# LIFE CYCLE CASE STUDY: UTILISING SURPLUS SOILS FOR CONSTRUCTING AN URBAN AREA IN A FLOOD PRONE ZONE

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**Abstract**

A streamlined Life Cycle Assessment was performed for the construction pilot site called a Dog Park, in Espoo in Perkkaa district. The pilot was carried out in the framework of the ABSOILS project that focuses on the utilisation of surplus soils and fly ash in civil engineering applications. The low quality soils in the area were stabilised with fly ash and cement and thus the geotechnical quality of the soils was improved. In the LCA, the stabilisation with fly ash was compared to stabilisation with pure cement and to a conventional method – filling with a commercial light weight material.

According to the preliminary results, the use of fly ash as a binder in stabilisation exerts less environmental impacts than the other alternatives. The fly ash produced in a nearby power plant would be considered waste without the utilisation target. Also, surplus soils originating from various construction sites are usually transported to landfills as their geotechnical quality is considered too low for conventional constructions.

The ABSOILS project is carried out in co-operation with Lemminkäinen Oy, Rudus Oy and Ramboll Finland Oy. The project is supported by the cities of Helsinki, Espoo and Vantaa as city developers/constructors and Ministry of the Environment. The aim of the project is to decrease landfilling of usable materials and the depletion of virgin natural resources such as rocks and gravel. The project is co-financed by the EU LIFE+ Environmental Policy & Governance programme (LIFE09 ENV/FI/000575).

**Keywords**

Streamlined LCA, fly ash, mass stabilisation, surplus soils, waste utilisation

## 1. INTRODUCTION

The streamlined LCA for the pilot Dog Park is part of the Verification action of the ABSOILS project (Sustainable Methods and Processes to Convert Abandoned Low-Quality Soils into Construction Materials). ABSOILS demonstrates conversion of abandoned and low-quality soils – such as silt, clay and mud – into construction materials. The project started in September 2010 and will be finished in December 2014.

The implementation of the ABSOILS project has been carried out with several actions in addition to Verification action; Preparation, Materials, Applications, Piloting, Dissemination and Management. The first four actions mentioned (Preparation…Piloting) all affect and feed information and data for the Verification action.

The area of the pilot Dog Park is located in a flood prone zone. The area used to be a sea bed and therefore the soil was very soft clay. The thickness of the clay layer is ~11…14 meters and the area had been classified as a very difficult constructing target due to its low load bearing capacity. The pilot structure is a higher embankment by +2…2.5 meters (ASL) to prevent flooding. In order to prevent mass exchange and landfilling of the soft soils, the original clay layer and some surplus soils from an adjacent construction site were mass stabilised.

In this LCA, the studied alternatives are (Figure 1 show the structural alternatives and the mass stabilisation technique):

- ALT 1 - stabilisation with cement (Alt 1),
- ALT 2 - stabilisation with cement and fly ash (Alt 2) and
- ALT 3 - a conventional method – filling with a light weight material (light expanded clay aggregate)

| Alt 1 | Alt 2 | Alt 3 |
|---|---|---|
| Preloading embankment | Preloading embankment | Embankment |
| Geotextile | Geotextile | Geotextile |
| Mass stabilisation (3,0 m) of surplus clay and natural clay: binder cement | Mass stabilisation (3,0 m) of surplus clay and natural clay: binders cement + fly ash | Removal of soft soil (1 m) and fill with light expanded clay aggregate (1,7 m) |
| | | Geotextile |
| Natural clay deposit | Natural clay deposit | Natural clay deposit |

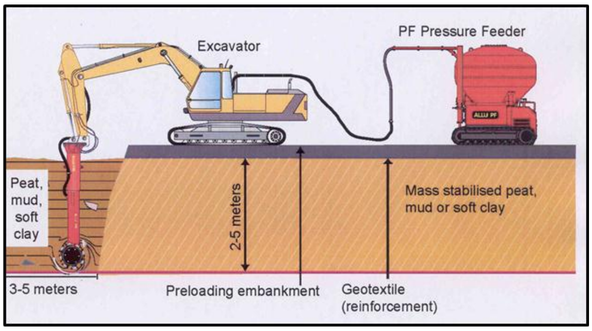


Figure 1: The structure alternatives in Dog Park pilot and the principle of the mass stabilisation technique.

