Absoils - Sustainable Methods and Processes to Convert Abandoned Low-Quality Soils into Construction Materials

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Abstract

ABSOILS is a five-year project which demonstrates the utilisation of abandoned and low-quality soils - like for instance clays - as construction materials. The ABSOILS project is carried out in co-operation of Biomaa Oy, Rudus Oy and Ramboll Finland Oy. The cities of Helsinki, Espoo and Vantaa are involved in the project in the role of city developers or constructors. The project is co-financed by the EU LIFE+ Environmental Policy & Governance programme (LIFE09 ENV/FI/000575). The possibilities to utilise the excess soils are demonstrated with the pilot applications in the capital area where around 4 million tonnes of abandoned soil is generated every year. For example, the currently prevailing trend in the city of Helsinki includes landfilling of its surplus poor quality soils in the surrounding cities and replacing them with crushed aggregate transported from other places. The target of the project is to demonstrate and promote eco-efficient utilising of the poor quality soils in-situ and owing to that to decrease the use and the transportation need of crushed aggregates. In the project the abandoned and low-quality soil is improved by stabilisation with fly ashes, cement, lime, sulphur removal by-products and other wastes.

Key words: stabilisation; abandoned soils; binders; waste

Introduction

The world's urban population has passed 50 per cent. Europe is leaving the rural world behind even faster with the urban population over 74 per cent. Rapid urbanisation is accompanied by other phenomena, such as for instance the growth of car numbers, a considerable increase in mobility or an increase of personal living space. As more people demand more dwelling space, existing cities expand, new settlements emerge and the infrastructure is under continual development. Urban construction sites all over the world generate vast amounts of excess soil when the quality of the encountered soil is considered too low for the building purposes. The prevailing practice in many places is to dispose soils of a low load bearing capacity in landfills and to transport rock aggregate or gravel as replacement. It has been estimated that in Finland about 20 to 30 million tonnes of excess or abandoned soil are generated and landfilled every year.

Helsinki and other cities of the capital area are under a continual process of constructing new districts and improving the already existing ones. Like many other Finnish cities, Helsinki, Vantaa and Espoo suffer from the shortage of areas that constitute geotechnically easy targets for construction and are relatively close to the

city centre, so there is a need to utilise also areas which are challenging because of their geological structure. As a result, construction has to be performed in areas with very soft postglacial clay, mud or peat. According to the estimations, the amount of surplus soils generated in the capital area reaches to about 4 million tonnes annually. Other problems encountered include the shortage of fill and embankment materials, as well as the shortage of landfill areas for excess soils.

In Helsinki around 340 000 m^3 of uncontaminated clay and silt are transported to landfill sites and about 400 000 m^3 of rock aggregate is brought from elsewhere for replacement. The city has currently exceeded its landfilling capacity and the neighbouring cities, Vantaa and Espoo have introduced a ban on receiving the abandoned soils from Helsinki. All this forces the city to increase the efforts towards the utilisation of the surplus soil materials generated.

2 Mass stabilisation

The utilisation of the excess soils is possible due to, for instance, mass stabilisation technology. Mass stabilisation is a ground improvement method where binder is mixed into peat, mud or soft clay. The binder agent reacts with the stabilised material forming bonds that enhance the compressive strength and modulus of the material. The stabilisation agent is usually cement, but also industrial by-products or waste can be utilised in this process. The procedure is carried out with the help of a mixing tool installed on an excavator machine. (Lahtinen & Niutanen 2009)

By improving the chemical and physical properties of the excavated or dredged low-quality masses they can be turned into construction materials and therefore considerably reduce the amount of spoil and requirements for imported gravel or blasted rock as replacement, together with the associated needs for transportation.

In the last two decades mass stabilisation has been used in tens of various projects in Finland. The method has been applied for such purposes as settlement reduction in embankments, stability improvement, support of slopes and excavations, improvement of bearing capacity, reduction of vibrations, immobilisation and/or confinement of polluted soils. For instance, one rapidly increasing application type is the stabilisation of contaminated sediments. However, in spite of the numerous examples of success application, the use of mass stabilisation as an established method of dealing with the utilisation of poor quality excavation soils is still hindered by various factors including, among others, the legislative aspects, knowledge and attitude problems or a lack of information.

