MASS STABILISATION AS A METHOD OF TREATMENT OF CONTAMINATED SEDIMENTS

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Abstract. The management of dredged, often contaminated, soft sediments constitutes a major problem and challenge for many European ports. One of the technically, economically and environmentally feasible solutions is to apply the mass stabilisation method and utilise the stabilised sediment as a soil filling material or to deposit it environmentally safely as contaminants can be immobilised with selected binder materials. Mass stabilisation has proved to be a successful method for the treatment of different types of soft soil, such as clay, peat, gyttja and soft sediments. New binder mixtures have been developed for various environmentally and technically demanding materials. Commercial cement and lime products are useful, but also slags, fly ashes and gypsum can often be considered as potential binder mixture components. Mass stabilisation method can be used in various in-situ and ex-situ applications. This paper describes the method and the binders applied through a few large scale demonstration projects: ABSOILS (LIFE09 ENV/FI/000575), STABLE (LIFE06 ENV/FIN/000195) and the Kokkola Harbour case (SMOCS project). In the ABSOILS project, dredged sediments were mass stabilised with cement and fly ash in the basins built beforehand. After curing time, stabilised sediments were transported to be utilised for various infrastructure construction purposes in the city of Helsinki. In the STABLE project, contaminated and technically demanding river sediments were mass stabilised with cement, slag and fly ash and utilised in harbour construction as a filling material. In the Port of Kokkola case, the challenge was the management of dredged sediments that were heavily contaminated with heavy metals. After mass stabilisation treatment, all the sediments were used as a material in the construction process of a new harbour field. Mass stabilisation was carried out using only reactive bio ash as a binder. The method was very economic and environmentally friendly.

Keywords: contaminated dredged sediments, mass stabilisation, secondary earth construction materials

1. Introduction

Marine sediments in the coastal areas are often contaminated as a consequence of industrial and port and shipyard activities, as well as the influence of cities located there. The maintenance of ports and seaways require dredging and handling of contaminated sediments since the level of contamination often inhibit dumping of dredged sediments into the sea (Kujala at al. 2010). Based on their geotechnical properties, most of these dredged sediments are regarded as too poor quality material for earth construction purposes. Economic, sustainable and environmentally safe management of contaminated, dredged sediments is a key issue for the further developing of the ports. Mass stabilisation technique offers an attractive solution to this end (Lahtinen at al. 2005).

Mass stabilisation technology was developed in Finland roughly 25 years ago. Initially, mass stabilisation was used as a soil improvement method in road construction applications (Lahtinen at al. 2009).

The first time this method was introduced as a way of handling dredged sediments was in the Port of Hamina, in 1996. Mass stabilised sediments were utilised during the construction of a container field in this harbour. After that, this method has been applied to stabilise sediments in various places, not only in Finland but also in other European countries. Figure 1 a-c presents some of the significant large port development projects from Finland, Norway and Spain.

a)

b)

c)

Fig 1. Port development projects in Helsinki, Norway and Spain: a – Port of Vuosaari in Helsinki; b – Port of Trondheim; c – Port of Valencia

The mass stabilisation method has been undergoing constant development to improve its technical, environmental and economic features and also to make it suitable for all type of sediments. One of the goals has been to obtain sufficiently good technical durability of the stabilised mass in various types of applications. The other issue of concern deals with environmental properties of the stabilisation process with a focus on immobilising contaminants that may occur in the sediments. In practice, this means that a mix of various binder components is developed in a case by case manner. This requires a possibility to use equipment that allows for simultaneous feeding of two components in a right proportion. Taking into consideration technical, environmental and economic reasons, in most cases the best binder mix can be obtained while industrial by-products such as fly ash, slags and gypsum are used (Lahtinen at al. 2008).

This paper concentrates on three applications carried out in Finland in the framework of various EU projects, namely Stable, Absoils and Smocs. The locations are highlighted in red in Figure 2.

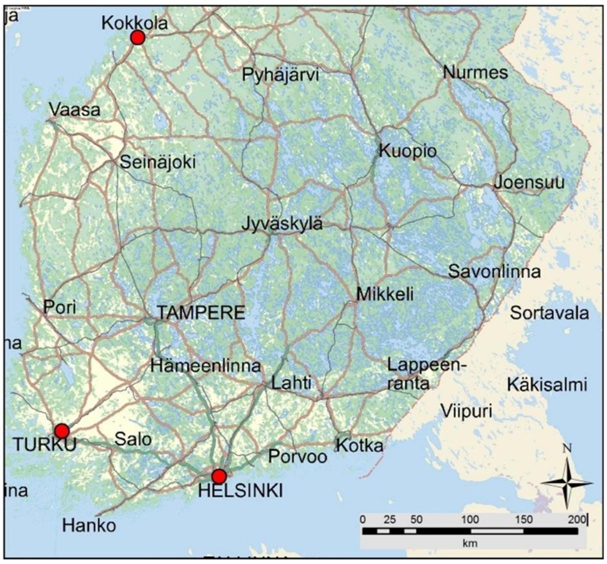

Fig 2. The location of the applications described in the article

2. Aurajoki River and Port of Turku case

The EU Life Stable project focused on the sediments of the Aurajoki river and answered the needs of the Port of Turku. The harbour site is placed at the estuary of the Aurajoki river. The annual natural migration of the sediments caused by the river flow reaches about 100 000 m^3. The river basin required dredging in order to sustain traffic in the harbour area. The estuary sediments were contaminated as a result of heavy vessel traffic and the city activities. The most critical contaminant was TBT which was mainly caused by industrial operations and ship building.