## 2. BACKGROUND INFORMATION

The LCA was carried out in order to verify that the pilot alternatives (stabilisation Alt 1 and Alt 2) are environmentally and economically sound and feasible in comparison to the conventional alternative (Alt 3). The LCA was performed according to the principles of EN ISO 14040:2006, though as a Streamlined LCA (not complete). Streamlining is based on available resources (time and financing) and data.

### 2.1 Scope of the study

The studied environmental impact categories are the global warming potential (GWP) and the depletion of natural resources. These categories are the major environmental impacts of infrastructure construction. Also, this choice was pragmatic due to the availability of data especially about the energy consumption of the individual processes. Energy consumption is a major cause for many airborne emissions and the depletion of natural resources. Moreover, the manufacturing of cement needs relatively large amounts of natural resources and energy. In this project's piloting, fly ash - a by-product from energy production - is used as a partial substituent for cement in order to decrease the environmental impacts (the global warming potential and the need for virgin non-renewable materials) of the construction of the embankment.

The Functional Unit (FU) for the LCA is chosen to be 100 $m^2$ of the construction.

### 2.2 Assumptions and available data

The following assumptions were made for the LCA study:

- Emissions from the generation of the fly ash and surplus soils are assumed to be zero. These materials are considered waste from the main productions: production of energy and moving earth from the adjacent mass replacement site. Normally, these materials are deposited into landfills involving landfill fees and landfill taxes.

- All structures (Alt 1 – Alt 3) are the established methods.
- The design of the pilot structures and the laboratory works of the project are not included in the calculations because the established practices do not require as detailed and wide-ranging work tasks as in the case of the new practices.
- The production of factories, production plants and landfills are not included as these investments have not been made because of the needs of individual construction projects.
- The production of the vehicles or machines used in the transportation and construction is not been included in the product system for the same reason as above.
- Production and transportation of fuels are not included for the same reason as above.

The data used in the LCA calculations is mainly public data, gathered from various environmental reports, public databases and other literature. For example, the available data for vehicles emission inventory originate from the VTT Technical Research Centre Finland's Lipasto database of 2012. This data takes into account the emissions generated in the production of fuels. Some data are based on the information from Ramboll and Lemminkäinen experts, like for instance the average values for rock material.

The inventory stage of the LCA calculation included the inventory of material production, transportation and construction. In the transportation inventory, the studied vehicles were a dump truck with 19 tons capacity and a tank truck with 40 tons of capacity. The tank truck is used for the transportation of binders (cement and fly ash). Fuel consumption is taken into account in the calculations for every inventory stage. In the construction stage, the calculations are based on the Building Information Cards and, in the case of mass stabilisation, on the actual capacities.

The depletion of natural resources refers to such material as gravel, crushed stone, etc.

## 3. RESULTS

According to the preliminary results, the use of fly ash as a substituent for cement in stabilisation (Alt 2) exerts less environmental impacts than the other alternatives (Figure 2). Both of the studied environmental impact categories are highest in Alt 3.

