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LIFE PROJECT NAME

Kukkia Circlet: Environmentally friendly systems to renovate secondary roads

Data Project

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(%) of elibible costs	50 %

Data Beneficiary

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1. EXECUTIVE SUMMARY

The project Kukkia Circlet (2001-2004) has been about the demonstration of sustainable, environmentally friendly methods and processes to renovate and maintain secondary road network. The project is co-financed by EU Life-Environment (Life02 ENV/FIN/000329), Finnish Road Administration, Luopioinen municipality, Council of Tampere Region and industrial partners Finncao Oy, Georgia-Pacific Finland Oy and Kemira Oyj. The project results have been evaluated by independent evaluators from Finnish Environment Institute, Finnish Road Administration and Tampere University of Technology.

The project innovations are based on earlier R&D in Finland, and include new types of road construction materials based on industrial by-products, different types of applications and structures for the new materials, new types of equipment for the mixing of the materials, and in-detail-controlled construction processes to ascertain the target quality and economic benefits of the renovation. The pilot constructions based on the by-products include stabilisation of existing road courses, structural courses to compensate for the conventional stone courses, a groundwater protection structure on the side of a road, and light traffic lanes. The pilot constructions have been implemented partly in the summer 2002 and partly in 2003, and the follow-up has been carried out to the end of 2004. The project has been carried out like planned with respect to the proposal to the Commission in 2001. The small deviations due to practical reasons have been discussed in relevant sections of the report.

In the following the report will give a short Introduction of the project (part 2). After this we are taking a general look at the project framework and organisation (part 3). The main changes have been the internal project management changes of FRE in 2004. This part is followed by a more detailed discussion about the technical issues of the project (part 4), i.e. about the methods and results of the pilot constructions in 2002 and 2004. The annex (1) will give detailed information about the follow-up results at the pilot sites during the project period. The next part (5) is about the important Impact Assessment of the project. The Impact Assessment has been made on the basis of the results from the follow-up, of the data from cost accounting for the new applications and appropriate reference applications, and of the experience gained during the planning and implementation of the pilots. A separate Impact Assessment report is available in Finnish at the project's www-sites (Vaikutusten arviointi). The evaluation reports of the external evaluators are given in Finnish and included in the Impact Assessment report. Part 6 is about the Dissemination activities, part 7 about the general evaluation and conclusion of the project and part 8 about the financial report.

The project period has been too short to get any final assessment and results about the new construction systems, i.e. the pilot constructions' behaviour and properties. During the project it has been possible to demonstrate and assess the construction and renovation methods of the different pilot structures, to assess the costs in case of full-scale implementation and to have the first results of the technical and environmental properties. However, it will be important to continue the follow-up and to develop some of the systems further.

2. Introduction

The main problems in the background of the project include: the constantly inferior quality and frost damage of the gravel roads (see Figure 1), the high costs of an effective conventional renovation, the dangerous narrow road sides for the cyclists and pedestrians in the rural and sparsely populated areas, the high volumes of non-renewable stone resources exploited for the conventional road maintenance and renovation, the environmental problems in connection with the exploitation of natural stone resources from rocks, hills or eskers, and the increasing societal and legislative constraints to the exploitation of natural stone resources.

Figure 1: Frost damage of a gravel road. Luopioinen 2002

In order to meet the challenging problems, Kukkia Circlet –project has combined all the know-how that has been obtained earlier during many different types of R&D projects on the use of industrial by-products in road construction. The project has been able to show that, based on the recycling of industrial by-products, there exist new, controlled, sustainable and efficient road construction processes that could be beneficiary for the different European societies having different types of problems to maintain and renovate secondary roads. The project beneficiary and partners wish to have given sufficient information that will encourage the European societies to eliminate major restrictions to the utilisation of industrial by-products in the soil construction.

In the long term the exploitation of the project results as well as other recycling methods in soil construction will significantly reduce the exploitation of non-renewable natural resources, the amount of waste and the need for deposit sites in Europe. The results can also be used in the work of European standardisation and legislation concerning the use of industrial by-products in construction.

3. LIFE-PROJECT FRAMEWORK

The following scheme (Figure 2) gives an overview of project tasks and organisation.

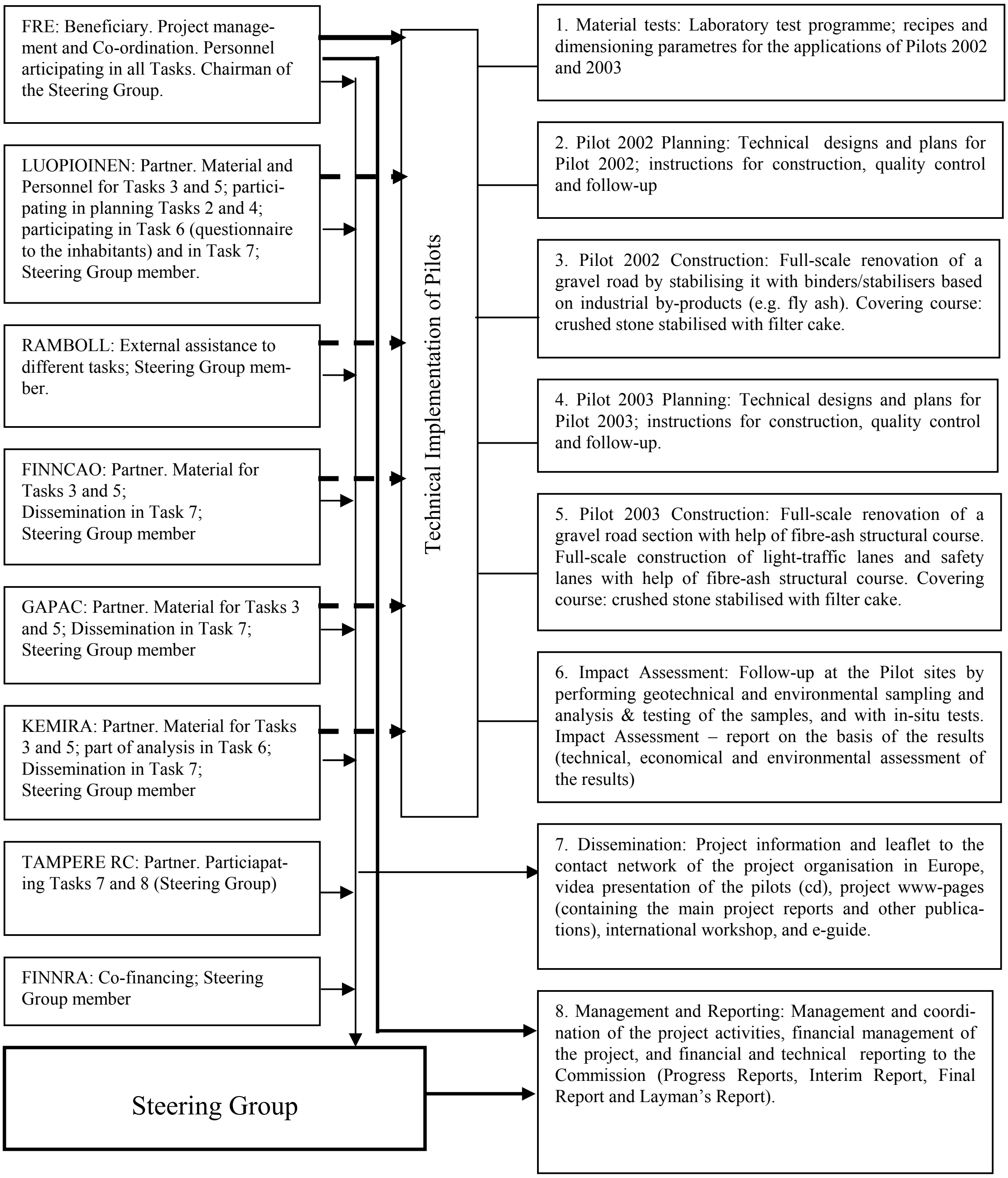

Figure 2: Description of the Kukkia Circlet organisation (left) and tasks (right).