The confined disposal of roughly 80 000 m^3 of contaminated dredged masses was regarded not a feasible solution due to the need of constructing a new disposal site on land. The underwater disposal would demand expensive sorting and cleansing of the material. The Stable project provided an alternative solution by proposing stabilisation of the dredged sediments, which would enable immobilising the contaminants and allow for the utilisation of the stabilised masses as a construction material in the development process of the harbour storage and operational fields (Lahtinen at.al. 2009).

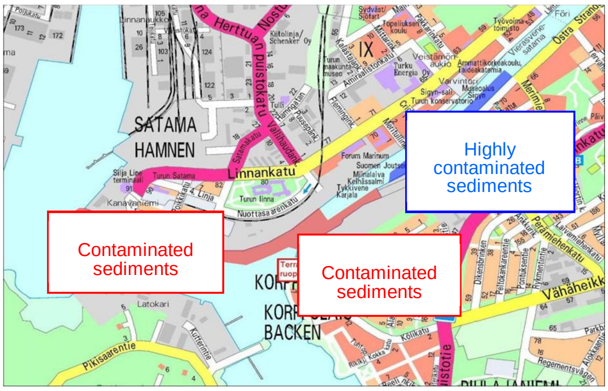

Fig 3. Map of the contaminated areas in the river Aurajoki (Stable, 2009 a)

The objective of the project was to determine binder recipes that would improve both the environmental and geotechnical properties of the dredged masses. Various other aspects of the stabilisation process also needed to be tested and developed. This included, inter alia, the application of a dredging method that would allow peeling only a thin and the most contaminated upper layer of the sediment and by taking only a very small amount of excess water into the barge and the development of a mixing station for process stabilisation.

Vast amounts of geotechnical and environmental tests were carried out for the project needs. The sediment samples were collected from the River Aura. The testing process embraced combining and homogenising of different sediment samples, the determination of appropriate binder admixtures with the help of 1-axial compression testing of the stabilised materials after different strength development periods, and the determination of the leaching of contaminants from stabilised materials (Lahtinen at al. 2009).

The binder components chosen for testing came from Finnish producers. These were: general cement and rapid cement, pulverised blast-furnace slag, oil shale fly ash from Estonia and fly ash from Fortum, Naantali coal burning power plant. The fly ash for testing was submitted dry and fresh from a silo; in the laboratory the fly ash was moisturised (to a water content w = 15 %) and stored for 7 days before using it as a binder component.

The aims of the technical tests included the determination of the effect of a given binder admixture and the amount of binders to the stabilisation process in order to choose the best alternatives, the determination of the variation of dredged sediment characteristics on the stabilisation with some chosen binder recipe, the determination of the strength development with a potential binder recipe (curing time for 28 – 536 days), the determination of the effect of fly ash properties (water content and storage for different time periods) on the stabilisation, and the control of the effect of variation of binder recipe on different dredged material samples.

The objective of using fly ash and other by-products as binder components was to achieve adequate strength of the stabilised material with a smaller amount of a commercial binder material. Also the transportation distance for those by-products was very short as they were generated in the vicinity of the project operation.

The targeted long-term compression strength was 180 kPa for the stabilised sediment which was to be deposited in the upper level of the final structure and 100 kPa for the stabilised sediment to be deposited in the lower level. The stabilised structure closer to the surface needed to become stronger and have a better bearing capacity than the structure at lower depths. The tests were made for sediment material at different water contents. The results of the technical tests have indicated that

- Fly ash as a binder component is advantageous for the strength development of dredged materials having high water content.
- If cement was to be used alone, its amount would be 250 kg/m^3. The combination of cement with fly ash and blast-furnace slag allowed for the decrease in the amount of cement to 45 kg/ m^3.
- The decreased amount of cement brings clear economic advantage, as its price at that time was about 100 €/t. It had also a positive impact on the CO_2 emissions, as manufacturing of 1 tonne of cement results in 0,8 tonne of this gas (Stable, 2009 b).

After testing of several binder admixtures the final tests for the determination of the binder admixture were based on three components: rapid cement (Pika), pulverised blast-furnace slag (KJ), and the fly ash (LT). The final tests with the varying proportion of the components and with the varying total amount of the binder were carried out in order to determine the required strength level and the safe tolerances for the binder amount. With the most promising binder recipes the testing was continued to check the strength development. These tests indicated that a long period reserved for the strength development of the stabilised foundation (under the preloading course but without any superstructure like a surface of asphalt) makes it possible to use less expensive binder admixtures. Especially the blast-furnace slag, which nowadays is less expensive than cement, requires a longer time period to react and give the structure its final strength level. Some of the technical test results are presented in Figure 4 (Stable, 2009 b).

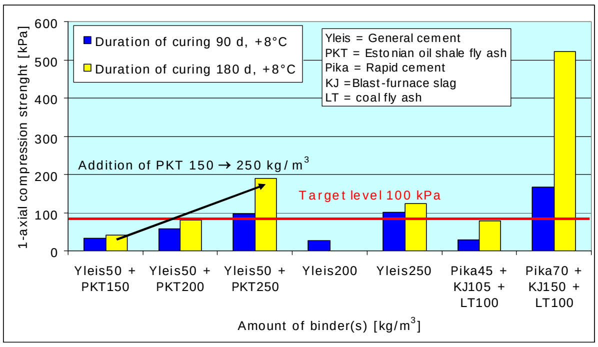

Fig 4. The most effective by-products combined with cement were coal fly ash, blast-furnace slag and oil shale ash. The number after binder code means the amount of binder (kg/m^3)

The test results indicated also that the water content and the storage time of the fly ash (FA) affect the stabilisation. The final binder recipes were determined for the four sampling sections. The water content of the dredged material and the possible depth at which the stabilised lot would be placed in the lagoon were among the determinants. The choice of the final recipes is shown in Table 1.

