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INSTALLATION OF FINE-GRAINED ORGANIC DREDGED MATERIALS IN COMBINATION WITH GEOSYNTHETICS IN THE GERMAN DREDGDIKES RESEARCH DIKE FACILITY

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Abstract. In the project DredgDikes with partners from Poland and Germany different dredged materials from the South Baltic Sea region are investigated with respect to their application in dike construction. Two large-scale experimental dikes have been built, one in Germany and one in Poland. Additionally, an extensive laboratory testing programme has been realised and a considerable monitoring test programme will be followed. Based on a short general description of the project this paper covers the issue of installation technology for the dredged materials used and a discussion of geotechnical parameters to be determined for material evaluation and quality control. Due to the high and variable natural water contents of the organic soils together with their inhomogenous composition the compactability is difficult to predict and proctor values may not be reliably determined. During the installation three different compaction technologies were compared and no extreme differences could be found, which is why the compaction with a caterpillar was chosen for efficiency on site. The critical analysis of the data, however, shows slightly better compaction results for the roller compactors. In general the degree of compaction was comparably low. Therefore, different possibilities to improve compaction are discussed in this paper, such as the homogenisation of the dredged material by simple in situ mixing technologies, which will be issues for further research.

Keywords: dredged material, dike, levee, installation technology, compaction, geosynthetics.

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Introduction

Large amounts of sediments are removed every year from water bodies in maintenance and environmental dredging projects. The major amount of these dredged materials is relocated within the water bodies (Netzband *et al.* 1998; HELCOM 2011), however, if the amount of fines in the sediment would cause turbidity at the placing area or contaminations are involved, the materials have to be taken ashore. Then they are considered a waste material after European regulations (Apitz 2010). Still, the materials are a valuable resource for agricultural use, landscaping or even as construction materials, particularly when they are not contaminated. Fine-grained organic dredged materials are usually processed (dewatering and ripening) before they can be re-used. Experience shows, that some of the materials are well suited for the recultivation layers of landfill cappings, where high erosion resistance and extreme water retention capacities could be observed. This resulted in the proposal to use this kind of dredged material as coastal dike cover material. The usual dike cover materials like marsh clay (North Sea) and glacial marl (Baltic Sea) are becoming short and they have to be mined, usually in environmentally

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sensitive regions, while the dredged materials are available and need to be used beneficially. Therefore, the cooperation project DredgDikes – part-financed by the European Union's South Baltic Programme – was initiated by the University of Rostock (UR), Chair or Geotechnics and Coastal Engineering, and Gdansk University of Technology (GUT), Chair of Geotechnics, Geology and Maritime Engineering. Five partners and 15 associated organisations from Poland, Germany, Latvia and Lithuania are involved in the project. The main aim of the project is to get different solutions for dredged materials application in dike construction implemented and therefore a recommendations handbook will be developed as final result. Information about the project can be found on www.dredgdikes.eu. The German partner institutions are investigating ripened fine-grained organic dredged materials in combination with geosynthetics solutions, while in Poland the GUT is investigating how different ashes and rather sandy dredged materials can be mixed to gain valuable dike construction materials for both the dike core and dike cover layers (Sikora, Ossowski 2013). This paper focuses on the German part of the project.

The dredged materials investigated in Rostock come from the Warnow river delta. High natural water contents even after several years of ripening may lead to shrinkage and cracking phenomena after installation. Geogrid reinforcement within the dike cover may cope with this problem. The erosion resistance against rainfall seems to be good, however, the erosion resistance against overflowing of bare or partly vegetated dredged materials is yet unknown. Also the materials can be comparably inhomogeneous; therefore rolled erosion control products (RECPs) are applied to strengthen the surfaces of the dike slopes. Finally, the consortium investigates whether a ripened top-soil-like dredged material can be used in a homogenous dike setup and whether innovative drainage solutions help to control the seepage line during hydraulic loading of the dike. During construction of the research dike in 2011 and 2012 different installation and compaction methods and technologies were investigated, the results of which are presented in this paper.

1. Scientific background

The use of fine-grained and organic dredged materials as construction material is a rather new idea and particularly their application in dike construction, where safety plays a major role. There is a considerable amount of research papers dealing with the application of dredged materials – often stabilised using binders or fly ash – in road construction (e.g. Zhang *et al.* 2011; Triboutt *et al.* 2012; Wang *et al.* 2012).