3 ABSOILS project

These challenges are addressed by the on-going EU LIFE+ project called ABSOILS. Its goal is to demonstrate the conversion of redundant and low-quality soils like soft clay into construction materials. The ABSOILS project is carried out in co-operation of the beneficiaries Biomaa Ltd, Rudus Ltd and Ramboll Finland Ldt, and with the support of the Ministry of the Environment and the cities Helsinki, Espoo and Vantaa. The project is co-financed by the EU LIFE+ Environmental Policy & Governance programme (LIFE09 ENV/FI/000575). The project started in September 2010 and will finish in December 2014. The objectives of the project include providing technical, environmental and methodological data and information on materials, materials mixtures and additives, storage, treatment and transports of materials as well as the diverse stages of construction. The project also involves a piloting action to demonstrate the practical implementation of different types of civil-engineering applications in full-scale pilots based on the use of redundant soft soils. The pilots enable addressing some crucial issues for the stabilisation process such

as: the determination of the most efficient recipes for the stabilisation of abandoned soils with commercial and non-commercial binder components, or the efficient mixing of different soft clay materials and powdery binder materials. The project's aim is also to create and demonstrate a Model for Sustainable Regional Material Service System (RMSS) for the capital area. The RMSS will direct the use of regionally produced and generated materials and aggregates to the short-term and long-term infrastructure construction projects with the assistance of practical logistics and Internet operated database. (Absoils Progress Report 2011)

4 ABSOILS project pilots

The ABSOILS project actions include demonstration of the proposed solutions with pilot applications. In 2011 two different pilot applications were performed (Ollila et al. 2012). Both of them took place in Helsinki and they were called the Arcada 2- and Jätkäsaari I –pilots.

Arcada 2: Clay was brought to the stabilisation site form the nearby sites which could not utilise it due to its poor quality ($V_{clay} \approx 32\ 000\ m^3$). The stabilised clay was designed to replace an old embankment floating over a clay layer. The area had a low stability and load bearing capacity. The site was originally filled from the sea with blasted rock in 1960's. The original aim was to displace the existing clay with blasted rock to create a foundation for a new highway. However, because of the deep clay layer and difficult circumstances the mass exchange failed leaving the blasted rock to float on top of the clay layer. The works included removing contaminated soils, lightening the blast rock structure and installing steel-pipe piles for a pile beam and slap structure to stop the lateral expansion caused by the blast rock structure. The "light weight structure" in the context of the Arcada 2 pilot means that the stabilised material (surplus clay and binders) was actually lighter than the blasted rock filling which had been replaced (Figure 1).