Table 1. The determined recipes for dredged sediments from different river areas and at different water contents

Dredging area	Water content of dredged material [%]	Recipe for placement at surface layers at a depth of 0 – 2 m [kg/m^3]	Recipe for placement at a depth deeper than 2 m [kg/m^3]
I and II	160 … 180	55 Pika + 105 KJ + 100 LT	45 Pika + 105 KJ + 100 LT
	180 … 220	60 Pika + 105 KJ + 100 LT	50 Pika + 105 KJ + 100 LT
III	< 260	55 Pika + 105 KJ + 100 LT	45 Pika + 105 KJ + 100 LT
	260 … 300	60 Pika + 105 KJ + 100 LT	50 Pika + 105 KJ + 100 LT
IV	< 220	45 Pika + 105 KJ + 100 LT	45 Pika + 105 KJ + 100 LT
Targeted compression strength		180 kPa	100 kPa

Pika = rapid cement
KJ = blast furnace slag, pulverised
LT = fly ash (w = 15 %, storage for 7 days)

The environmental tests included both the analysis of the total content of certain contaminants in the sediment samples taken and the leaching tests of the stabilised test pieces for the determination of the potential, long-term transport of contaminants from the stabilised masses into the sea environment close to the stabilisation lagoon.

The curing time of the stabilised test pieces was about 60 days. After this the leaching test, the modified diffusion test (NVN 7347/1999) started. The modified diffusion test differs from the standard diffusion test with number of the analysed samples, i.e. three samples are analysed instead of eight as set in the standard (Stable, 2009 b).

Organic tin compounds and different organic and inorganic contaminants (Sb, As, Hg, Cd, Co, Cr, Cu, Pb, Mb, Ni, Zn, V, organic tin compounds, total PCB and PAH) were determined from the water samples after the following times from the start of the test: 6, 24, 54 hours and 4, 9, 16, 36, 64 days. The results were compared with the results of some reference cases. The leaching of all tested contaminants was very low, often much lower than the limit of detection of the analysing method. It seems that fly ash could bind TBT more effectively than only cement (Havukainen at al. 2008).

Once the binder recipes were determined, dredging and the stabilisation works started. Dredging was carried out with the use of environmental grab (Figure 6). This was crucial for peeling the sediment layer without extra water.

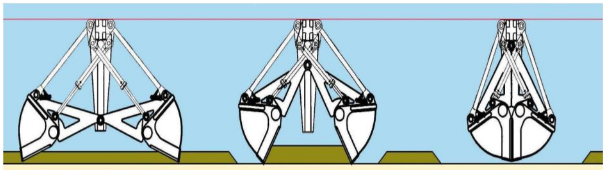

Fig 6. Environmental grab can peel off the required layer accurately. Thence, dredging work can be focused on contaminated layer only.

The dredged masses were transported with barges to the Pansio port where they were stabilised and used as filling material in the basin which was separated with a rock embankment. The mass stabilisation method was used to homogenise the sediment before feeding it into the process stabilisation equipment. The process stabilisation equipment is presented in Figure 7.

Fig 7. The principle of process stabilisation

The work progressed successfully and the results of this project convinced the environmental authorities that the solutions implemented in this case were very suitable for this purpose. For the Port of Turku it turned out to be an economically and environmentally feasible way to solve the problem of contaminated sediments. By turning waste into material, the Port acquired about 100 000 m^3 of good quality filling material needed for the development of the Port of Pansio (Lahtinen, 2009 a).

Fig 8. Stabilisation and filling basin of the Pansio port

3. Port of Kokkola

The port of Kokkola is one of the largest northern ports in the Baltic Sea. Its history reaches back to the year 1824 and the port is still expanding and developing due to increasing traffic. The sea area in Kokkola is polluted by the emissions from both industry and the city. The sediments include harmful substances at levels which locally cause substantial toxicity harm to benthic community. Both point source and diffuse pollution are detrimental. The principal noxious substances are As, Cd, Cu, Pb, Hg, Ni, Zn and TBT (SMOCS, 2013).

Building of the new quays and deepening of the fairways both required dredging of sediments. The level of contamination inhibited dumping of dredged sediments into sea, therefore it was decided that the sediment would be stabilised in a embanked stabilisation pool. In the Port of Kokkola case, dredging of 12 550 m^3 of contaminated sediments was carried out done in the Silverstone (Hopeakivi) port area where a new quay will be built in the future (Figure 9). Dredging was carried out in July and August 2011 with the environmental dredging method.

Fig 9. Extension plans in the Port of Kokkola; Silverstone (Hopeakivi) and Deep Port

The dredged sediments were transported by barges to the Deep Port extension area, where they were moved into the deposit basin by an excavator. The stabilisation was performed in the basin by the mass stabilisation technology. Before stabilisation work, the binder recipes used for stabilisation were determined. During and after stabilisation, the quality control and quality assurance were conducted.