The beneficiary and co-ordinator of Kukkia Circlet is the Finnish Road Enterprise. Other partners are Luopioinen Municipality, Council of Tampere Region, Finncao Oy, Georgia-Pacific Finland Oy and Kemira Oyj (chemicals plant in Kokkola). The beneficiary, the partners, the co-financier (Finnra) and external assistant (Ramboll) participated the project's Steering Group. The expert personnel of the former organisations participated also in the technical implementation of Pilots 2002 and 2003. A major part of testing and follow-up as well as the planning of the new structures for the pilots were subcontracted from Ramboll Finland Oy (former SCC Viatek Oy).

The major change in project personnel was the change of the project manager and co-ordinator, as MSc, Ms. Hannele Kulmala took the position and responsibility as the Head of the Häme Service Unit of FRE in March 2004. The minor changes took place as Kemira's chemical plant in Kokkola merged to TETRA Chemicals Europe Oy, and SCC Viatek's name was changed to Ramboll Finland Oy in 2004.

In general, the project tasks have been carried out as planned in the technical part of the project proposal. A smaller exception has been the Workshop as part of the Dissemination (Task 7). The Workshop was planned as a specific project workshop in Tampere in June 2004. However, at the same time a more extensive 7th International Symposium on Environmental Geotechnology and Global Sustainable Development with workshops was being planned by the International Society of Environmental Geotechnology, the Finnish Environmental Institute and the Helsinki University of Technology. The target audience included the same target group as Kukkia Circlet. The project Steering Group was given the opportunity to have the project presentations in connection of this Symposium (a dedicated workshop was finally not possible). The symposium was held in Espoo, Finland in June 8-10, 2004. The report has been submitted as an annex of the Progress Report IV (1.4. – 30.9.2004). The other exception is the Guide (or "advice and instructions for the use of fly ash and fibre sludge in the renovation and construction of secondary roads") that is being published at the project www-pages only in Finnish, so far. However, also the video (DVD, that is available at the www-pages) gives illustrative guidelines for the potential users of the technology both in English and in Finnish.

4. Technology and Results

Kukkia Circlet project has been testing innovative processes to renovate gravel roads, and to construct groundwater protection and light traffic lane structures on the sides of the gravel roads. The special technical focus has been on the logistics, mixing and other work methods. The follow-up during the project has been directed at the long-term properties, environmental impact and costs of the new applications in comparison with the conventional road structures.

The pilots involve following tests and applications:

Pilot 2002: Stabilisation of an existing gravel road with help of binder admixtures based on fly ash. This application has been implemented during the summer 2002 (see: Annex 1 of the Interim Report. Report on Technical Progress 1.12.2001 – 31.12.2002; http://www.tieliikelaitos.fi/tieliikelaitos/yhteistyokumppanit/).

Pilot 2003: The following pilot structures have been implemented in summer 2003 (see: Progress Report No 2 covering the project activities from 1.3.2003 to 30.9.2003; http://www.tieliikelaitos.fi/tieliikelaitos/yhteistyokumppanit/):

1. Renovation of a frost damaged road with help of fibre-ash structural road courses.
2. Construction of a groundwater protection structure using fibreclay.
3. Construction of new alternatives for light traffic lanes with fibre-ashes and geo-reinforcements.

4.1. Pilot 2002

The principle of the process has been described both in the report for Pilot 2002 (see above) and in the video-presentation. The recipes for stabilisation and binder admixtures were determined by laboratory tests well before starting any measures for the renovation. All component materials needed for the binder admixtures were transported into a storage and mixing site close to the pilot road. The main component, fly ash was stored in piles (moisturised on the surface to prevent dusting), and cement, gypsum and other dry additives were in watertight containers.

The new, massive and data-controlled stationary mixing system was an important part of the process to be tested. This equipment was used for other than conventional stone aggregates for the first time, and proved to be a feasible and effective mixing method. However, its high capacity could not be fully and most efficiently exploited during the relatively small pilot process.

Summer 2002 was very hot and dry in Finland. This caused exceptional dusting problems at the storage site. Huge amounts of water were needed to protect the environment against dusting and to maintain proper water content of the binder admixtures during stabilisation. The mixing process was controlled by the progress at the stabilisation site: the admixtures had to be used within a few hours after the mixing and the addition of water in order to ascertain the proper reactivity for the stabilisation.

Before starting the stabilisation, the biggest stones were removed from the road, and the surface was levelled and moisturised. Actually, in the dry and hot weather conditions, water had to be sprinkled on the road continuously, from early morning until late evening, in order to keep the road surface adequately soft and moist for the stabilisation.

The stabilisation process started by spreading a 50 mm layer of binder admixture on the section to be stabilised. The admixture was mixed into the road, a depth of 200 mm, with a milling cutter. After compaction with a roller, the road was ready for use. Later in September, the surface was covered with a 100 mm course of crushed stone stabilised with filtercake (a by-product from the salt production that helps to prevent the surface from dusting). Local traffic was allowed to pass the renovation site during the work process, though at reduced speed. The on-going stabilisation process can be seen in Figure (3) below.

Figure 3: Stabilisation is going on at Pilot 2002 road. In the background the spreading machine, in the middle the milling cutter, and in the front the roller. Luopioinen, summer 2002.

The total length of 12 kilometres of the Pilot road involves both different stabilised sections and reference sections. The reference sections have been treated with normal maintenance methods for gravel roads like; a) filter cloth and 30 cm crushed material and a 20 mm covering course of crushed aggregates (0-16 mm), b) only a 20 mm covering course of crushed aggregates (0-16 mm), and c) only a covering course with 50 mm crushed aggregates plus another 50 mm of filtercake+crushed aggregates –mixture.

The mixture of filtercake with the crushed aggregate was actually used widely for the covering courses of the pilots, both in 2002 and later in 2003. The filtercake is a by-product from the manufacture of calcium chloride. Calcium chloride is used e.g. for the dust and frost prevention of the gravel road. The project is testing the possibility to stabilise the covering course and make a longer lasting dust/frost prevention effect on the road by mixing the crushed aggregate with a smaller quantity of filtercake containing salt.

4.2. Pilot 2003

4.2.1. Renovation of a frost-damaged road with the fibre-ash structural course

Pilot construction to test the feasibility to renovate gravel roads with fibre-ash structural courses was carried out in the summer 2003. Fibre-ash is a mixture of fibre sludge or 'fibre-clay' from the paper manufacturing and fly ash from (bark, sludge and peat) combusting power plants. In addition to these main components the fibre-ash may contain some binder additive, like cement.

Recipes for the different applications (also the other Pilot 2003 applications) were produced with help of extensive laboratory well before the start of Pilot construction. The tests included environmental tests that determine the leaching of harmful substances from fibre-ash (Column test NEN 7343). The test results did not indicate any potential risk to the environment. The environmental permits for the storage of the by-product materials and for the Pilot 2003 construction were given by the authorities of the Pirkanmaa Regional Environment Centre.

The components for the renovation process: fibre-clay, fly ash, binders and crushed aggregates were collected at the mixing site well ahead of the start of the construction process. Stack mixing system was chosen to be tested for this pilot construction, Figure (4). The stack was made by measuring at first the required amount of fibre-clay at the bottom of the stack, and then the required amount of fly-ash on the fibre-clay. After mixing these components into a homogeneous mass, the additives or binders were added – in our case a relatively small amount of cement. Stack mixing is a very effective method, and its benefits would be more obvious when mixing larger volumes of material than for the pilot project. The mixture of fibre-ash has to be used for construction within a few hours after mixing. In case of longer delay, like over a night, the stabilisation of the mixture will proceed quite far and this will have negative effect on the stabilisation of the structural course after construction.

Preparations for the construction included planing of the old road surface and forming of the edge supports with help of the old road surface aggregates. The edge supports, Figure (5) will prevent the fibre-ash from drifting to the ditch during spreading, and ascertain an even compaction of the structural course from one edge of the road to the other.

