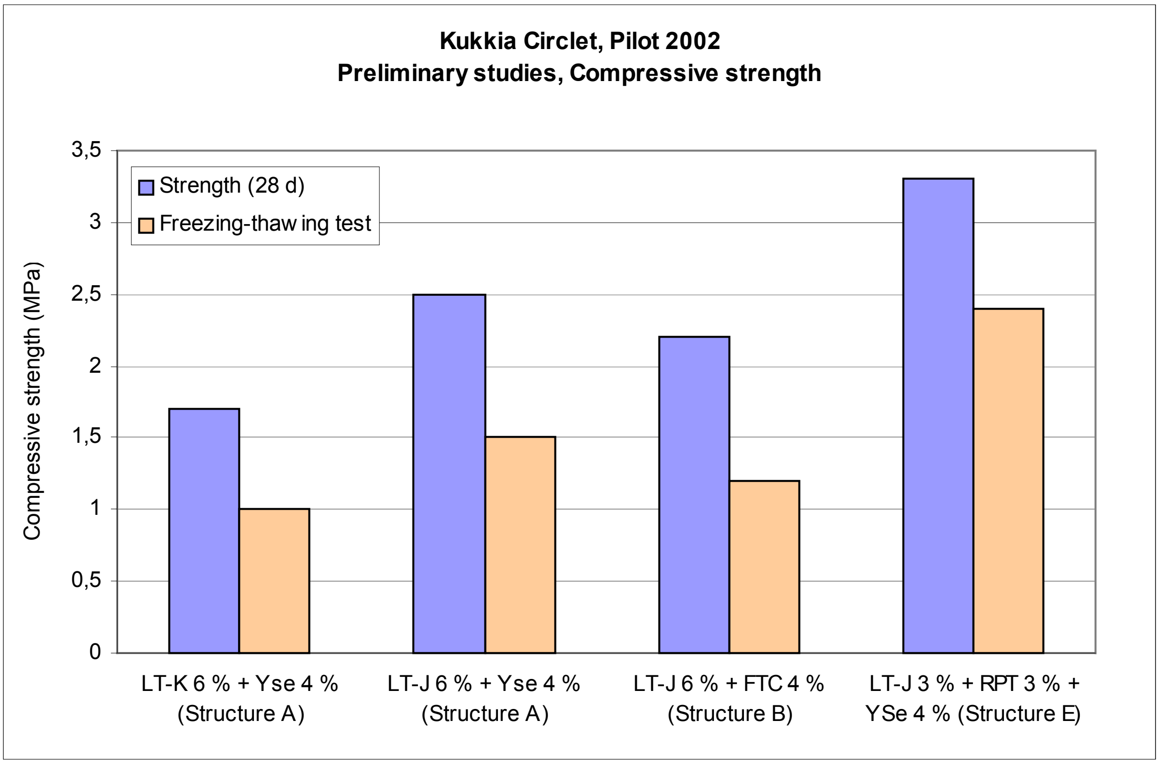

Figure 6. The compression strengths of the crushed material stabilised with different binder admixtures for stabilisation. (LT-K = Kaipola fly ash, LT-J = Jämsänkoski fly ash, Yse = cement, FTC = Finnstabi® mixture of the Nordkalk Ltd, RPT = fly gas desulphurisation residue).

2.4. Construction

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 emerging 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.

The storage and mixing of the material masses took place at a closed disposal site of the municipality of Luopioinen (the site called Rankkimäki). Cement and FTC were supplied dry and in water tight containers to Rankkimäki, and the industrial by-products were supplied 'wet', from the industrial deposits.

The industrial by-products were stored in piles until they were mixed with a new station mixer of the Finnish Road Enterprise, Figure 7. The binder admixture was transported to the construction site after mixing, in adequate batches in an open lorry synchronously with the construction process, Figure 8. It is important that the admixtures are being spread, mixed into the road course and compacted during the same day. Otherwise the reactivity of the admixtures will suffer significantly.

Figure 7. Testing of the new Station Mixer in Luopioinen, in August 2002

Figure 8. Transport of admixtures from the mixing station to the construction site, August 2002, Luopioinen.