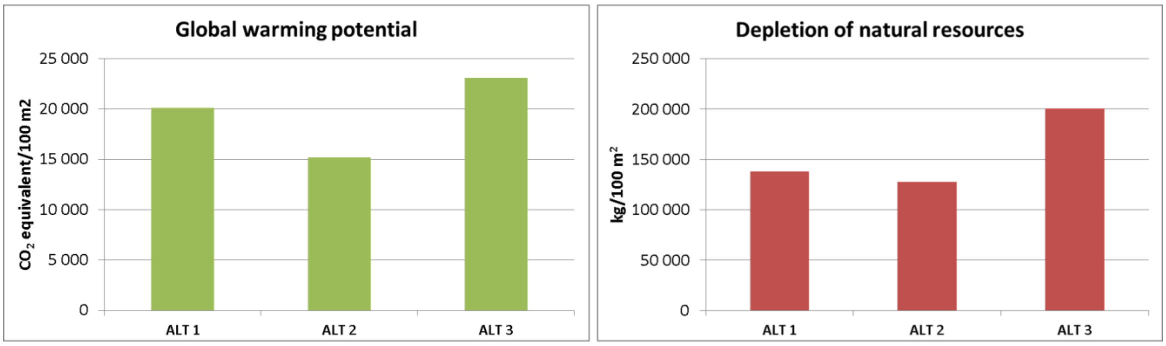


Figure 2: GWP and depletion of natural resources in different alternatives.

In Figure 3, the numerical values of each environmental impact categories and energy consumption are totalled without units and scaled to be of the equivalent magnitude in order to obtain a reasonable graphic presentation. All the environmental loads in Alt 2 diminish when cement is partly replaced with fly ash.

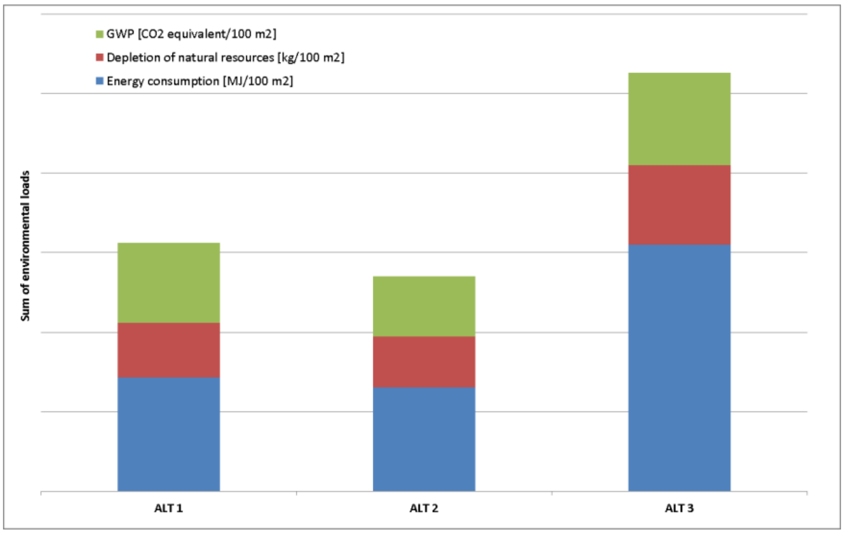


Figure 3: The sum of environmental loads.

## 4. CONCLUSIONS

This LCA is part of the Verification action of the ABSOILS project. According to the results, it can be assumed that the utilisation of surplus soils and substituting part of the cement with fly ash in stabilisation cause less environmental impacts than construction with a conventional structure or while using cement as the only binder in stabilisation.

Environmental impacts are both local and global. The local environmental impacts are changes in the land use. The area was previously un-built, so building the Dog Park has certainly affected the ecology of the area. Yet, according to the nature survey made in the area in 2007, there were no such nature values that would have prevented building actions. Previously the area was unutilised, but now it plays an important leisure role. The airborne release of greenhouse gases from the different unit processes affects globally, e.g. the climate change that is indicated by the Global Warming Potential (GWP).

The project details, reports, information of different pilots and other useful data can be found at the website http://projektit.ramboll.fi/life/absoils/index_eng.htm.

## ACKNOWLEDGEMENTS

Special thanks to EU LIFE+ programme for funding the ABSOILS project (LIFE09 ENV/FI/000575). The need for utilising surplus soils is urgent all over Europe, so hopefully with the information gathered in this project, new pilots and technologies using low quality soils and industrial by-products can be promoted.