Dredging and stabilisation of the contaminated sediments in the Port of Kokkola Silverstone (Hopeakivi) area occurred in the framework of the SMOCS project. The quality and contamination of the sediment in the port and the fairway were investigated. The binder material selection was based on testing in the laboratory. Testing included geotechnical properties of stabilised material, strength, development of strength along time, water permeability and environmental suitability. On the basis of the preliminary results of the laboratory studies it was decided to perform a field test at the Port of Kokkola (Lindroos at al. 2012).

Turbidity was monitored during dredging and stabilisation works and a substantial amount of samples was collected to ensure the quality of stabilisation. The results of the field test created a base for the design and execution of the sediment stabilisation method for the expansion of the port area. The results will also be used in the future handling of the sediments resulting from dredging of fairways. Then properties of the stabilised masses fulfil well the requirements for land construction of harbour areas. The Kokkola port is expanding towards the sea and building of the harbour areas demands filling of millions of cubic meters. With dredged sediments, the requirements for filling can be reached relatively fast. Transporting of corresponding masses from the land would be slow and expensive. The upper level of the sediment was mainly silt with water content of 50-82% and underneath was silt-sand layer with water content of 13-25%. The upper layer was the most contaminated.

Several potential components such as cement, fly ash from the combustion of bio fuel, oil shale ash, gypsum and blast furnace slag were chosen for the binder mixture. The target was to find the most economic binder mixture with an adequate technical durability and environmental acceptability. The tests showed that oil shale ash and cement with fly ash (from the combustion of bio fuel) were the most potential components for the purpose. Because oil shale ash was not included in the environmental permission it could not be used in this case. Therefore, the mixture of cement and fly ash from the bio fuel combustion was chosen for the project application. The first tests were carried out for the upper sediment layer and the final recipe for the mixture of upper and deeper layer which would be the stabilisation material after dredging (Lindroos at al. 2012).

Figure 10 shows the technical test results of the mixed sediment. The target value for the unconfined strength was 150 kPa in the laboratory and 100 kPa in the field. Figure 10 shows the results for the cement and fly ash from the bio fuel combustion mixture. It can be concluded seen that a very small amount of cement (about 30 kg/m^3) together with fly ash is enough to acquire an adequate and even too good strength. Fly ash from bio fuel combustion was also tested alone and the test results showed that 200 kg/m^3 enabled to achieve the strength of 150 kPa. Therefore, the piloting was started with the cement + fly ash mixture but the mixture was changed soon afterwards to bio fuel combustion fly ash only. The quality tests in the field confirmed this decision. Environmental acceptability was ensured by the leaching tests accomplished in the laboratory and by the risk analysis (Lindroos at al. 2012).

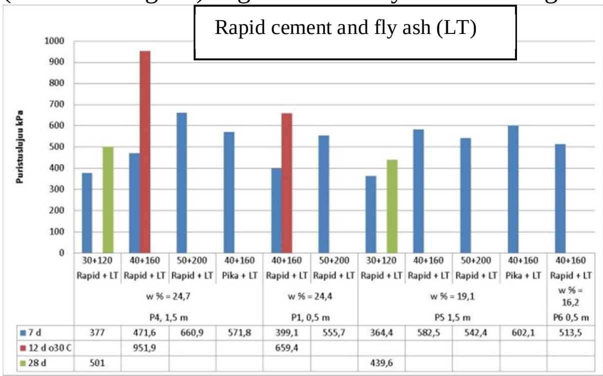

Fig 10. Results of the compression strength of mixtures involving Rapid-cement and fly ash of Alholmens Kraft PowerPlan (LT) as binder materials. Samples are taken from aggregate of banking area

The dredging site was in front of an old part of the harbour and the dumping site was in the new harbour part (Figure 12). Mass stabilisation work succeeded well. At the beginning, a double pressure feeder was needed for the feeding of cement and fly ash binder mixture (Figure 13).