The fibre-ash was transported to the pilot site in trucks. After this it was spread and shaped with a blade grader, and compacted with a road roller. As the targeted, compacted depth of the structural course was about 20 cm, the need for a loose fibre-ash course was at least 40 cm. For compaction the fibre-ash course was covered with a thin course of crushed aggregate. Finally, the covering courses of crushed aggregate and filtercake-mixed crushed aggregate were spread and shaped on the compacted fibre-ash structural course.

Thermosensors were installed in a pilot section and in a reference section of the road in order to follow up continuously the temperature at different depths of the sections (during 2003-2004). The target was to test and control the insulating effect of the fibre-ash course. The results are given in Annex (1).

Figure 4: Stack mixing for Pilot 2003 Fibre-ash. Left: the stack mixer. Right: the stack mixer working with a stack of fly ash and fibre-clay. Because of dusting the mixing site must be chosen carefully and the workers must be equipped with respirators. Luopioinen, summer 2003.

Figure 5: Working of the edge supports is going on for the pilot road. Luopioinen, summer 2003.

4.2.2. Groundwater protection structure with fibre-clay

Fibre-clay has been tested and used for the sealing courses of closing landfills and for the bottom sealing of new landfills, as a substitute for more common and expensive materials. The results have been very positive. Because of this, the project was testing the potential to use fibre-clay as a sealing course in circumstances where the critical part of the process, i.e. the compaction will be more difficult than when compacting a sealing course of a landfill. The most effective compaction methods like road rollers cannot be used for the groundwater protection structure that runs over road shoulder and narrow ditches.

Preparing of the site for construction included removing of the covering soil from the construction area into a heap. The sealing course of fibre-clay was planned to meet the original height level of the ditch after construction. The removed soil was to be used for the final covering course of the sealing course. After this clearing process, the drainage pipes were laid on the ditch and covered with soil material.

The first stages of the construction included the spreading, shaping and compaction of the fibre-clay on the cleared site. The equipment included a scoop shovel and a vibrating plate. The compacted depth of the fibre-clay course was targeted to be about 50 cm. The fibre-clay was spread and compacted in two successive layers, Figure (6). The compaction result was controlled with help of a volumeter. The fibre-clay course was covered with the original soil material, for about 30 cm. In bigger projects all soil maybe cannot be re-used as effectively as here, but it is important to find some beneficiary use for the excess soil close to the construction site.

Thermosensors were installed also into this structure during 2003-2004. This was made in order to follow up continuously the temperature at different depths, and to control the freezing of the fibre-clay course

Figure 6: Compaction of fibre-clay going on. The compacted fibre-clay course should act as an impermeable sealing course of the groundwater protection structure. Early autumn 2003, Luopioinen.

4.2.3. Ligth traffic lanes and safety lanes with fibre-ash

The light traffic lanes are scarce in rural and sparsely-populated areas in Finland, mainly because of the relatively high costs of construction and maintenance. However, the safety of the cyclists and the pedestrians make the need for light traffic lanes very obvious also here. The roads that run through the area are usually quite narrow and the cars are driving fast which is risky to the light traffic. This fact is pronounced during the dark autumn and snowy winter periods.

Separate light traffic lanes

Before construction, already in February-March 2003 at the soft soil areas, the soil base had to be reinforced. The reinforcement was made by preloading the base, i.e. by covering the base with a geotextile and a loading berm of moraine. Also otherwise the site had to be cleared for the light traffic lanes. Soil was removed and the light traffic lane base was covered with moraine and graded for totally about 1,2 kilometres.

The construction process was following: At the mixing site the fibre-ash mixture was made with a stack mixer. The base (covered with moraine) was covered by a filter cloth and further with a 10 cm layer of crushed aggregates in order to help the traffic of the working equipment. The edge supports for the base structure were constructed in order to prevent the fibre-ash from drifting to the ditch during spreading, and to ascertain an even compaction of the structural course from one edge of the lane to the other. Next, the fibre-ash was transported to the site, spread and shaped on the lane. A thin course of crushed aggregates was spread on the fibre-ash course to help the compaction with a roller. Figure (7) shows the result before final covering course and finishing.

For the covering course, the effect of two different filtercake admixtures are being tested; the other contains also bitumen and the other fibre-clay. The covering course mixtures were made with a scoop mixer. The mixture was spread on the fibre-ash course with a asphalt mixer. Finally, the finishing of the slopes was carried out.

Figure 7: A section of the new light traffic lane, pending final covering course and finish of the slopes. Luopioinen, summer 2003.

Safety lanes

In addition to the light traffic lanes, the safety lanes (extensions of the driveway for the pedestrians and cyclists) are being tested as an alternative safe route for the light traffic. Also the structure of safety lanes is based on the use of fibre-ash, the reference structure being the conventional one with crushed aggregates.

Before construction, the slopes of the road had to be cut open, as deep as possible for the new structures with the fibre-ash. After cutting, the base for the new structure had to be graded (levelled). The mixing of the fibre-ash was made with a scoop mixer, Allu-scoop, Figure (8).

Figure 8: The mixing with scoop. Luopioinen, summer 2003.

The construction process of the fibre-ash sections was carried out as follows: The reinforcement textile or geonet was spread on the base. Fibre-ash was spread and shaped on it. The edges of the geonet were turned onto the fibre-ash course. The geonet was to prevent the fibre-ash from drifting down the slope. Figure (9). At steep places, a supporting plate or form had to be used as an additional tool, Figure (10). The use of this tool was too slow and the system needs further development. A thin layer of crushed aggregates was spread on the covering geonet, and the compaction was made with help of a vibrating plate. After this, the final covering course containing filtercake was spread on the structure, and the final compaction was carried out. Figure (11) shows the safety lane before finishing. The finishing with thin pavement and serrated stripes was made in the summer 2004 because the winter came suddenly at the beginning of October 2003.

Figure 9: Works going on at the fibre-ash section of the safety lane. Luopioinen, early autumn 2003.

Figure 10: Supporting plate used for the construction of the safety lane at a steep site. Luopioinen, early autumn 2003.

Figure 11: The safety lane before finishing. Luopioinen, early autumn 2003.

4.3. Follow-up of the Pilots 2002 and 2003

The technological part of the project was composed of the planning and implementation of the processes for pilots in 2002 and 2003 (Chapters 4.1 and 4.2), and the follow-up of the behaviour and properties of the pilot structures and materials based on the industrial by-products. The task of the follow-up has been to monitor the behaviour and properties of the pilot structures and get short-term results for the project reporting. The objective has been to show that the new construction systems based on the reuse and recycling of high-volume industrial waste are environmentally, technically and economically viable, sound and sustainable.

The follow-up programme has included geotechnical in-situ tests, geotechnical instruments where appropriate (temperature measurements of fibre-ash and fibre-clay structures), geotechnical laboratory tests and environmental analysis on samples taken from the structures, the soil and the wells.

The project period has been too short to get any final assessment about the new construction systems, i.e. the pilot constructions' behaviour and properties. During the project it has been possible to demonstrate and assess the construction and renovation methods of the different pilot structures, to assess the costs in case of full-scale implementation and to have the first results of the technical and environmental properties. Thus, it will be important to continue the follow-up as well as to develop some of the systems further.

A summary of the follow-up and observations is given here; the follow-up has been described in more detail in the Annex (1) of this Final Report (Report on Technical and Environmental Follow-up of Pilots 2002 and 2003) and in the reports in Finnish

(Teknisen seurannan loppuraportti, Ympäristöseurannan loppuraportti) that can be found in the project www-pages.

RENOVATION OF A GRAVEL ROAD BY STABILISATION WITH BINDERS BASED ON FLY ASH

Originally, the road was badly damaged before the pilot renovation. Since the pilot works of 2002, the road has been in good condition because of the stabilisation and the newly repaired ditches. The stabilised sections have been durable and carried well the load of the frost-damage season, and the road's bearing capacity and strength have improved significantly.

The road users are unsatisfied only with the partial improvement of the road, as there remain several reference sections which have not been stabilised but treated with conventional methods. The reference sections have not been improved like the stabilised sections. Another reason for discontent has been the narrowing of the road because of the pilot renovation. The reason was the improvement and uncovering of the drainage ditches of the road (before renovation the ditches had been filled up with vegetation and materials from the road, and the maintenance of the drainage had been neglected for several years).