The pilot construction started as planned on 19th August 2002. The order of the different sections was as follows: stabilisation A, stabilisation B, stabilisation E and finally the reference structures. The stabilisation process moved forward as follows:

- The surface of the road was watered and certain road sections were harrowed again (see above)
- The binder admixture was spread with an asphalt spreader and mixed evenly into (in average) 200 mm of the old road course with a stabilising milling machine, Figure 9.
- After this, the surface was compacted and levelled with roller machine, Figure 10.
- The covering course (100 mm) was spread on the surface after a few weeks of the smoothing of the traffic.

In order to have the road open for the local traffic, the process moved on at one side of the road at a time. The process of Pilot 2002 was finished with the covering courses at the end of September 2002. The local inhabitants of the municipality were thankful for the renovation process and celebrated it as an “opening of a new road” on 25th September 2002, Figure 11.

Figure 9. Spreading of admixture on the surface of the old road. After this, the milling machine will mix the admixture into the old road course, into a depth of 200 mm, August 2002 in Luopioinen.

Figure 10. Roller machine compacting the stabilised road. August 2002, Luopioinen.

Figure 11. Opening of the “new” road in Luopioinen, on 25th September 2002. The opening celebration was participated by representatives of the municipality administration, the inhabitants, Finnish Road administration and Finnish Road Enterprise.

Some problems occurred during the construction. Because of the warm and dry summer and autumn, the components (cement, FTC, fly ash) and the binder admixtures were mainly too dry and dusty in spite of water addition during the storage, mixing, transports and construction process. Another type of problem was caused by the big stones that broke the cutter plates of the milling machine (see above) because this caused stops of the whole process; it was evident, that the process with relatively heavy equipment is very vulnerable. At least these aspects need further consideration and improving measures for the future implementation.

Quality control at the mixing site involved the control of the water content of the by-product components and of the admixtures. The optimal water content of the admixture was around 7.5 % but as the mixture dried too much more water had to be added and therefore the optimal water content was exceeded. Quality control at the construction site included control of the compaction effect with Troxler measurements, and sampling at site and laboratory testing of the stabilised course materials. The compression strength results are given in the Figures 12 and 13.

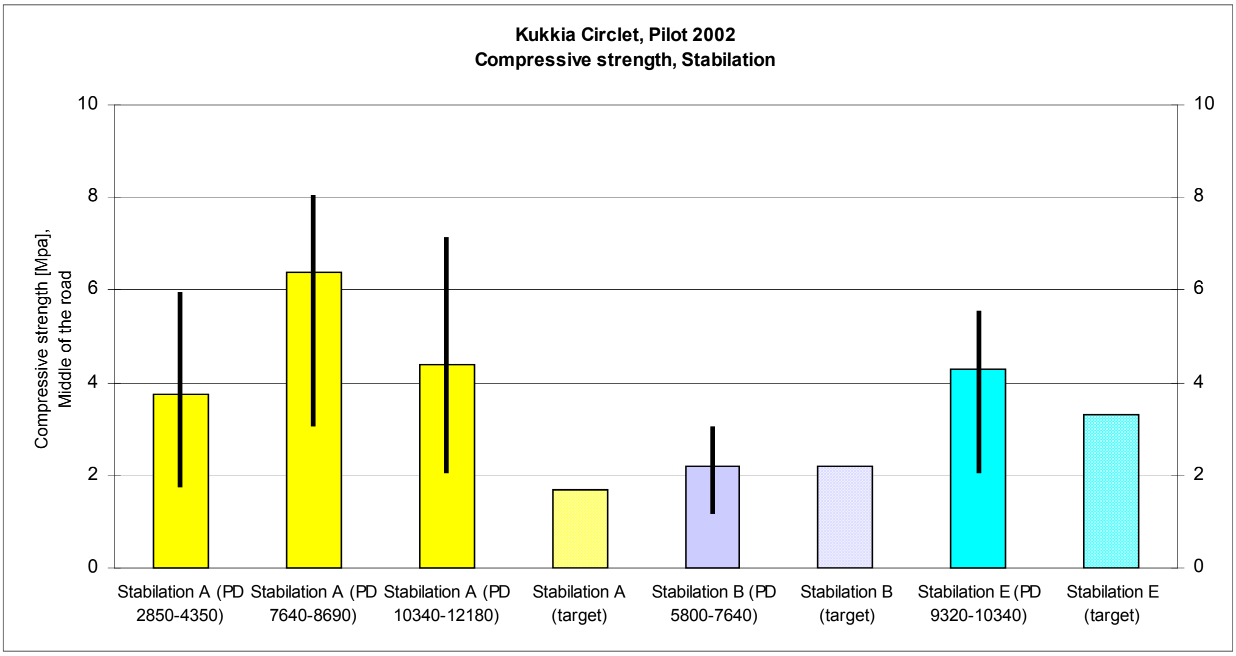

Figure 12. Compression strengths of the stabilised materials sampled from the middle of the road at the construction site (28 days after making the test pieces). Construction site samples. The black lines indicate the variation of the test results. Target values show the results of preliminary laboratory tests.