After current German recommendations, dredged materials should only be used in dike construction if they meet particular geotechnical criteria, comparable to other dike construction materials (Weißmann, Richwien 2003; EAK 2002/2007). The geotechnical characteristics of the dredged materials investigated here show low permeability and sufficient strength in the lab. Other parameters, like the Atterberg limits or the decomposition time after Weißmann (Weißmann, Richwien 2003) cannot be determined in reproducible quality, so that different criteria may need to be developed. In dry periods there is also a tendency to shrinkage and cracking among the materials with high natural water contents, even after several years of ripening on the drying fields. Therefore investigation is needed with respect to the general applicability of the materials, the necessary characterisation of materials to be used in dike construction (including characteristic laboratory tests), efficient installation technologies, the improvement of the materials to reduce cracking, and methods to prove and if necessary enhance the materials' erosion resistance – the most important issue when it comes to sea dike covers (Pohl, Vavrina 2008).

At the University of Rostock, there has been a long tradition of dredged materials research, including both dewatering and ripening (Morscheck 1992) and particularly regarding the beneficial use of ripened dredged materials in agriculture, landscaping and landfill recultivation (Henneberg 2000; Quandt, Henneberg 2011). There is also a tradition of geosynthetics research at the department, already starting in the 1980s and still continuing, with focus on geosynthetics used in the interface of geotechnical and hydraulic engineering (Saathoff 2003; Saathoff *et al.* 2007; Cantré, Saathoff 2011) and with respect to dike reconstruction (Saathoff 2006; Cantré *et al.* 2013; Cantré, Saathoff 2013).

In recent years, research and application of dredged materials for dike construction has also been performed in Hamburg (Beyer *et al.* 2012; Gröngröft *et al.* 2005) and Bremen, where also contaminated materials are considered to be re-used in geotechnical applications. In China and France Zdiri *et al.* (2009) and Wang *et al.* (2013) looked at the use of stabilised dredged materials in road construction and the concept finally led to the idea to use these stabilised sediments also in dike construction, which will be realised in the project PRISMA with partners from Belgium, France, Netherlands and the UK (www.prisma-projects.eu).

2. Investigated dredged materials

In the German research dike five different dredged materials have been used to build dike core, cover layer and homogenous dike cross-sections. The dredged materials are ripened dredged sediments from the Warnow river delta in Rostock. They have been processed on the City of Rostock's containment area "Radelsee". The containment area consists of two classification polders, long enough for the separation of different grain size classes of the dredged material: pure sand, mixed "top soil" (M3 in Table 1), and fine-grained organic materials (M1/2). After one year of dewatering the materials are usually removed from the classification polders and set up to heaps on the ripening fields. The ripening is particularly important for the fine-grained organic materials. M1 and M3 had been ripened for 6 years prior to installation, while M2 had been ripened for only 3 years when installed in the test dike while they had been ripened 5 and 2 years prior to testing respectively. In Table 1 some important soil mechanical values are given for characterization. More detailed information about the geotechnical characteristics of the dredged materials used in the project, including the comparison to other dredged materials and standard dike construction materials have been published by Große and Saathoff (2013).

Table 1. Selected geotechnical properties

	M1	M2	M3
Clay [%]	25–28	22–25	15
Sand [%]	29–34	40–47	54
Water content w [%]	61–68	55–73	46
Organic matter OM [%]	10–11	9–10	6
Lime content LC [%]	9–10	8	10
c_u [kPa][1)]	53–132	19–34	> 120
φ [°][2)]	28–30	28–31	30
c [kN/m²][2)]	35–47	13–19	59
k_f [m/s]	5E–08	8E–10	5E–09
OD [g/cm³]	1.1–1.2	1.3	1.4
w_{opt} [%]	40–43	32–35	31

M1: Organic silt ripened for 5 yrs; M2: Organic silt ripened for 2 yrs; M3: Sandy silt, slightly organic; [1)]Results from vane shear testing, M3 above the upper limit of the vane shear tester used; [2)]Results from direct shear tests.