RENOVATION OF A GRAVEL ROAD WITH HELP OF FIBRE-ASH STRUCTURAL COURSES

The renovation of a gravel road with fibre-ash structural courses was made at two 500 m long and badly damaged section of the road in the summer 2003. At least so far, the renovated sections have been in good condition. Although the project implemented only a partial renovation, the choice of the pilot sites was optimal as the serviceability of the total road has been improved. The inhabitants and other regular road users have been content, and wish to have similar renovation to cover the total road as well as other local gravel roads.

Immediately after the renovation in 2003, the improved sections were noted to have some settlements. This was evident where the compaction has been least effective, i.e. at the end of the renovation sections and close to the steep road shoulders. After a year, in 2004, the renovated road sections were totally in good condition and the fibre-ash structural courses were solid.

The target of the renovation was not only to improve the bearing capacity although this has been slightly improved. More important has been to construct an insulating, isolating and resilient structural course in order to reduce the depth of frost penetration, to prevent the mixing of the covering course with the road base and to even out the frost heaving. On the basis of the drilling samples, the fibre-ash course's stabilisation and strength development have been like expected, even better. On the basis of the temperature monitoring results the fibre-ash functions as an insulating course which has reduced the frost penetration and delayed the frost thawing, i.e. reduced the frost heaving.

GROUNDWATER PROTECTION STRUCTURE USING FIBRECLAY

Groundwater protection is needed at sites where the road passes through or close to important groundwater catchment's areas. It is important to prevent the harmful discharges into groundwater from traffic or because of road maintenance (like salts used as antiskid or dust holding treatment). The basic requirement for the sealing course of the groundwater protection structure is its water tightness, i.e. water permeability $k < 1*10^{-9}$ m/s. The conventional materials that meet these requirements, like bentonite clay, are relatively expensive. Fibre-clay that mainly consists of wood fibres and kaolin has been tested for example as the sealing course for closing landfills since the middle of the 1990's. With help of careful and effective compaction water permeability at the level of $k < 10^{-10}$ m/s has been obtained. This is the reason to test the use of fibre-clay for the sealing course of a groundwater protection structure.

The measurements at the pilot site with infiltrometer equipment have shown that the required and targeted water permeability of the pilot structure has not been obtained. The results have shown values $k \sim 10^{-7}$ m/s though the targeted value was $k < 10^{-9}$ m/s. It is evident that the compaction work has been inadequate. Additionally, the compacting load of the covering soil course has been too low because it was made too thin. Improvement and development of the working methods and new and more successful pilot tests with fibre-clay are needed before any final conclusions should be made about the applicability of fibre-clay to groundwater protection.

LIGHT-TRAFFIC LANES WITH FIBRE-ASH STRUCTURAL COURSES

The local opinion survey was conducted in the summer 2004 on the serviceability and other aspects of the new light traffic lanes constructed in Luopioinen in the summer 2003. The general opinion has been very positive because of the improvements of the light traffic safety and the increasing possibilities to move by foots or by bicycling. Only complaints were given because of the lack of lightning, some omissions of the winter maintenance and the uneven (non-asphalt) quality of the surface.

The light traffic lane close to the lake was in good condition but the lane closer to the village had several narrow cracks in the spring 2004. The cause of the cracks was noted to be mainly the inadequate thickness of fibre-ash courses at some places. However, in the following autumn the cracks had been disappeared and the lane seemed to be in good condition. The fibre-ash courses were solid and sound.

Normally, the bearing capacity of a road is at its lowest in the springtime. However, the measurements on the light traffic lanes did not give any significant differences of the bearing capacity values in the spring and the autumn. The bearing capacity was not high. However, the more important target has been to construct an insulating, isolating and resilient structure like in the renovation of the gravel road (see above).

According to the opinion poll the local road users take a very positive view on the new safety lanes that increase the safety to go by foots or by bicycling between home and the village centrum. The complaints have been about the narrowness of the safety lanes, the quality of the surface and the steep shoulders of the road. The finishing of the safety lanes was carried out in the summer 2004, including the pavement and the serrated stripes to separate the drive way and the safety lane. The serrated stripe is working and preventing the motor traffic to enter the safety lanes during the spring, summer and autumn, but the winter time with snow covering the serrated stripes might be a problem (a maintenance system that is not too expensive, that keeps the lanes open and is not harming the serrated stripes, is pending).

During the follow-up in the summer and autumn 2004 no visible damages on the safety lanes have been noted. However, the strength and bearing capacity of the new fibre-ash safety lanes have not been developing as well as was expected with respect to the pre-construction laboratory test. The reason was too ineffective and light compaction during the construction process. The structure is more solid at the site where the movable supporting plate has been used (at a site of a very steep road shoulder). Thus, it is evident that the use of supporting equipment would be advantageous when constructing or extending the safety lanes. Also, it might be more advantageous that the spreading and compaction is made in several successive thin layers than in one to two thicker layers.

In general, the construction methods, the system to separate the drive-way and the safety lane, and the winter maintenance system for the safety lanes need further consideration and development.

COVERING COURSE WITH CRUSHED AGGREGATES MIXED WITH FILTERCAKE

During the Kukkia Circlet project, the different pilot structures were tested with a covering course mixture of crushed aggregates with filtercake. Filtercake is being generated as a by-product of the manufacture of calcium chloride. Calcium chloride is used, for example, as a dust-preventing salt on the non-pavement roads. Filtercake consists of calcium chloride as well as other calcium compounds. With respect to the results from earlier tests, the filtercake would increase the abrasion resistance of the covering course and decrease the need for spraying salt on the road each spring and autumn. Additionally, the filtercake will help to prevent the road surface from freezing even as low as at (minus) -5 ^{o}C degrees. The hygroscopic effect of the filtercake will naturally decrease with the dissolution of the salt from the filtercake. The need for maintenance (i.e. additional mixing of filtercake on the surface) might be every other year.

Especially at the Pilot 2002 site, some smaller surface damages were noted in the summer 2004. The probable reason was the impermeable and strong stabilised course which would not allow the rain water to filtrate downwards during heavy rainfall. The covering course became too wet and muddy, but only when the road's slope angle was too small. Additionally, the filtercake may have caused increase of the relative amount of fines in the covering course increasing the muddiness during a rainy season. Therefore, there is need for improvements and for further development of "cheap but durable" covering course materials.

In addition to the crushed aggregate with filtercake, also different other types of components are being tested on the light traffic lanes' covering course materials. Thus, some new information will be available later for the further development.

GENERAL CONCLUSION OF THE FOLLOW-UP RESULTS

The results of the follow-up (until 2004) imply the technical problems and/or the deviations with respect to the technical planning (for example the compaction efficiency or the course thickness). The quality control has an important role during the construction process especially when the new types of materials and structures are not previously known to the working staff.

No major problems or drawbacks have been encountered during the project period. However, it is important to note that the follow-up period has been too short for any final conclusions of the results at these pilot sites. The project has given a lot of information and learning for the further development of the process and the methods.

5. IMPACT ASSESSMENT

The Impact Assessment has been made on the basis of the results from the follow-up, of the data from cost accounting for the new applications and appropriate reference applications, and of the experience gained during the planning and implementation of the pilots. Impact Assessment has been reported in Finnish as is available at the project's www-sites (Vaikutusten arviointi). The Impact Assessment and reporting have been carried out with help of the specialists of the project partner organisations and the external specialists and project evaluators of the Finnish Environment Institute (Dr Jouko Saarela), Finnish Road Administration (MSc Tuomo Kallionpää) and Tampere University of Technology (Dr Pauli Kolisoja). The reporting has been slower and more complicated than anticipated, and thus the Finnish Impact Assessment report has been published in the www-pages not earlier than in March 2005. However, the project partners and the evaluators find that even the current Impact Assessment indicates that the new construction systems are economically, technically and environmentally feasible and sustainable. In the following are presented the main content and conclusions of the Impact Assessment report.