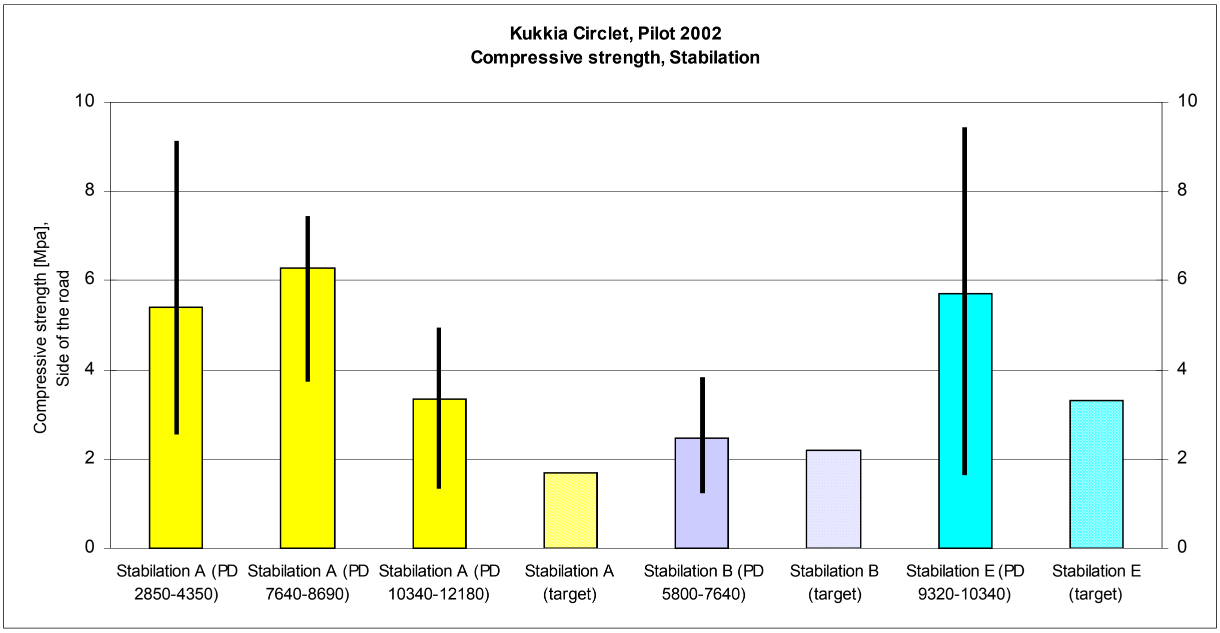

Figure 13. Compression strengths of the stabilised materials sampled from the side of the road at the construction site (28 days after making the test pieces). Construction site samples. The black lines indicate the variation of the test results. Target values show the results of preliminary laboratory tests.

2.5. Environmental studies

After the renovation (stabilisation), the environmental impacts of the construction will be followed up for three years, at least. The follow-up includes sampling and analysis of soil material and water from wells and drainage ditches close to the stabilised road sections. The samples will be taken each year in August-September.

For reference purposes these samples were collected also before the start of any activities on the road. Samples were analysed in and accredited laboratory (GTK in Espoo) to determine the heavy metal contents with ICP-MS. Also pH and conductivity were analysed. The results of the follow-up samples will be compared with these reference results.

2.6. Other follow-up studies

Visual follow-up after the pilot construction have shown that the road has remained in good shape.

Geotechnical follow-up studies will test and measure the development of the bearing capacity and strength of the stabilised and reference road sections. Also visual follow-up and test pit studies will be included. The follow-up will continue at least until 2005. The follow-up programme is shown in the following table (2):

Table 2. Follow-up programme of the Pilot 2002.