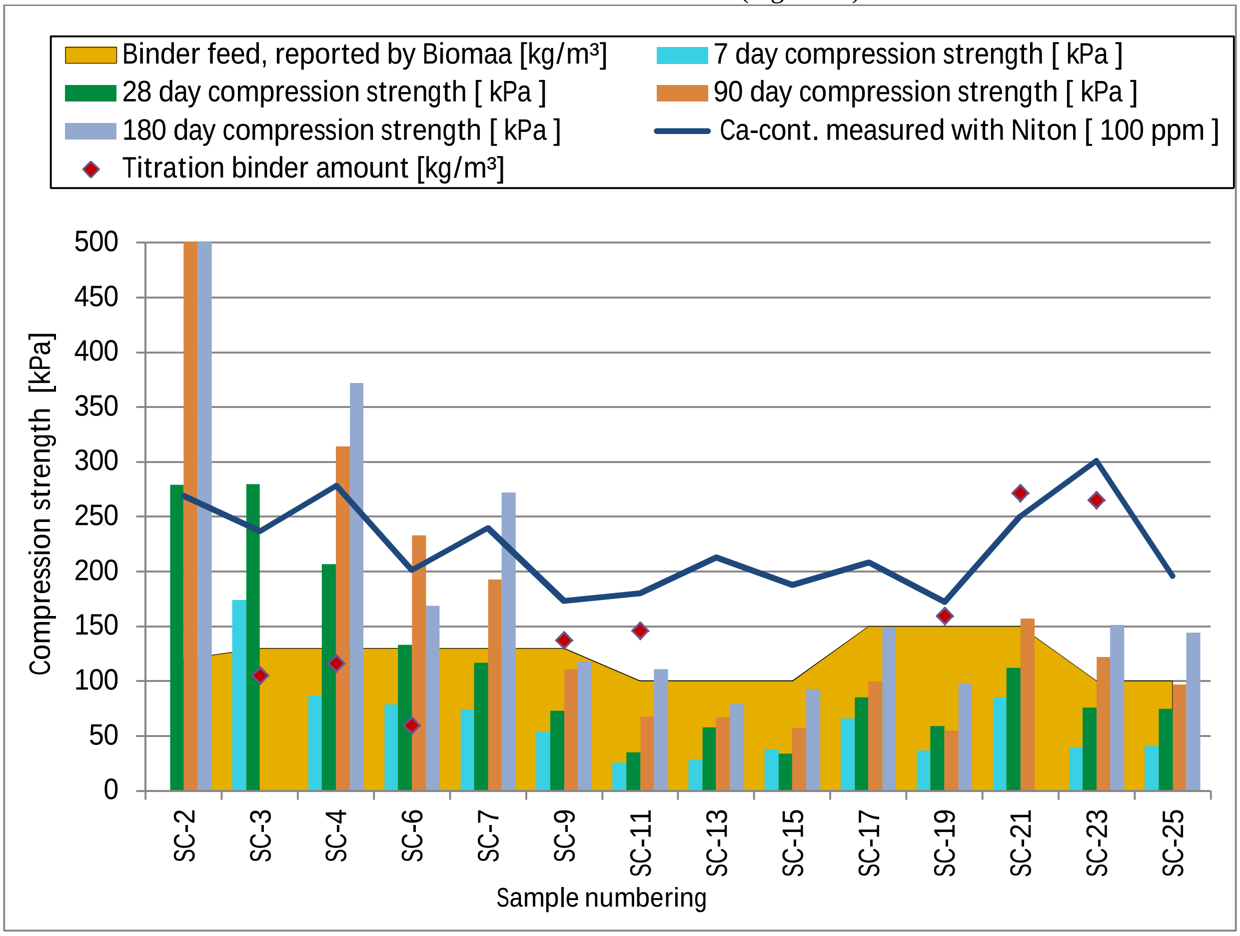

Fig 11. Compressive strengths of stabilised mass after 7 and 28 days. Also shown titration results from the masses, Ca concentrations measured with Niton XRF-analyser, and the amounts of binders fed reported by the contractor.

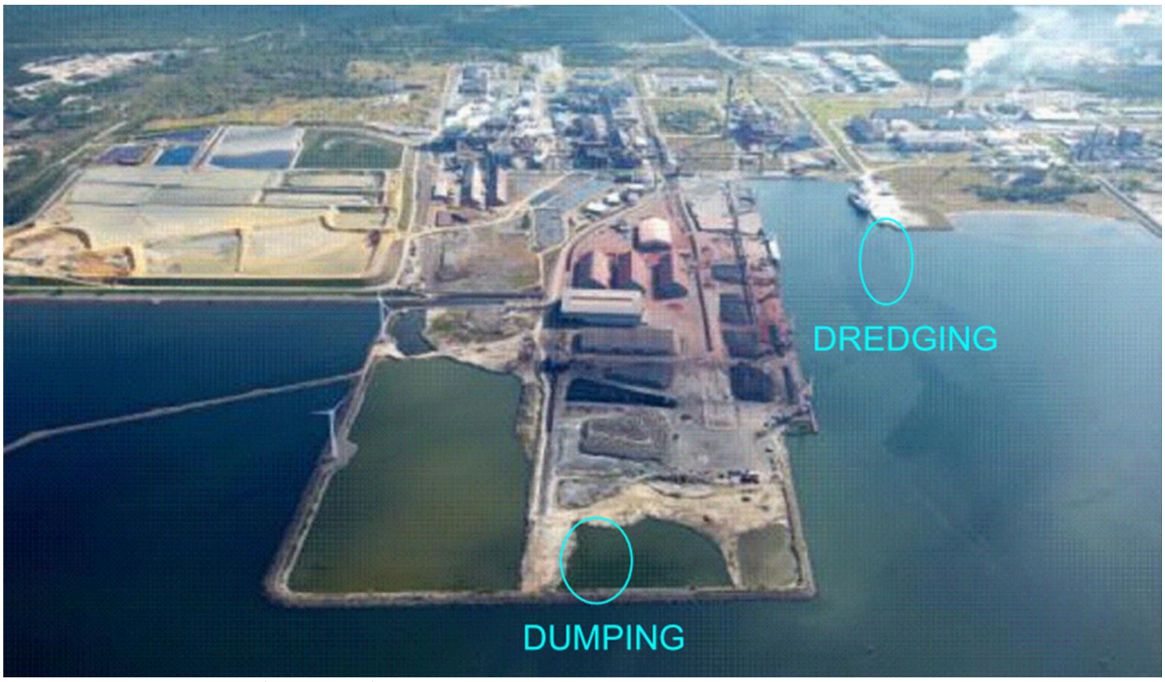

Fig 12. The overall view of the Port of Kokkola with dredging and dumping places marked.

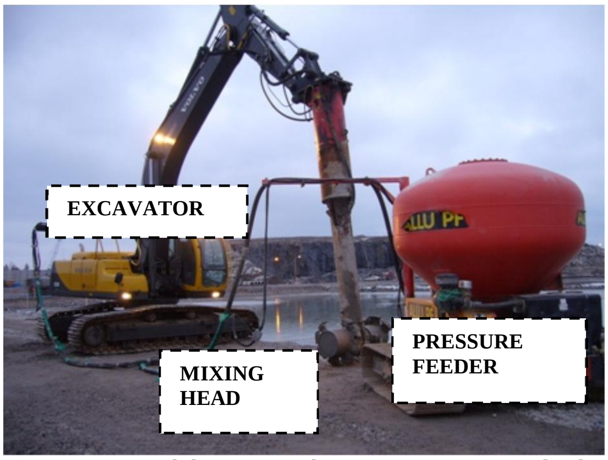

Fig 13. Mass stabilisation machinery in Vuosaari (Helsinki) harbour contaminated sediment treatment project. Similar set up was used in Kokkola stabilisation project.