3. Experimental dike with geosynthetics solutions

The large-scale experimental dike in Rostock consists of two parallel dikes (West and East) which are connected with earth dams to form a three-polder system (Fig. 1). The polders can be filled with water separately for hydraulic loading. There are ten different dike cross-sections, all separated by mineral sealing material to prevent seepage water to spread between the cross-sections. Most of the cross-sections have been realised twice, on the Eastern and the Western dike respectively.

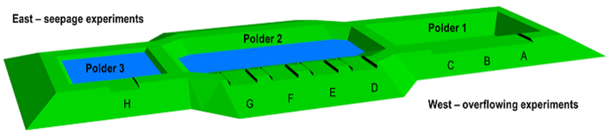

Fig. 1. Rostock research dike, West view, A–H different cross-sections

The Eastern dike has been instrumented extensively to measure the seepage into and through the dike core, using tensiometers, volumetric moisture content probes, piezometers, and tip counters. The Western dike is mainly used for overflowing tests. Therefore, flexible timber flumes have been installed on the Western slopes. The water level inside the polders can be regulated so that water flows over the crest-areas particularly lowered to realise overflow on defined parts of the slopes. The base of the construction is sealed by a geosynthetic clay liner for a defined hydraulic boundary condition. Five different dredged materials and four different geosynthetic solutions have been installed in the German test dike.

Three general types of cross-sections were realised: The dikes of polder 1 consist of a sand core covered with a layer of fine-grained dredged material with a thickness of 1.5 m on the outer (water side) slope and 1.0 m on the inner (land side) slope and a slope inclination of 1:2. In polder 2 slopes with an inclination of 1:3 are realised. The cross-sections consist of a sand core covered with a layer of fine-grained dredged material of 1.0 m thickness. Cross-section H in polder 3 is a homogenous dike made from material M3. Table 2 gives an overview of all materials used in each cross-section.

To reduce shrinkage cracking in the dike cover layer, a geosynthetic reinforcement product was installed in surface parallel layers. Since the tensile stresses at crack development are assumed to be very

Table 2. Overview of materials installed in the test dike

Section	M1	M2	M3	M5	RECP	Grid	Drain
A	x			x			
B	x	x	x	x	x	x	x
C	x	x		x	x	x	
D		x		x	x		
E		x		x			
F				x			
G				x			
H				*			

M1/2/3/5: see Table 1. RECP: Rolled erosion control products; Grid: three-dimensional erosion control grid for reinforcement; Drain: geosynthetic drainage composite; A–H compare Fig. 1; *homogenous cross-sections, no sand core.

low compared to the tensile strength of geosynthetic materials and the friction between soil and reinforcement material needs to be high even for very small displacements, a three-dimensional geosynthetic erosion control grid (Huesker Fortrac 3D) was used (Grid in Table 2). Without reinforcement large cracks are expected that may reach the sand core. With reinforcement installed, a larger number of smaller cracks are expected, not exceeding the reinforcement (Fig. 2A).

To strengthen the surface of the greened slopes against erosion from wave attack or overflowing/overtopping events, a rolled erosion control product (Colbond Enkamat) has been installed on several cross-sections (C, E, F in Fig. 1), covered by up to 5 cm of dredged material before greening (RECP in Table 2). The above three-dimensional grid was also used as surface erosion control solution on one of the steep cross-sections. Without RECP considerable erosion may occur, particularly in bare or partly vegetated state, while with RECP the surface will be protected (Fig. 2B).

In the homogenous cross-sections of polder 3, innovative drainage solutions were installed using a geosynthetic drainage composite (Colbond Enkadrain). Without installed drainage composite seepage water may soak the whole cross-section, coming out anywhere on the inner slope. With drainage composite, the seepage line will drop to the drainage layer and come out at a defined line along the slope or dike toe (Fig. 2C).

4. Installation technology

Before and during the construction of the experimental dike in Rostock, the installation and compaction was tested using different technologies. Both the general workability of the dredged materials and their compactability were issues for investigation.