Follow-up task	Method	Done by	Year/quarter												
			02	03				04				05			
			4	1	2	3	4	1	2	3	4	1	2	3	4
Condition check; video filming	Visual estimate	TLL, Viatek	x		x x				x x						
Bearing capacity	Drop gravity test	TLL			x		x		x		x		x		
Strength development	Test pits / drilled samples	Viatek				x				x					
Water samples	Inorganic; ICP-MS	Viatek				x				x				x	
Soil samples	Inorganic; ICP-MS	Viatek				x				x				x	

2.7. Cost efficiency

One of the objectives of this project was to compare the cost efficiency of the new admixtures and processes with conventional maintenance and renovation processes.

The economical follow-up of the construction has shown (Table 3) that the total cost for a 9339 meters section of stabilisation was roughly 411 000 € or 44 026 €/km. The total costs of the conventional 2850 meters' reference sections was 80 400 €, or 52 456 €/km for the "pot-hole renovation" section and 4800 €/km for the "autumn renovation" section. The actual stabilisation took two weeks, and the effective work progress was on average 2 kilometres of stabilised and renovation road each working day.

These figures give only the figures for the renovation or maintenance activities but do not show the long-term benefits of the new systems. For conventional renovation or maintenance, there is need for maintenance activities at least every other year. In case there is no need for maintenance of the stabilised sections during the project period, until the end of 2004, the new process is successful and the objectives have been met.

In general, the whole process and the transportation logistics worked effectively, but have to be improved in relation to the vulnerability of the process (the breakage of a machine may not interrupt the process or take long to repair) and in relation to the dusting during mixing, transports and construction (watering systems in connection of the other equipment and/or encased feeding equipment for dry admixtures).

Table 3. Costs of Pilot 2002 (stabilisation)

Cost items	**€**	
Mixing of admixtures	48390	
Costs of admixtures; commercial materials and all freight	73222	
Milling machine & operations	62564	
Spreading operations	97606	
Ditching and harrowing	22489	
Personnel / labour costs – not included in machinery operations	37805	
Planning and quality control	68684	
Stabilisation total	**410760**	**€**
Cost per km	**44026**	**€/km**
Reference structures	**80360**	**€**
- “pot-hole renovation”	73438	€
Cost per km	52456	€/km
- “autumn renovation”	6922	€
Cost per km	4774	€/km
Total	**491120**	**€**

Lengths	12180	m
- Stabilised sections	9330	m
- reference sections	2850	m

(1400m/“pot-hole renovation” + 1450m/“autumn renovation”)

3. PREPARATIONS FOR PILOT 2003

3.1. Structural course for renovation

The Pihtisalmentie (Pt 13981, Auraanpohja road section) in Luopioinen will be renovated by compensating for 500 meters of a existing, badly damaged road course with a fibre-ash structural course. Fibre-ash is a given name for a mixture of fly ash with fibre sludge, in this case fly ash from UPM-Kymmene Ltd's power stations in Jämsänjokilaakso and fibre sludge from Georgia-Pacific Finland Oy's paper mill in Nokia.

The structure is being described below, Figure 14. The renovation process will start by levelling the old road surface and by piling these surface materials on the road edges (like supports for the fibre-ash). A 20 cm course of fibre-ash will be spread and compacted on the surface, and the fibre-ash course will be covered by a 10 cm course of crushed aggregate material (0-16 mm).

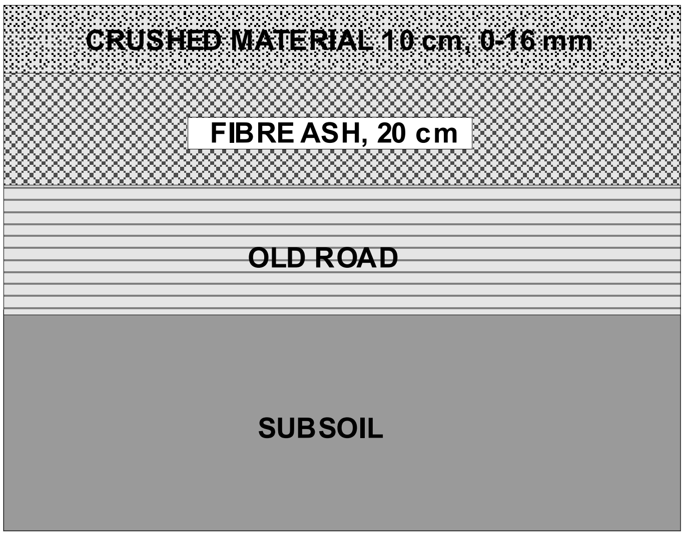

Figure 14. Cross section of the fibre-ash structure for Pilot 2003

A mixture of fly ash (LT) and fibre sludge (SJ, deinking sludge) will be used for this structure. Different mixtures of the component materials and other admixtures have been tested in the laboratory of SCC Viatek Ltd during the year 2002. The final tests for the recipe will continue until the beginning of April in 2003; the tests will involve two alternative mixtures SJ:LT 10:7 + FTC 6 % and SJ:LT 10:10 + FTC 6 %. FTC is a commercial binder admixture of Nordkalk. This admixture includes also by-product components from TiO_2 and limestone production. Also leaching tests will be carried out on a mixture with the largest share of fly ash during 2003.