5.1. Indicators of the need for new alternatives of construction

5.1.1. Need for sustainable maintenance of the road network

In general, the condition of the gravel road network is structurally weak causing inconveniences and harm to the trade and industry as well as society. The improvement of this part of the infrastructure is quite slow because of the annual budgetary limitations and the low priority of the secondary roads. Fifty to hundred kilometres of damaged gravel roads are being renovated and improved each year, but the total need for renovation is still about thousands of kilometres in Finland.

The Finnish road administration and municipalities find it very important to improve the status of the light traffic in order to increase the choice of the modes and safety of mobility. The safe light traffic routes are especially important for the children, physically restricted and old people, but also for the general recreation. However, mainly because of budgetary restrictions, the status and priority of the light traffic with respect to the infrastructure development targets is nowadays relatively low.

The discharges and emissions of the traffic as well as the road maintenance are risk factors for example to the ground water sources. One of the sources of discharge is the use of salt on the road surface for the dust and frost prevention. The risks can be reduced with help of groundwater protection structures at the road sides as well as by introducing new and more environmentally safe methods to compensate for the salt.

The project aims at giving cost-effective and environmentally sound alternatives for the road construction and the gravel road renovation and, thus, at making it possible to increase the annual length of renovation and light traffic lanes. Additionally, the project aims at giving a feasible alternative for the groundwater protection structure, and new covering materials that reduce the need for salt in road maintenance.

5.1.2. Generation of industrial wastes of the project in Finland and Europe

The processes of the Finnish forest industry generate about 0,226 Million (dry) tonnes of ashes from the incineration of bark and peat and about 0,400 Million (dry) tonnes of fibre sludge. Almost 96 % of fibre sludge and about a half of the ashes were reused in 2003. The share of these by-products was about 2,9 % of the total Finnish paper and cardboard production, about 15,2 Million tonnes in 2003.

The fibre sludge was used mainly for closing and construction of landfills, and the fly ashes for other purposes in construction. The closing of old and construction of new landfills will gradually slow down. This means that the reusage share of fibre sludge will not continue as high as nowadays in case there are not found alternative reuse applications for the sludge.

According to the information of the association of Finnish Forest Industries the paper and cardboard production has been about 90 Million tonnes in Europe (including the Finnish production) in 2003. The waste statistics give no specifications according to the different waste items, but it is reasonable to assess that it conforms the Finnish figures (see above). Thus, the total waste production the European forest industry would include about 1,4 Million (dry) tonnes of ash and 1,24 Million (dry) tonnes of fibre sludge. Many European forest industry mills combust at least a part of the fibre sludge in the energy production processes.

The generation of the third important industrial waste of the project, the filtercake, is statistically more straightforward. The only European producer of calcium chloride and, thus, of filtercake is TETRA Chemicals Europe Oy (former: Kemira) in Kokkola, Finland. The annual production of filtercake is 20 000 – 22 000 tonnes.

5.1.3. The use of non-renewable natural resources in the construction (in Finland)

Natural aggregates like sand, gravel and crushed rock have been used in average 17 – 19 tonnes per inhabitant in Finland in 2002. Crushed rock were used totally around 40 Million tonnes, gravel and sand around 50 Million tonnes. Approximately 80 – 85 % were used for soil construction and, more specifically, around 25 % (about 23 Million tonnes) for road construction and maintenance. Additionally and outside the former figures are the crushed aggregates that are taken from the construction sites.

The availability of gravel and other stone aggregates is gradually getting more and more scarce, especially in the economical vicinity of bigger population centres. Also, the environmental regulations with tightened targets for the protection of groundwater resources and preventing of other environmental degradation have affected the future possibilities for environmental permits to extract gravel and other natural aggregates. Consequently, the longer hauling distances make the natural aggregates more expensive. On the other hand, high quality stone aggregates are still needed for the pavements of crowded roads and highways, and in these cases the higher price of the aggregates can be economically justifiable. The secondary road network, however, should be maintained and improved with secondary and alternative materials instead of natural aggregates.

5.2. Technical and economical impact assessment

5.2.1. The pilot structures and construction

The pilot constructions are based on the applications of conventional and general soil construction technology and work methods. However, the work methods and the process have some special features with respect to the industrial by-products the behaviour of which differs from the behaviour of conventional natural aggregates. The important feature of the logistics and process is the short-term storage of the by-product components and the quick "on-time" processing of the construction from the material mixing to the final compaction. The work methods and the process have been described in more detail in the technical reports and the Guide. It is important to note, that the use of the new types of materials in road constructions can be carried out with existing and conventional construction equipment.

Table (1) takes a look at the different pilot structures and some conventional reference structures that have been chosen for subsequent life-cycle cost etc. calculations (it must noted that the reference structures have been chosen by the project manager amongst several possible reference structures).

Table 1: Pilot and reference structures

	Pilot	Reference
1	Renovation of an existing gravel road by stabilisation with a binder based on fly ash. Costs of pilot: 44 000 €/km	Conventional frost heave renovation with help of filter cloth and 300 mm of crushed aggregates. Costs: 52 400 €/km – min. 26 200 €/km
2	Renovation of an existing gravel road with fibre-ash structural course. Costs of pilot: 61 000 €/km	Like above
3	Construction of a light traffic lane with fibre-ash structural course. Different material mixtures of the covering course based on a mixture of crushed stone + filtercake. Costs of pilot: 63 000 €/km (without preloading of the basement).	Conventional low-cost light traffic lane meant for sparsely populated areas. Surfacing with gravel + bituminous binder or pavement with asphalt-concrete. Costs: 62 000 – 70 000 €/km
4	Safety lane for light traffic with fibre-ash structural course. Pavement with soft asphalt-concrete. Costs of pilot: 52 500 €/km	Safety lane with conventional stone aggregates. Pavement with soft asphalt-concrete. Costs: 37 000 €/km
5	Groundwater protection structure at the roadside. Sealing material: fibre-clay. Costs of pilot could not be estimated in a reliable way.	Conventional groundwater protection structure at the roadside (bentonite clay as sealing material) .

The costs given in the table (1) include probably also some inefficiency costs of the pilot structures. The cost data include work and material costs, but not any overheads, profit margin or VAT.

There are a lot of long-term background references and data about the conventional reference structures. This is not the advantage of the pilot structures. The pilot structures have been designed on the basis of results from earlier laboratory tests, different test constructions and other field tests. The long-term behaviour and properties of the pilot structures will depend on the homogeneity and quality of the material components and their mixtures as well as on the quality of the methods and technology used at the different stages of the construction process. However, there are certain technical and economical expectations from the pilot structures, mainly the following ones:

- Renovation and improvement of the existing gravel roads by stabilisation or with fibre-ash structural course will give significantly more sustainable results than renovation with the conventional methods. The results will be obtained eco-efficiently: there is no need for virgin stone aggregates and industrial by-products (or waste) will be reused as the main material component.

- Light traffic lanes based on fibre-ash structural courses will be more eco-efficient (see above), durable and cost-effective constructions than the conventional alternatives. This will increase the possibilities to construct safe light traffic lanes even in the sparsely populated districts. Also the safety lanes based on fibre-ash structural courses are safe and eco-efficient alternatives to improve the light traffic safety especially when the total driveway will be renovated or (at least) will get a new pavement or covering course. In order to obtain their real benefits, the work methods of both alternatives have to be improved and the surfacing materials need further development.

- Groundwater protection structure at the roadside with fibre-clay will be an eco-efficient alternative to the conventional structures. In order to obtain its real benefits especially the compaction method has to be developed.

5.2.2. *Eco-efficiency and life-cycle costs*

Table (1) above gives also the cost information used for the subsequent calculation of eco-efficiency and life-cycle costs. Costs of the pilots have been taken from the records of FRE and include only direct work costs and material costs (inclusive transports). The industrial by-products do not have any market price at present. The material costs have been estimated on the basis of the known material treatment and transport costs. The costs of the reference structures have been roughly estimated to the corresponding cost level and with respect to the public price information of the Finnish Road Administration.