Several follow-up tests to ensure the quality were made during the stabilisation work. Samples were taken from the site after the work was finished - 7, 28, 90 and 180 days – and strength and Ca-content were tested. Figure 11 shows that the results were satisfactory. The fly ash from bio fuel combustion needed longer curing time – at least 90 days or even 180 days. The final construction is presented in Figure 14.

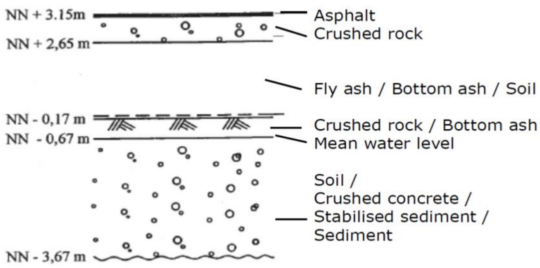

Fig 14. Superstructures on top of the stabilised material.

4. Jätkäsaari case in Helsinki

Jätkäsaari is a new living district of Helsinki which is located in the area of an old container harbour. The area was originally a group of islands (Jätkäsaari, Hietasaari and Saukko) and through sea filling in the 1930's a peninsula was created. The place served primarily the harbour's needs but since the harbour was moved to Vuosaari in 2008, it was freed for other purposes. Various construction works have been carried out in the Jätkäsaari area including sea sediments' dredging, the construction of roads, pavements and recreational areas as well as houses.

This site has served the piloting needs of the EU LIFE+ project called Absoils (LIFE09 ENV/FI/000575). The area is a pre-construction site where clean dredged sediments are utilised in the fillings and contaminated sediments are treated in the basins. Four temporary basins were constructed to allow the treatment of contaminated dredged sediments with the mass stabilisation method. The overall volume of the stabilisation pools is about 90 000 m^3. The stabilisation works at the site are conducted by the

Lemminkäinen company. The aerial picture is presented in Figure 15.

Fig 15. The aerial photos of the stabilisation basins. Stabilisation process on-going (by the City of Helsinki).

The Jätkäsaari case differs from the previously described cases mainly in the way how the stabilised masses are further utilised. The stabilised masses are not meant to be used for the port development needs, but they are stabilised on the site and after the curing time either partially temporarily stored there or transported as construction material to various sites in the city of Helsinki. The applications the Jätkäsaari stabilised sediments have so far been used include the Ida Aalberg park and the Vuosaari landfill landscaping works in Helsinki (Forsman at al. 2013).

Dredging works in Jätkäsaari were carried out in stages. Therefore, also stabilisation works took place in different phases. In spring 2011, the first stabilisation works took place. After curing time, the basins were emptied and filled again with new sediments. The second round took place in autumn 2012, and the third will take place in February…March 2014.

Prior to the start of the stabilisation works in 2011, the properties of the sediments were studied in the laboratory (Ramboll Finland Oy) and the binder determination process took place. The water content of the samples varied from 65% to 131% and was on average about 100%. The density of the samples varied between 1370 and 1610 kg/m^3. The lowest LOI (2,6) that the driest sample and the higher LOIs (4,5…4,6) had the wetter samples. The pH of the samples was around 8. In 2012, testing was repeated for the needs of the new stabilisation round. The water content of the samples varied from 70 to 90% with few samples over and under those variation limits. The LOI level was around 3% with most of the samples only a few samples of lower or higher LOI. All of the samples were clays except for two samples which included organic matter as well (Ollila at al. 2012).

Various potential binder mixtures were tested including fly ash and FGD (flu gas desulphuristation gypsum). The results of the stabilisation tests after 28 days for the first stage of stabilisation in 2011 revealed that the utilisation of gypsum together with cement and fly ash or with lime and cement (KC) is beneficial to the strength development. The results show also that the wetter samples had lower compressive strengths than the drier ones. The test results after 90 days of stabilisation are presented in Figure 17.

The results show that a significant strength development occurred after 28 days of stabilisation. The best binder options, according to these results, were Cem (cement) + FA (fly ash from Hanasaari) + Gyp (gypsum) and KC (lime and cement) + Gyp (FGD) mixtures which gave the best compressive strengths with low binder amounts. After 6 months' time, new samples were to be made from these materials to check how much the strength would increase in the longer run (ABSOILS, 2012).

Although, based on the test results, it was recommended to use a binder mix including industrial by-products, the finally applied binder was Portland cement and the amount was 60 kg/m3. This was because the environmental permit of the site prevented the use of industrial by-products as binders. Stabilisation begun in 2011 with the preparations which included the removal of larger pieces of blast rock from the sides of the basins, rounding-out the slopes leading to the basins and creating a refilling station for the binder. The sides of the basin were stabilised first in 5 m x 5 m blocks using the supportive banks of the basin. After the stabilisation, a geotextile and a loading embankment were spread on top of the stabilised layer to create a platform for the excavator. The stabilisation work progressed from the outer limits of the basin towards the middle of the basin (Figure 16).