Follow-up will be performed at the construction site and in the neighbourhood during the years 2003-2005 like shown in the follow-up programme in the table 4. The follow-up involves sampling for environmental and geotechnical analysis and tests.

Table 4. Follow-up programme of Pilot 2003.

Follow-up task	Method	Done by	Year/quarter											
			03				04				05			
			1	2	3	4	1	2	3	4	1	2	3	4
General condition; video filming	Visual estimate	TLL, Viatek		E E		x		x x		x		x		
Bearing capacity	Drop gravity test	TLL				x		x		x		x		
Strength development	Test pits / drilled samples	Viatek				x			x					
Water samples.	Inorganic, ICP-MS	Viatek			E				x				x	
Soil samples	Inorganic, ICP-MS	Viatek			E				x				x	

E = preliminary examination

Water and **soil samples** will be collected before the construction, and after the construction in autumn for at least two years after construction. Water samples will be collected from the nearby wells by the health officer of the federation of municipalities. The well mapping will be done before the construction during May-June 2003. Soil samples will be collected close to the construction site about 1-2 meters from the side and from the soil layers below the by-product course.

Inorganic elements (As, B, Ba, Cd, Cr, Cu, Mo, Ni, Sb, Se, Zn) will be analysed in laboratory as well as TOC; pH and electric conductivity.

3.2. Groundwater protection structure

In connection to the renovation of Pihtisalmentie the performance of fibre sludge as structural material for groundwater protection will be tested. A 0.5 meters thick fibre clay layer will be used as the sealing or impermeable course of the groundwater protection structure.

The groundwater protection structure will run along the edge of Pihtisalmentie for about 20-30 meters with a width of 5 meters from the edge of the road over the ditch and into the other side of the road, like shown in Figure 15.