The transport distances of the by-products to the pilot sites have been relatively long; 85 kilometres of the fibre-clay, about 95 kilometres of the fly ash, and 350 kilometres of the filtercake. The economically feasible transport distance should be determined case by case with respect to the competitive situation. A general approximation has been made in earlier studies and on the basis of current price level of the natural aggregates [see references of Impact Assessment Report, in Finnish]; in case the transport distance of natural stone materials is about ten kilometres the economically and competitively feasible transport distance of industrial by-products is at least 50 kilometres. In case the use of by-products will reduce the total amount of materials needed for a construction project the feasible transport distance may be even longer. Also the technical properties like strengthening ability and weight affect the judgment.

5.2.2.1. Eco-efficiency

For assessing of the eco-efficiency of the alternative structures one needs both economical and environmental information. Eco-efficient operations will produce more economical value with less environmental (negative) impacts. With help of the data of the Kukkia Circlet project it is possible to calculate the eco-efficiency on the basis of a structure's construction costs (= value) vs. the amount of non-renewable stone aggregates needed for the structure (= impact). This information is readily available for the calculations and gives following eco-efficiency results (costs / amount of natural aggregates) e.g. for renovation of a road having the width of 6,0 metres and the length of one kilometre:

1) Stabilisation of an existing gravel road: construction costs 44 000 €/km and the need for non-renewable natural aggregates only for the covering course 600 m^3. Eco-efficiency = 44000:600 = 73
2) Renovation of an existing gravel road with fibre-ash structural course: construction costs 61 000 €/km and the need for non-renewable natural aggregates only for the covering course 600 m^3. Eco-efficiency = 61000:600 = 101
3) Reference method of renovation: construction costs 52 400 €/km and the need for non-renewable natural aggregates 1800 m^3. Eco-efficiency = 52400:1800 = 29
4) The former with costs of only 26 200 €/km and the need for non-renewable natural aggregates 1800 m^3. Eco-efficiency = 26200:1800 = 15

On the basis of the former calculations, the increase of costs or the decrease of the use of natural aggregates will increase the eco-efficiency. The results are not unambiguous and we have noted the need for more indicators (like the total energy consumption and corresponding emissions of the different alternatives).

5.2.2.2. Life-cycle costs

The Impact Assessment report (in Finnish) includes comparisons for different covering course materials, different renovation alternatives of existing gravel roads and the different light traffic lane alternatives. This report includes only the LCC calculations of the different renovation alternatives of existing gravel roads as the tested pilot structures seem to be quite ready for wider exploitation in Finland and in other European countries. The LCC calculations are taking a time horizon of 25 years and using 5 % rate of interest. The salvage value after 25 years as well as the financing costs of renovation have been omitted in these calculations.

The LCC calculations are made for following alternatives

1. The reference method where the levelled road surface is covered with filter cloth and this with a 300 mm thick layer of crushed stone aggregates. The highest cost estimation in table (1).
2. The reference method where the levelled road surface is covered with filter cloth and this with a 300 mm thick layer of crushed stone aggregates. The lower cost estimation in table (1).
3. Pilot 2002 renovation of the existing gravel road by stabilisation with binders based on fly ash, and

4. Pilot 2003 renovation of the existing gravel road with fibre-ash structural course

The maintenance strategy of the road renovated with the reference method (alternatives 1 – 2) is following: Need for renovation (with the reference method) due to abrasion, settlements, erosion and frost heave is usually evident every 8th year. Additionally, the surfacing (with stone aggregates) has to be made every 5th year (4800 €/km), the ditches opened at the roadsides every 3rd year (3000 €/km) and the repair of spotholes etc. performed every year (280 €/km) after the latest renovation. The salt is spread for dust prevention every year (in the spring), but the costs of this measure are omitted in this calculation.

The assessment of the maintenance need and the strategy for the pilot alternatives are as follows:

- Pilot 2002 (alternative 3): the renovation or stabilisation will be repeated every 15th year, the ditch opening will be needed every 5th year (3000 €/km) after stabilisation, and the potholes and other patching will be repeated every 3rd year (280 €/km) after stabilisation.

- Pilot 2003 (alternative 4): The renovation with new fibre-ash course will be repeated every 20th year. The ditch opening and patching will be made like for the alternative 3.

Also in these pilot cases the dust prevention is omitted. So far, no considerations have been made in regard to the treatment of the existing materials of the different alternatives when repeating the renovation. The target is, however, that there will be no transfer or exchange of the existing material masses; those will be reused in the renovation process – even when completely repairing the road after 25 to 40 years.

The LCC calculation results are given in table (2). The renovation or "investment" costs are taken from table (1). On the basis of these calculations and the maintenance strategies the pilot alternatives 3 and 4 are more economical than the reference alternative 1 (higher cost level), and the alternative 3 (stabilisation) also more economical than the reference alternative 2 (lower cost level).

Table 2: LCC comparison of different renovation alternatives

	Renovation Alternatives			
	1	2	3	4
Present Value of the investment (year 0)	52 400	26 200	44 000	61 000
Present Value of maintenance (25 years period)	92 392	53 602	29 908	31 733
Total Present Value	144 792	79 802	73 908	92 733
Annual Cost	10 273	5 662	5 244	6 580
Difference of the alternative in relation to alternative 1 [%]			-49 / -7	-36 / 16

5.3. The environmental impact of the pilot alternatives

5.3.1. The impact on the amount of waste and need for natural aggregates in construction

The project is based on the reuse of industrial by-products (or currently: waste) as road construction materials. The objective of the project is to demonstrate that the industrial by-products can compensate for the natural stone aggregates in many applications. Consequently, the industrial by-products will be exploited beneficially instead of dumping them in landfills, and the natural stone resources can be saved and restricted for specific usage.

The demonstrated pilot alternatives for the construction and renovation of secondary roads are technically feasible where there are suitable industrial by-products available close to the construction or renovation site. The following calculations will indicate the potential of saving natural stone resources in case all fly ash and fibre sludge from the Finnish and European forest industry will be used in the road construction. Also the other pilot structures of Kukkia Circlet project could be examples of the potential to reuse industrial by-products and save natural stone resources though we have chosen to make only the given calculations. The calculations are made for one kilometre of road of six metres width and with following unit consumption data:

- Reference alternative, i.e. conventional renovation with filter cloth and 300 mm crushed stone: Crushed stone (#0-16 mm), the bulk weight $\rho \sim 1,8$ (wet) tonnes/m^3; the consumption 1750 tonnes/road-km or c. 970 m^3/road-km.

- Pilot 2002, i.e. stabilisation with a binder based on fly ash: The binder material is fly-ash + cement, 10 % of the bulk weight of the existing stone material of the road; the bulk weight of fly ash is $\rho \sim 0,75$ (dry) tonnes/m^3, the consumption of fly ash is 158 tonnes/km or c. 211 m^3/km.

- Pilot 2003, i.e. renovation of an existing gravel road with fibre-ash structural course: The fibre-ash mixture is 56 % fibre-clay and 39 % fly ash and 5 % binder (omitted here). The bulk weight of fibre-clay is $\rho \sim 0,85$ (wet) tonnes/m^3 and of fly ash $\rho \sim 0,9$ (wet)tonnes/m^3. The consumption of fibre-clay is about 855 tonnes/km or c. 1006 m^3/km and of fly ash about 599 tonnes/km or c. 665 m^3/km.

On the basis of the calculated unit consumption of different alternatives above we have made following conclusions:

- The available, not yet recycled amount of fly ash could be used to renovate over 700 kilometres of secondary gravel roads by stabilisation in Finland each year. Regarding the LCC calculations presented in table (2), the annual costs of this method could be even about 50 % smaller than the costs of conventional maintenance. Thus, it could be possible to double the renovation of frost damaged gravel roads without increasing the current budget level in Finland.

- In Europe, in the regions of the existing paper mills, at least 8500 kilometres corresponding secondary roads could be renovated by stabilisation with help of the fly ashes from the energy production.