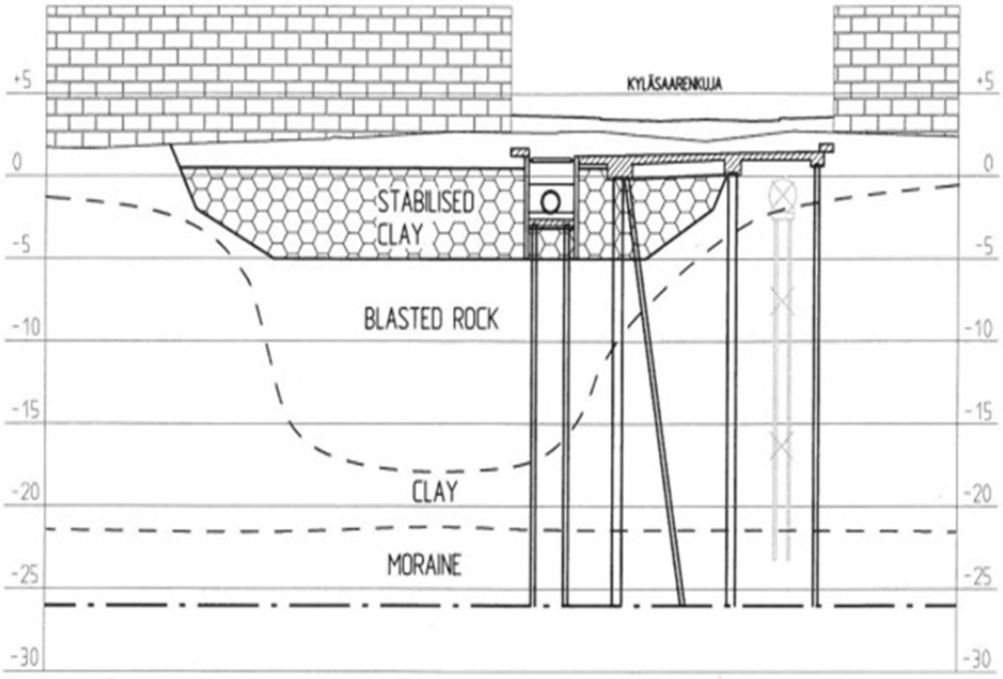

Figure 1. Arcada II cross sectional cut of the site with stabilised clay and steel-pipe columns. (Ollila et al. 2012)

In the case of the Arcada 2 pilot, there was no obligation to obtain environmental permit for the stabilisation process as it was performed with cement as a binder. The original plan, however, was to use industrial waste (fly ash or FGD) in order to diminish the amount of cement needed in the stabilisation. This solution would be more economic and environmentally feasible because of decreased CO_2 emissions resulting from the cement production. However, the expected duration of environmental permit process was considered a considerable hinder to the implementation of the Arcada 2 pilot and therefore it was given up.

Jätkäsaari I: The other pilot application carried out in 2011 dealt with the stabilisation of dredged sediments ($V_{sediments} \approx 20\ 000\ m^3$) in the Helsinki West Harbour area (Jätkäsaari). The Jätkäsaari pilot has been divided into two stages. In spring 2011 - in the first stage - part of the dredged sediments were stabilised (see Picture 2) with the use of commercial binder (cement). Since the current environmental permit allows only for cement stabilisation, there is a need for a new environmental permit in order to use fly ash and sulphur removal product in the stabilisation of the second stage of this pilot. The new permit application has been delivered to the authorities but the length of the permit procedure causes some uncertainties to the schedule of the pilot's second stage.

Figure 2. Stabilisation in progress in Jätkäsaari I pilot application.

Perkkaa: The next planned pilot application - a Dog Park in Espoo - is aimed to be carried out by utilising the low quality soil and industrial wastes as binders. The area of the park is 3 500 m^2 and it lies in the flood prone zone. The soil of the area is soft clay with low load bearing capacity. The thickness of the clay is about 12-14 m and the area is classified as a very difficult constructing target. It is aimed to raise the area to prevent flooding. This will be performed with poor quality excess soils from a neighbouring construction site by stabilising them together with the upper part of the original soil (the transportation distance is only 200…500 meters). It has been concluded that for this particular pilot site, the mass stabilisation is the only feasible solution. Since no high load bearing is required from the area, the utilisation amount of binders will be small. The area of the dog park is owned by the ABSOILS steering group member - the city of Espoo. Also this pilot application requires environmental permit due to the planned use of the industrial wastes in the stabilisation process.

Laboratory tests: The piloting action includes material tests in the laboratory before the launch of the construction works and the follow-up studies after the construction. The stabilisation properties of the materials are studied in laboratory by making specimens and studying the compressive strength of the

specimen (diameter 42 mm and height 84 mm) after specified curing time. Unconfined compressive strength test is done according to the SFS 179-2 – CEN ISO/TS 17892-7:fi standard. Usually several different binders and binder amounts are tested to determine the most suitable binder mixture for the construction. This is a way to gather data about the structures and to create information about the properties and possibilities of the abandoned soils.

Also the LCA and LCC studies concerning the solutions implemented by the pilot applications are carried out during the project.

5 Logistical and legal aspects

In order to make the utilisation of poor quality surplus soils an established practice in the Finnish cities, there is a need of various changes both in the awareness of the stakeholders and legislation. The solutions proposed by the ABSOILS project require good synchronisation of various flows of materials and wastes. Poor quality soils can either be utilised in situ or soils from various sources might be used in a neighbouring construction site and in this way it would eliminate landfilling. This demands, among others, a creation of a system which would allow to identify the potential sources and to follow materials flow. The ABSOILS projects aims to create such a system. However, in order to function properly, such a system will require active participation of all the actors involved in the infrastructure construction process.