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## ANALYSE DU CYCLE DE VIE : MISE À PROFIT DES SOLS EXCÉDENTAIRES DANS L'AMÉNAGEMENT URBAIN DE TERRAINS FACILEMENT INONDABLES

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Une analyse du cycle de vie (ACV) simplifiée a été réalisée sur un site pilote faisant parti du projet ABSOILS, lequel site a accueilli la construction d'un parc canin de Perkkaa à Espoo utilisant des sols excédentaires et des cendres volantes. L'analyse du cycle de vie fait partie de l'évaluation des solutions pilotes, c'est-à-dire de l'utilisation des sols excédentaires mous dans les travaux de génie civil dans le contexte du projet ABSOILS financé par EU Life+ (LIFE09 ENV/FI/000575). Lemminkäinen (anciennement Biomaa Oy), Rudus Oy ainsi que Ramboll Finland Oy ont participé à ce projet. Le projet a débuté en septembre 2010 et prendra fin en décembre 2014.

Les sols sur le site du futur parc canin de Perkkaa étaient de très mauvaise qualité. Le site du parc est situé sur un terrain inondable qui était autrefois recouvert par la mer. Les sols sont constitués d'argiles extrêmement molles et l'épaisseur de la couche argileuse peut atteindre entre 11 et 14 mètres. La zone est classée comme difficilement constructible en raison de la capacité portante peu élevée du site. Le terrain du parc canin a été rehaussé de 2 à 2,5 mètres pour éviter les inondations. Afin de ne pas recourir aux échanges de sols et la mise en décharge, la couche argileuse d'origine et les sols excédentaires de terrains à bâtir avoisinant ont été stabilisés. Dans cette analyse du cycle de vie, les alternatives à comparer étaient : stabilisation à l'aide de ciment (Alt 1), stabilisation à l'aide d'un mélange de ciment et de cendres volantes (Alt 2), et utilisation d'une structure d'allègement (Alt 3).

L'analyse du cycle de vie ambitionne de vérifier que l'alternative pilote de stabilisation à l'aide de ciment et cendres volantes s'avère un choix judicieux en termes environnementaux et économiques par rapport à l'alternative de composition plus traditionnelle.

L'analyse s'est intéressée plus particulièrement à l'impact sur l'environnement des alternatives, notamment à leur contribution au réchauffement global (PRG) et à la consommation des ressources naturelles. Ce choix découle du fait que secteur des travaux publics a de fortes incidences sur ces derniers. De même, la quantité et la qualité des informations facilement disponibles ont rendu possible l'analyse de ces impacts environnementaux. Au stade de l'inventaire, l'évaluation de la consommation énergétique de certains processus a servi de base pour mesurer les émissions des gaz à effet de serre dans l'atmosphère et, de ce fait, les effets de ces processus dans le réchauffement climatique. L'unité fonctionnelle de l'analyse du cycle de vie représente 100 $m^2$ de la structure à évaluer.

Les résultats de cette analyse montrent que la stabilisation effectuée utilisant un mélange de ciment et de cendres volantes a un impact moins important sur l'environnement. Cela s'explique principalement par le fait qu'une partie du ciment est remplacée par des cendres volantes. Dans les calculs, les cendres volantes ne sont pas associées à des émissions, puisqu'elles sont un résidu industriel qui est généré lors de l'opérations des centrales électriques et thermiques. Si les cendres volantes ne sont pas utilisées, elles deviendront un déchet de la production d'énergie et seront, selon toute vraisemblance, mises en décharges.

Si le producteur des cendres volantes les met à profit, il peut éviter les frais de mise en décharge et les taxes sur les déchets. L'alternative qui envisage l'usage d'une structure d'allègement présente, dans cette étude, des impacts environnementaux plus importants. La production de galets d'argile expansée utilisée dans la structure d'allègement est responsable de nombreuses émissions et demande beaucoup d'énergie. La stabilisation à l'aide de ciment et la structure d'allègement sont comparables quant à leur contribution au réchauffement climatique.