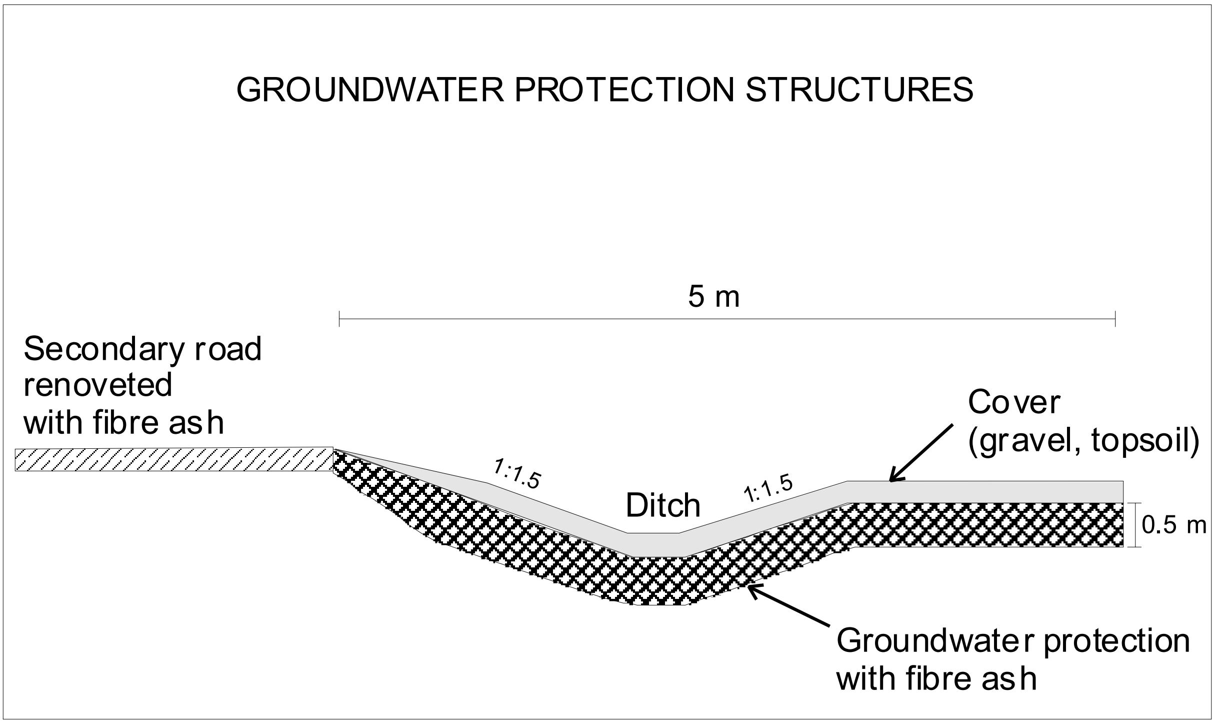

Figure 15. Principle of the groundwater protection structure.

The fibre sludge chosen for this purpose has to be the most homogeneous type available, for example the quality class U1 of Georgia-Pacific Finland Oy. This U1 is based on the deinking of high quality paper waste collected from the offices (other types are U2, based on the deinking of newspaper waste and U3, based on miscellaneous household waste paper). The material tests for the fibre sludge will be made in 2003 in order to determine its durability and impermeability. The tests involve permeability and freezing-thawing tests.

3.3. Light Traffic Paths

About four kilometres of light traffic path is planned to be constructed on the sides of the local road KT 322 passing by the central village of Luopioinen municipality. The narrow roads of rural districts and close to the villages are being considered relatively dangerous to the light traffic, i.e. pedestrians and cyclists. The roads are dangerous because of the relatively high speed of the by-passing motor traffic (cars, lorries etc.) and the narrow space for the light traffic. This is problem and constraint on the moving of the local inhabitants; for example and for safety reasons children cannot be allowed to walk alone but have to be transported by car to school.

The improvement of the light traffic's situation at rural districts is a financial question for the municipality and the road administration. In general, most of the financing for infrastructure improvements is cut too low to finance anything but some renovation and maintenance of rural roads. The only possibility is to cut down the costs of maintenance and new infrastructure investments, for example with help of recycling, new types of materials and improved, more efficient processes. The objective of the light traffic pilot is to obtain cost efficient applications for light traffic paths with help of industrial by-products.

The light traffic path applications will be tested as 1) a floating structure on a soft soil of Mikkolanlahti (Figure 16), 2) a structure on an firm embankment (Figure 17), and 3) an one meter's extension of the sides of the local road kt 322 which will be made (Figure18).