One other issue is legislation and timing. The improvement of the technical and chemical properties of surplus soils can be obtained owing to stabilisation. In order to make stabilisation economically feasible and to enhance the utilisation of the industrial wastes fly ashes, flue gas desulphurisation gypsum and other gypsum by-products are tested and used as binder components. From a legislative point of view, the utilisation of ashes is nowadays possible in Finland on the basis of the decree number 403/2009 with only a notification to the authorities, if the fly ash alone is used as an own layer structure in road/field. However, if the fly ash is used as a binder in uncontaminated soil material the legislation requires an environmental permit.

As mentioned above, there was a need to apply for environmental permit for two pilot applications because of the intended use of fly ash. The permitting process is rather lengthy and creates a threat to the planned piloting applications, especially due to the fact that the timetables have to be synchronised with other construction works as the source of the surplus soils. There is also a lack of a consistent approach towards the issue of using industrial wastes in the stabilisation process and there seem to be considerable differences among various local permit authorities throughout the whole country. In general, the permitting issue in connection with the binders for the stabilisation process other than cement, constitutes a considerable hinder for the establishment of the eco-efficient practices in the field of abandoned soils and their utilisation.

The problem was communicated to the Ministry of Environment when the subject of the permit for the piloting in Espoo – the Dog Park was discussed. This has led to a discussion with a wider audience and the recognition of a need for a change. The Ministry of Environment hosted a seminar devoted to this issue on in September 2011 and the process of development of the legislation has been initiated. It is difficult to foresee whether the changes in the national legislation will occur during the ABSOILS project lifetime. However, the project will continue to be actively involved in this process.

One of the ways how the ABSOILS project is contributing to the development of the local legislation is by providing the authorities with the results of the current and previous projects that add to the creation of a database concerning various aspects of stabilisation. For instance, the results of the leaching tests performed

by the Rudus Oy for the Jätkäsaari sediments stabilised with an admixture containing cement, fly ash (Hanasaari hard coal power plant) and FGD products were part of a broader report on the environmental acceptability of using fly ash as a binder component in the stabilisation of the sediments.

The sediment samples used for the leaching tests originated from a Jätkäsaari sedimentation pond and a temporary storage pond. The test method applied was based on a Dutch standard NVN 7347/1999. The results indicate the amount of contaminants diffusing from the open surface of a test piece into the surrounding water during a certain time period. The amounts of the leaching contaminants is compared to the limit values set for a solidified material (a layer made of such solidified material cannot be thicker than 0.7m). The test results indicated that the leaching values were clearly below the limit. For the diffusion tests, there is not limit set by the Finnish Environment Institute for the sulphate and chloride leaching. However, it was observed that leaching of sulphate and chloride occurs also in samples stabilised only with cement.

6 Conclusions

- Rapid urbanisation process in Europe results in continual improvements and construction of new infrastructure.
- Urban construction sites all over the world generate vast amounts of excess soil when the quality of the encountered soil is considered too low for the building purposes.
- Landfilling of excess soil and replacing it with transported aggregates is not an eco-efficient practice.
- The cities in the capital area of Finland suffer from the shortage of areas that constitute geotechnically easy targets for construction.
- The amount of surplus soils generated in the capital area reaches to about 4 million tonnes annually.
- The shortage of fill and embankment materials, as well as the shortage of landfill areas for excess soils force the cities to come up with some solutions.
- Mass stabilisation enables the utilisation of the excess soils.
- By improving the chemical and physical properties of the excavated or dredged low-quality masses they can be turned into construction materials and therefore considerably reduce the amount of spoil and requirements for imported gravel or blasted rock as replacement.
- Various factors including low awareness, lack of knowledge and inconsistent legislation hinder the application of mass stabilisation in the utilisation of the excess poor quality soil masses.
- ABSOILS project demonstrates the eco-efficient way of utilising abandoned soils with the pilot applications.
- The project leads to raising awareness in this field and contributes to the development of the legislation.

Acknowledgements

This project would not be possible without the support of the European Union (LIFE+ programme), the Finnish Ministry of the Environment and the partnering cities (Helsinki, Vantaa and Espoo). We express our gratitude to all the stakeholders involved.

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