Fig 16. Stabilisation work in basin 2, 2011 (in the front right corner - loading embankment and geotextile; at the back - stabilisation machine running

In 2012, stabilisation works started in August and they were completed in November. With sediments stabilisation, one of the challenges is usually a high water content in the dredged sediments which requires big amounts of cement. For instance, the Jätkäsaari application in 2012 demanded ~6200 t of cement for the stabilisation of ~88 000 m^3 of dredged sediments. This application also allowed for piloting stabilisation with the use of fly ash. Based on the results obtained, it is possible to conclude that at least half of the amount of cement used could have been replaced with fly ash.

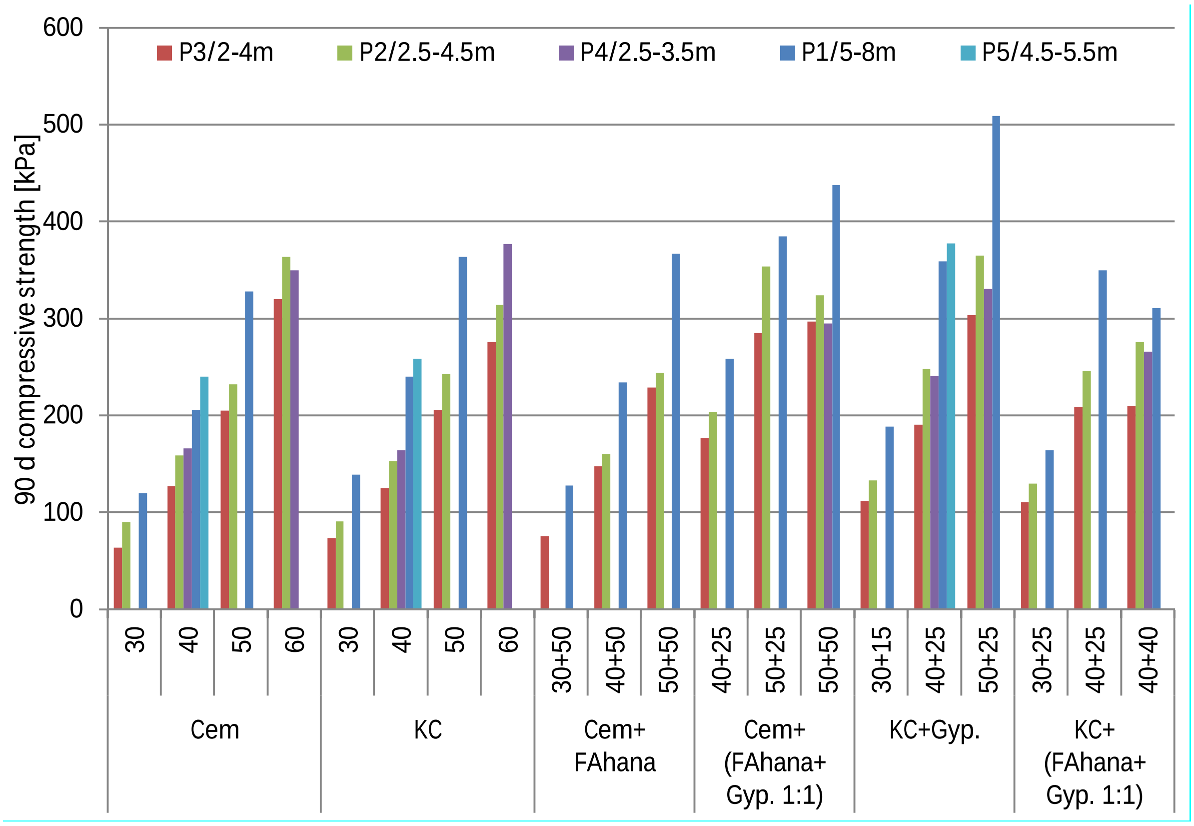

Fig 17. Jätkäsaari stabilisation test results after 90 days of stabilisation (laboratory tests, 2011). Cem = cement, KC = lime and cement, FAhana = fly ash from Hanasaari boiler, Gyp. = gypsum.

Further laboratory tests were carried out in 2012 and 2013 before the implementation of the stabilisation works for the phase II and III of the pilot applications. The 1-axial compression strength tests were performed for the stabilised samples after one and three months of curing time. For the samples that contained only cement as a binder material, the achieved compression strength varied between 200…400 kPa with the binder amount 60…80 kg/m^3. For the samples that were stabilised with the mixture of PlusCement (50 kg/m^3) and fly ash (150 kg/m^3), the achieved compression strength varied between 140…180 kPa. The fly ash from the Hanansaari Power Plant is not particularly reactive and in the laboratory conditions its impact on the strength development is not considerable. However, if fly ash is used in-situ stabilisation it allows to decrease the amount of cement required even by half without a decrease in the strength. The use of fly ash has also a positive impact on the homogeneity of the stabilised mass. Table 2 presents the amounts of sediments stabilised in various stages of the project and the binder type used.

Due to considerable variations in quality of the mass stabilised sediments, the need for an active quality control in all stages of work is indispensable. The quality control methods embrace, e.g. water and organic matter content tests, XRF-measurements, pocket vane shear test, fall cone test, column and cone penetrometers, plate load tests, settlement plates.

Table 2. Amounts of sediments and type of binder used in the Jätkäsaari case.