- It would be possible to save even 175 000 tonnes of natural stone aggregates in case 100 kilometres of gravel roads will be renovated by stabilisation or with help of fibre-ash structural courses. This is not much in comparison with the total usage of stone aggregates in Finland (for roads about 23 Million tonnes each year), but even this means savings - also in energy consumption.

- We assume that a lorry can carry about 40 m^3 loads of material. Thus, one renovated road kilometre needs about five to six loads of fly ash (stabilisation) or alternatively 24 to 25 loads of crushed stone. The fuel consumptions and the discharges into the environment depend also on the transport distances but will correspond to the former figures (though not calculated for this report).

- In case most of the fibre-clay production will be used for the renovation of the secondary road network in Finland it is possible to renovate more than 400 kilometres of gravel roads with help of fibre-ash structural courses. With this method the life-cycle costs may be even 36 % less than the life-cycle costs of the reference method (see table 2). Without increasing the current budget level it could be possible to renovate 300 kilometres frost damaged gravel roads with this pilot alternative in Finland each year.

- In the European area the corresponding potential with fibre-ash structural courses is almost 2500 road-kilometres each year.

5.3.2. Other environmental impacts

The environmental follow-up at the pilot sites has been active during the project period. The follow-up has been made by analysing the content of harmful inorganic elements in soil samples from the sides of the pilot structures and in water samples from the wells close to the pilot structures. The samples have been taken before any pilot construction and then in the early autumn of 2002 (for Pilot 2002) and 2003 (for all pilots). The results have shown no such changes in the environment that could be caused by the pilot structures. The latest and the project period's final results of the environmental follow-up are given in Annex (1) of this report. The environmental follow-up will continue in 2005, at least.

Dusting of the dry fly ash and other dry binder materials was noted at the storage and mixing site during the Pilot 2002 processing especially in the very dry summer 2002. This has been a well known problem already before the start of the project, and the dusting could be restricted by choosing a storage and mixing area that was distant from the human settlements, and by moisturising and covering the dry materials both for the transports and during the storage. The personnel working in the storage, mixing and construction area was provided with protective equipment because of the dusting.

Earlier test projects with fly ash and fibre-ash have shown that a rainy weather is usually not a problem. In the case of fibre ash even a heavy rainfall (in the summer 2003) did not cause any problems (a heavy rainfall on uncovered fly ash would have been more disastrous). Summer 2002 was very dry and some rain would have helped with the construction process. As this was not possible a lot of lake water was needed to have adequate moisture on the surface of the road and in the materials.

6. DISSEMINATION ACTIVITIES AND DELIVERABLES

The objectives of dissemination were stated in the original proposal as follows: "We will raise awareness of the target groups and promote the exploitation of the project results for the environmental, technical and economical benefits of the European societies by disseminating information of the new management systems to reuse and recycle high volumes of industrial waste in road construction. The dissemination activities will ascertain that we will reach and widely cover the potential target groups and effectively channel the exploitation of the project results in Europe."

The target groups of the project have been especially the producers of waste (the industry), the road administration organisations and institutes, the civil engineering and construction sector, the waste management sector, the environmental authorities and institutes, the municipalities and the standardisation organisations in Europe.

Dissemination plan included following activities:

1. Creation of the contact network
2. Creation and spreading of the project leaflet to the contact network
3. Creation and upkeeping of the project web-pages
4. Video filming of the Pilots 2002 and 2003
5. Arranging of a Workshop in June 2004
6. Guide for the instruction and advice to exploit the new construction systems

The dissemination activities have been accomplished according to the plan although some deviations with respect to the plan have been necessary. The actual dissemination activities were following:

1. **Contact network** was "created" during the first project year, in August – September 2002. The target was to create a list of contacts by collecting the contact information from the partners. It was soon evident that each partner wished to use their own appropriate contact networks to inform about the project, and no common list of contacts was available. However, all partners have informed to have their contact network and this was accepted by the beneficiary FRE. The contact network of Ramboll Finland (then: Viatek) was also used for the spreading of project information.
2. **A leaflet** that informed about the project plan was available in August 2002, and this leaflet was sent to the project partners and through them to the contact network. The leaflet information is still available at the project www-pages (e.g. the English pages' link "project").
3. **WWW-pages** of the project were created and started in September 2002. The www-pages include the published project material like the reports, also the progress reports to the Commission. The pages include also the video presentation (see next).

4. **Video presentation** about the Pilots 2002 and 2003 was made during the project period. The video was finalised in the spring 2004 and published in DVD-disks that are possible to display at least with the newest DVD-players and computer systems. Like told above the video- or rather DVD-presentation is now available in the www-pages. The presentation is actually a practical guide to the new construction systems of the pilots.
5. **Project workshop** was planned to be arranged to the target groups in Tampere in June 2004. However, in the autumn 2003 the Finnish Environment Institute informed about the arrangements of a more extensive 7th International Symposium on Environmental Geotechnology and Global Sustainable Development. The Symposium was planned by the International Society of Environmental Geotechnology, the Finnish Environmental Institute and the Helsinki University of Technology. The target audience included the same target group as Kukkia Circlet. The Steering Group was given the opportunity to have the project presentations in connection of this Symposium (a specific workshop for the project was finally not possible). The symposium was held in Espoo, Finland in June 8-10, 2004. The report has been submitted as an annex of the Progress Report IV (1.4. – 30.9.2004). Though this workshop did not totally fulfil the idea of the project workshop it would have been impossible to arrange any other event or workshop at the same time.
6. The **Guide** completes the video- or DVD-presentation with more detailed instructions and advice on the implementation of the pilot structures. The Guide is available in the project's Finnish www-pages – and probably in the future also in the English www-pages. The completion of the Guide was possible only after all project follow-up information has been available and commented by the external evaluators. Therefore, the Guide (in Finnish) has been finished only in March 2005.

In addition there have been different meetings of the industrial partners, like Kemira, Gapac and Finncao, with their industrial colleges in Europe to spread information about the project. Also, the project has been presented in many events in Nordic and other European countries, for example in some important conferences having participants from different target groups. Amongst the important events have been the 9th International Conference "Ashes from Power Generation" in Poland in October 2002 (attended by Pentti Lahtinen, Viatek), workshop "Industrial By-products in Infrastructures" in Tampere in November 2002 (arranged by FRE, Viatek and the industry), and the 5th International Conference on the Environmental and Technical Implications of Construction with Alternative Materials, WASCON 2003 in Spain in June 2003 (attended by Seppo Kolkka and Aino Maijala as representatives of the project).

Also local events have been arranged during the project. The most important events have been the presentations of the project to the local inhabitants before the pilot constructions were started. Reciprocally, the inhabitants of the municipality arranged an opening of the newly opened renovated "Pilot 2002 road" at the end of September 2002. Corresponding openings of Pilot 2003 sites were discussed but have not been arranged. And finally but not least, the national press has been regularly interested in the project and spread information about its different stages during the project period.

7. EVALUATION AND CONCLUSIONS

PROCESS

Evaluation of the process that has been described and partly also evaluated in chapter refers here in the position taken by the external evaluations from Finnish Road Administration (Tuomo Kallionpää) and Tampere University of Technology (Pauli Kolisoja).

The constraints on the reuse of industrial by-products (or recycled materials) in soil construction applications involve factors that are on the other hand technical and legislative and on the other hand based on the prejudice and lack of knowledge. Most of the prejudices are based on the lack of knowledge about the technical properties and environmental impacts of the recycled materials as well as inadequate practical experience of the technical behaviour of the different applications and the construction with recycled materials. The demonstration projects like Kukkia Circlet have therefore a very important role in the development towards sustainable and environmentally controlled soil construction technology and processes.

With respect to the pilot construction processes and follow-up results the pilot structures in general have performed well and met the technical objectives, and with respect to the results of the local opinion poll the inhabitants and other road users have been very satisfied. However, there are some parts of Pilot 2003 that did not totally meet the targeted quality and need further development like the groundwater protection structure and the safety lanes on the roadsides. The reasons and needs for the development have been discussed in the relevant reports.