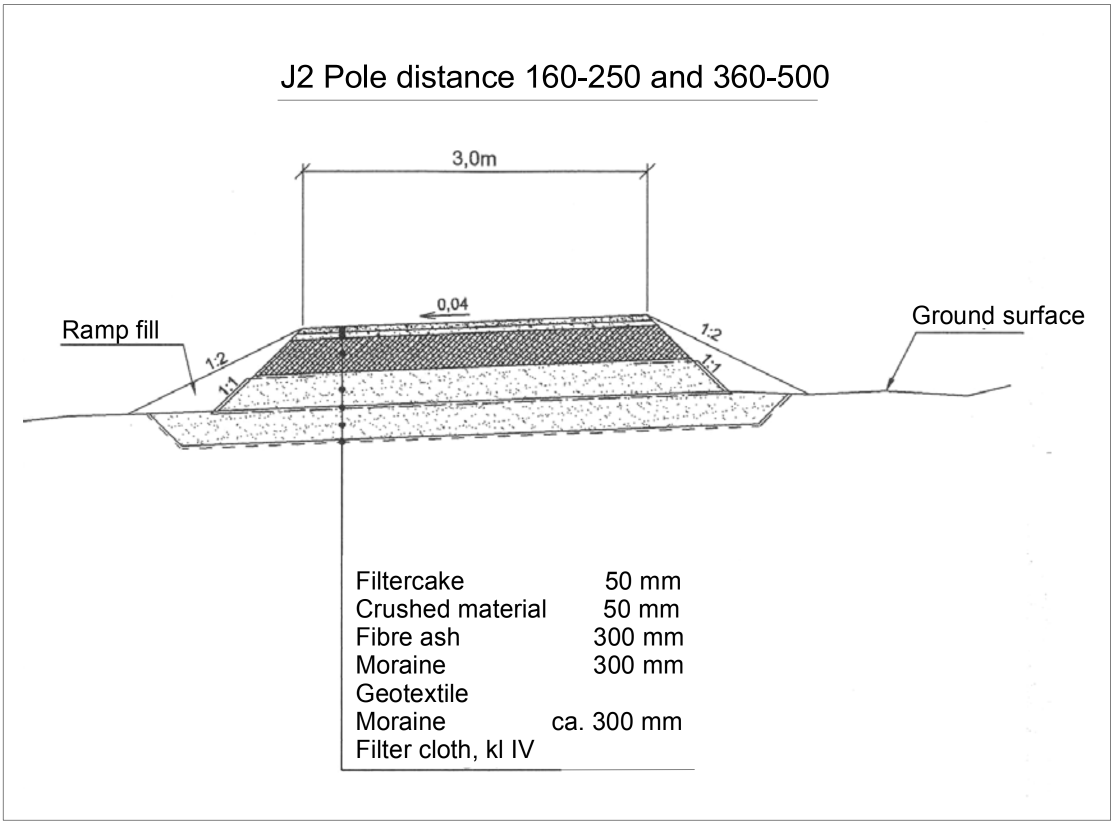

Figure 16. Principle of the floating structure.