Stage	Sediment amount in m^3	Dredging time	Stabilisa-tion works	Binder
I	≈ 12 500	2009	04/2011… 05/2011	PlusCement
II	≈ 88 000	2011 /2012	08/2012… 11/2012	PlusCement and Fly ash +cement as a trial
III	≈ 22 500	06/2013	02/2014… 03/2014	Cement + FA and FGD; lime cement + FA and FGD
total:	≈ 123 000			

Column penetrometer and vane penetrometer for columns are the two most common methods for quality control soundings in mass stabilised structures. Column penetration sounding is by far the most used method of quality control for deep stabilisation (column stabilisation and mass stabilisation) in Finland and Sweden. The soundings provide information about the strength properties of the material.

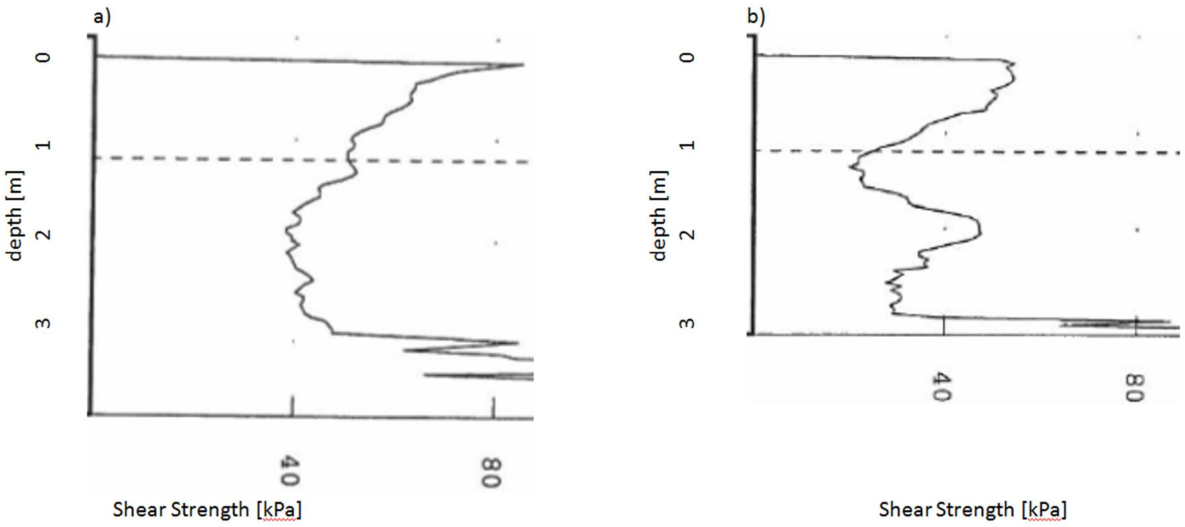

Fig 18. Results of the column sounding tests in 2012 a) material stabilised with PlusCement 40 + Fly ash 150 kg/m^3; curing time ≈ 1,5 month; b) material stabilised with PlusCement 80 kg/m^3 ; 2012 curing time ≈ 2,5 month. Average value diagrams which represent about 5 soundings

The results of the column soundings tests carried out in 2012 (Figure 18) show that by adding fly ash to cement the following advantages are achieved in comparison to the application of cement only:

- better shear strength
- better homogeneity

Other advantages of applying fly ash as a binder component include the lower carbon footprint due to the decreased amount of cement used with 50% and about 10 times shorter transportation distance for the fly ash (transportation of fly ash to a disposal site ≈ 65 km, transportation of fly ash to the pilot site ≈ 6 km). Fly ash has also a binding potential that decreases leaching of potential contaminants from the aggregate material.

In the Jätkäsaari area, the quality control testing is on-going and some new results will be available in 2014.

5. Conclusions

1. Mass stabilisation is a feasible method for the stabilisation of contaminated and clean soft sediments and for the utilisation of stabilised sediments.
2. The stabilisation technology requires technical and environmental material tests in the laboratory before the launch of construction works and follow-up studies afterward.
3. Technical properties of the materials are determined by laboratory studies including compression strength tests after a specified curing time. Several different binders and their amounts are tested in order to determine a suitable binder mixture for a given application.
4. The most commonly applied binder in stabilisation has so far been cement. However, its high price and its considerably high carbon footprint encourage searching for alternative solutions. The replacement of cement with binders based on fly ash from coal combustion in the stabilisation of dredged sediments has been studies both in the laboratory and on the site.
5. Several kinds of industrial by-products are applicable in binder mixtures. These products make the method more economic and environmentally friendly.
6. The environmental acceptability is evaluated by testing leaching of contaminants from the stabilised material in the laboratory. The results of the tests provide good reasons for the use of fly ash based binders in the process of stabilisation of dredged sediments.
7. Several applications for the utilisation of stabilised sediments have already been developed but it is still possible to find new potential applications.
8. So far, the knowledge of the environmental authorities regarding the environmental advantages of the method has been increasing. There have been cases in Finland where the use of the mass stabilisation method for the treatment of the sediments was a pre-condition to the fulfilment of a project
9. Mass stabilisation equipment is currently technically on a high level. The equipment is mobile and therefore easy to use in various locations. A double pressure feeder makes it easy to use two separate binder components in the mixture so there is no need to mix the binders beforehand.

Nomenclature

ABSOILS - LIFE09 ENV/FI/000575; Sustainable Methods and Processes to Convert Abandoned Low-Quality Soils into Construction Materials
SMOCS - Sustainable Management of Contaminated Sediments
STABLE - (LIFE06 ENV/FIN/000195); Controlled Treatment of TBT-Contaminated Dredged Sediments for the Beneficial Use in Infrastructure Applications. Case: Aurajoki – Turku, Finland

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