The work has to continue to remove the constraints to the use of recycled materials in soil construction. The important steps should include

- Theoretical dimensioning models for recycled materials that would help in the design and engineering of the appropriate structural applications and in the more reliable forecasting of the long-term behaviour, durability and life of the structures based on recycled materials. The reliable forecasts are absolute prerequisites to the reliable life-cycle cost assessments for example in relation to the conventional reference structures.

- The conclusions on the performance and durability of the pilot structures need well-planned, controlled and documented follow-up tests and studies in the longer term. This is important for the verification and acceptance of the new types of (recycled) materials and the structures based on them.

- In addition to the life-cycle performance we need more discussions, research and development with respect to the period when the structures based on recycled materials are at the end of their lifetime. The basic presumption must be that the recycled materials will be reused beneficially at the same renovated site or at other construction sites.

PROJECT MANAGEMENT, PROBLEMS ENCOUNTERED, PARTNERSHIPS AND THEIR ADDED VALUE

The project management or co-operation of the partners have not encountered any problems or drawbacks during the project period. FRE as the beneficiary has carried out the main responsibility for the project performance in all tasks. The industrial partners Finncao, Gapac and Kemira have provided the project with by-product materials and recipes and instructions for the construction. The municipality of Luopioinen has provided the project with the personnel for the upkeeping of the www-pages during the project period, the storage and mixing site and local personnel to help in construction, and arranged the meetings with the local inhabitants and the local opinion poll. The Council of Tampere Region has provided the video filming and production of the DVD-presentations, and financed partly also other dissemination. Expert representatives of the partners have been members of the project Steering Group and participated in totally eight SG-meetings apart from the separate working group meetings for the implementation of the pilots. The partners also have participated in compiling the project reports.

TECHNICAL AND COMMERCIAL APPLICATION (REPRODUCIBILITY, ECONOMIC FEASIBILITY, LIMITING FACTORS)

The technical limits have been stated above (see e.g. Process). Chapter (5) about Impact Assessment has given further evaluation about the projects' pilots economical, technical and environmental feasibility.

The Impact Assessment is mainly based on assumptions on the long-term performance of the pilot structures and on the choice of the reference structures. Also, the construction costs are only based on very narrow information from the project and on the general or public price information of the reference structures. A complete Impact Assessment would need a lot more reliable and long-term data and more detailed calculations than were possible. The Impact Assessment is indicative and shows the economical and technical potential of the recycled materials in Europe. Consequently, we find that similar applications based on recycled materials can be reproduced anywhere in Europe where there are forest industry. However, careful attention has to be given to the further need for development of some of the pilot structures.

RESULTS FOR POTENTIAL TARGET GROUPS

The project results are available to the potential target groups (the producers of waste (the industry), the road administration organisations and institutes, the civil engineering and construction sector, the waste management sector, the environmental authorities and institutes, the municipalities and the standardisation organisations in Europe) at the project www-sites. We have also on many occasions been able to spread and discuss the information and knowledge about the project and its results to the target groups during the project period (see Ch. 6).

COMPARISON TO THE PROJECT-OBJECTIVES

The project objectives have originally been stated as follows: “The project objective is to demonstrate the competitive ability, sustainability and environmental benefits of road construction methods that reuse old road material and recycle high-volume waste from the paper and chemical industry in construction and maintenance of secondary road network. The project will test new, innovative methods in the full scale, ascertain the proper performance of the new processes and show the favourable long-term behaviour and the environmental, technical, societal and economical benefits of the new methods to various interest groups in Europe.”

Referring to the project reports and the other chapters of this final report we have been able to meet the project objectives during the project period. However, we also have noted that the conclusions on the performance of the pilot structures cannot be made during the short project period, and that there is need for further development of some of the methods and technology before those are fully appropriate to be introduced in the European construction market.

ENVIRONMENTAL BENEFITS

Environmental benefits have been evaluated above in Chapter 5 (Impact Assessment) especially with respect to the possibility to compensate for the natural aggregates in construction and to beneficially reuse the industrial waste instead of dumping it in the landfills.

APPLICATION POSSIBILITIES IN SAME AND OTHER SECTORS (TRANSFERABILITY) ON LOCAL AND EU LEVEL (LIMITING FACTORS)

The similar structures and methods are applicable and transferable in the soil construction on both local and EU level. Limiting factors include the existence of the proper industry (the pilots and the project have been based on the ashes and fibre sludge of the forest industry) and on the hauling distance of the materials.

THE INNOVATIVE ASPECTS OF THE PROJECT ON (INTER)NATIONAL LEVEL

Ashes have been used in many countries in soil construction as filling materials or other road courses. Fibre sludge has been used in some countries (e.g. in Spain and Great Britain) for the closing landfills. Only in Finland there are tests on the fibre-ashes or ashes as stabilisation materials for road construction. The recycling of fibre-ash with its cost-efficiency and its frost resistant, resilient and durability properties is one of the major innovations of the project. Additionally, there is the method to cost-effectively renovate a road with binders based on reactive fly ash from the forest industry. This is also a process innovation and a new aspect to the soil construction sector: we really do not need to have new special machinery for the stabilisation but we need to carry out the work in a continuous and well-controlled process. Innovations include also the different types of structures like the groundwater protection structures with fibre sludge as the sealing material though the implementation of all structures were not successful during the project.

EFFECTIVENESS OF DISSEMINATION ACTIVITIES

The effectiveness of the dissemination activities has not been measured. However, both FRE, project partners and Ramboll have received interested inquiries and messages concerning the project and its results (both from national and EU-level).

RELEVANCE TO THE EU LEGISLATIVE FRAMEWORK (DIRECTIVES, POLICY DEVELOPMENT, ETC.)

The EU legislative framework, the policy papers like following ones

- COM(2004)38 final: Towards Sustainable technologies; an EU action plan for environmental technologies (we have the paper in Finnish and this is not a direct translation)

- COM(2001)31 final: Environment 2010: Our future, our choice. Communication on the sixth environment action programme of the European Community

- COM(2003)31 final: Towards a thematic strategy on the prevention and recycling of waste

imply that there must be development of technologies that make it possible to recycle appropriate waste for example in construction. Of course, the most important community target is to reduce the waste generation as far as possible. This is not totally possible and therefore the availability of feasible recycling technologies is a politically essential question. However, the project Kukkia Circlet acts as one important step towards the sustainable society.

In Finland the decree on the recycling of certain waste materials in construction is under drafting. The decree will involve certain waste types, like ashes, the use of which is permitted by a declaration procedure in case the waste material fulfils certain criteria with respect to the content and leaching of some harmful substances. The ashes of the forest industry are included in the decree at the first stage, and we hope that others (like fibre sludge) will follow. The project wishes to give additional information for these legislative procedures in Finland, and for the on-going and future legislative and standardisation processes in Europe.

8. FINANCIAL REPORT, COMMENTS

The summary of the financial report is in the following table.

	Cost category	Total cost according to the Commission's decision (budget) [€]	Costs incurred from 1.12.2001 to 31.12.2004 [€]	Incurred % total	Incurred % budget
1.	Personnel	305.834	251.144	21	82
2.	Travel	17.750	20.624	2	116
3.	External assistance	415.903	404.545	33	97
4.	Durables: total non-depreciated cost	-	-	-	-
	- *Infrastructure*	-	-	-	-
	- *Equipment*	-	-	-	-
	- *Prototypes*	-	-	-	-
5.	Consumables	417.903	444.737	37	106
6.	Other costs	63.000	64.368	5	102
7.	Overheads	33.797	26.029	2	77
	SUM TOTAL	**1.253.630**	**1.211.447**	100	97

The project has met 97 per cent of the total budgeted costs on 31st December 2004. The major cost categories of this kind of a project involving a lot of construction works have been the personnel, external assistance and consumables categories. During the project it was not found necessary to make any changes to the budget figures or categories although

1) some of the cost items slightly increase the targeted budget level (Travel, Consumables, Other costs). This was noted finally quite late during the final project year.

2) there has been argumentation and discussion as to the interpretation of the category for some cost items, especially those involving the usage of FRE's own equipment and storage materials for the implementation of the pilot constructions.

9. ANNEX

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