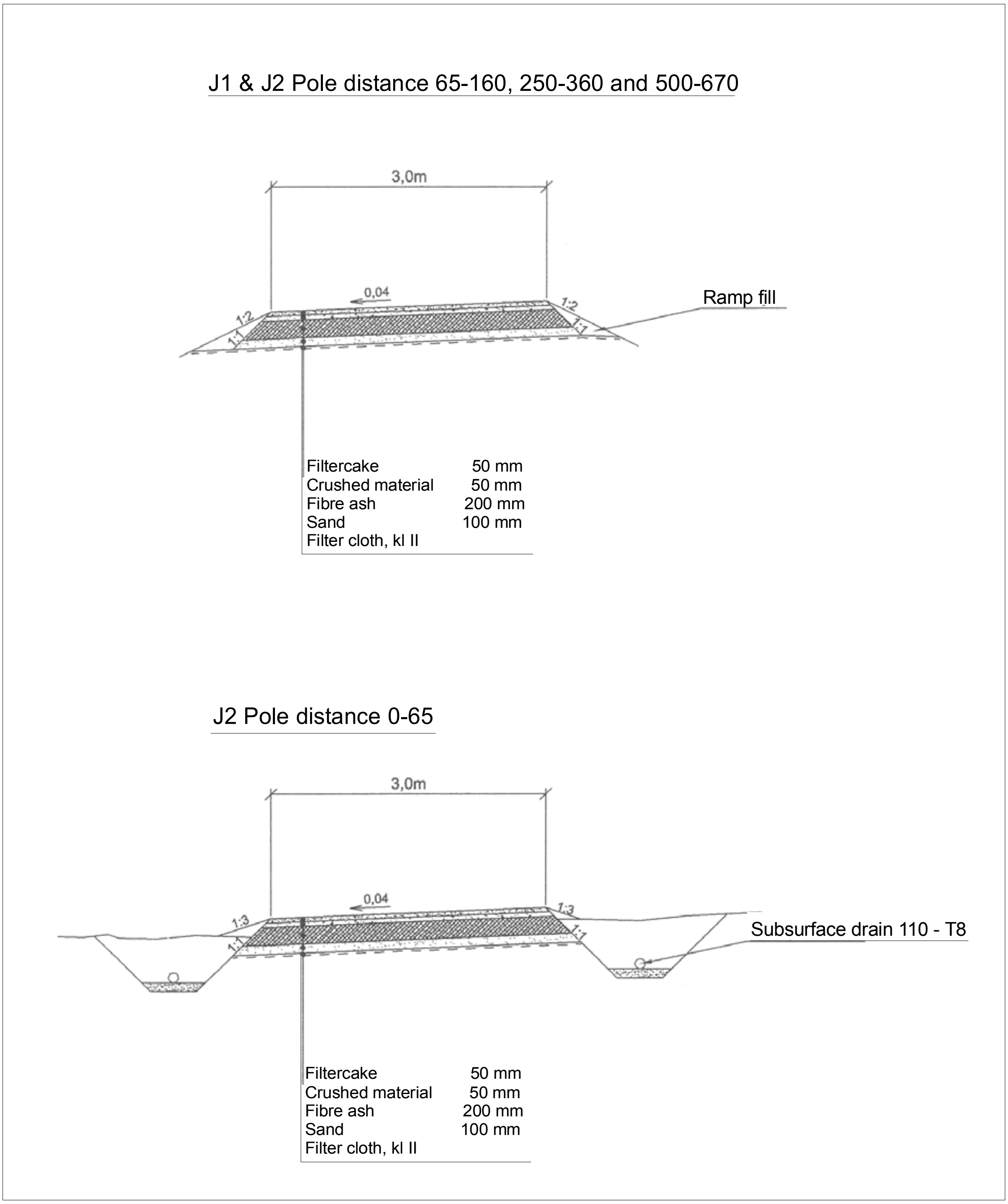

Figure 17. Principles of the structures on firm embankment.

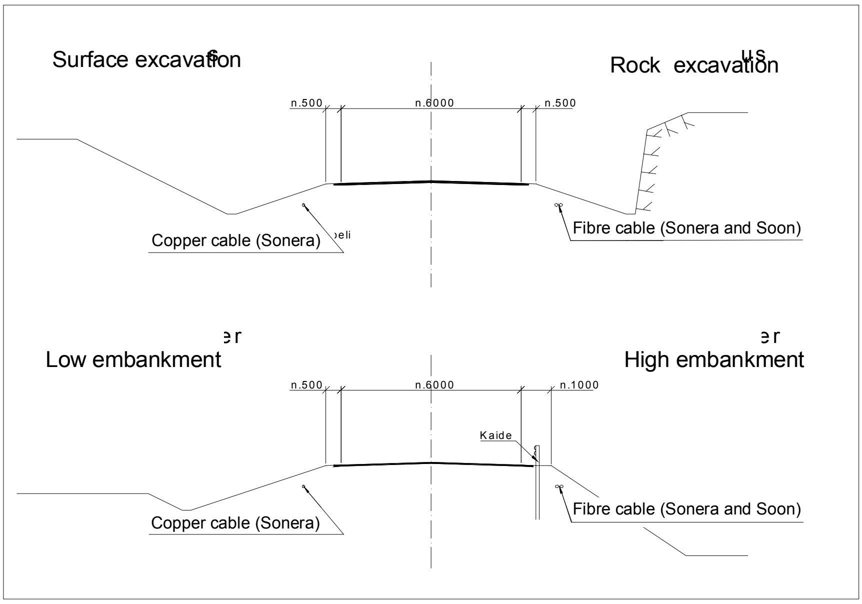

Figure 18. Principles of the road extensions for light traffic paths.

Construction materials will be fibre ash and geotextiles. The testing for these materials (fibre-ash) will be the same as for the structural course materials.

The soil investigations of the site for the light traffic paths was carried out with sampling and ground penetrating radar (GPR) during the autumn 2002. The radar gave information of the soil structure and characteristics below the planned path sites. Soil samples were collected from these sites for basic geotechnical laboratory tests. These results will be used in dimensioning and designing of the structures for the light traffic path applications.

4. SUMMARY

Kukkia Circlet project aims at proving that it is possible to obtain 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. During the Life-Environmental project, new technologies and processes to renovate and improve rural secondary road network will be tested in Luopioinen, Finland. The project will show ways to improve and develop the rural infrastructure despite scarce financing resources, and this will be possible by saving significant amounts of non-renewable natural resources and beautiful nature for the future generations.

One of the tests started in Luopioinen in summer 2002. Roughly twelve kilometres of old road suffering from severe frost damage was renovated and repaired by new methods of stabilisation and by conventional reference methods. The stabilisation was based on the use of binder admixtures of fly ash with other additives. Follow-up during the next 2-3 years will show the technical and environmental outcome of the work. The costs of renovation have shown that new process has cost advantage in comparison with the conventional methods: for example, the costs per kilometre of the stabilisation were around 16 % less than in the pot-hole renovation (44 026 €/km vs. 52 456 €/km).

Significant material tests were done to find best mixtures for the Pilots 2002 and 2003 during the year 2002. The tests should have been finished in 2002, but have to continue at the beginning of 2003. This is because of revised planning of the test programme on the basis of the earlier results for the Pilot 2003. Main part of the engineering for Pilot 2003 has been done during the autumn 2002, but the structures of light traffic paths to be tested have taken more time than planned. The planning and material tests will be finished during the spring 2003, well on time before starting the implementation of Pilot 2003 in the summer 2003.