4.1. Dike construction technology

In 2011 a compaction testing field was built to test the installation of the materials M1 and M2. The soil was installed in layers of 30 cm using a caterpillar and a 12.5 ton sheep's foot roller for the compaction. The caterpillar installation was unproblematic and thus focus was set to the compaction technology to reach a demanded degree of compaction (DOC) of 90% (Proctor's density). In the wet summer of 2011 none of the materials was dry enough to reach this value. The variation of crossing counts did not show a significant effect and the vibration seemed to have no effect either (Figs 3 and 4).

In spring 2012 the actual dike construction started. Due to the different slope inclinations and cross-sectional designs the construction technology was adjusted several times. Usually, the sand core would be hydraulically installed and then profiled. However, due to the size of the research construction the sand core was built dry and compacted with a roller compactor with vibration.

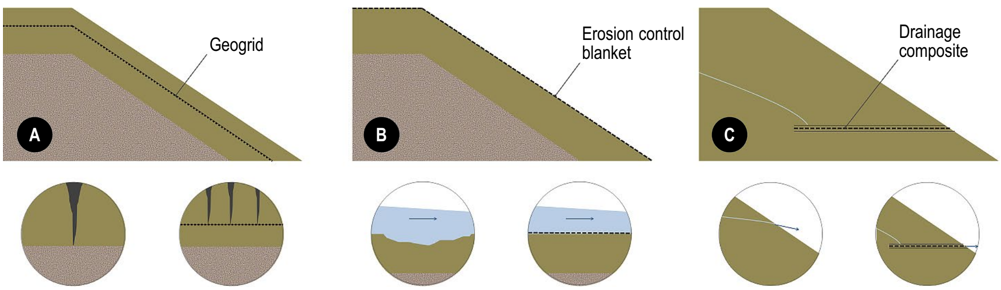

Fig. 2. Schematic cross-sections: (A) Sand core & geogrid reinforced dredged material cover. Without geogrid large cracks. With geogrid more smaller cracks not exceeding the geogrid; (B) Sand core & erosion protected dredged material cover. Without erosion control blanket surface erosion due to overflowing. With erosion control no erosion is expected; (C) Homogenous dike with geosynthetic drainage composite. Without composite seepage may occur on the inner slope. With composite defined drainage

The homogenous dike of polder 3 was built in horizontal layers of 30 cm. The bottom half was compacted with the standard roller compactor. The upper part was built up using the caterpillar only with the material removed during the profiling of the lower part.

The installation of the cover layer in polder 1 on the steep slopes with a 1:2 inclination was not trivial. Usually the cover layer on a dike would be installed in layers across the sand core surface (Fig. 5). However, the slope was too steep for this technology. The cover layer on the Western dike was installed by putting considerably more material in front of the sand core. However, the proposed layer thickness of 30 cm could not be realised, because the profiled sand core would have been destroyed during compaction (Fig. 6). The thicker layers on the other hand may not be as well compacted in the lower parts (compaction see Fig. 10; this was not controlled).

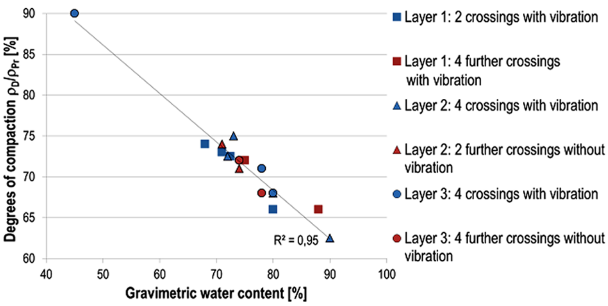

Fig. 3. DOC for M1 and different installation and compaction modes with/ without vibration, variation of crossings

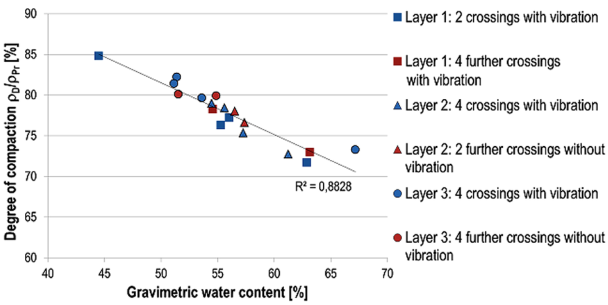

Fig. 4. DOC for M2 and different installation and compaction modes with/ without vibration, variation of crossings

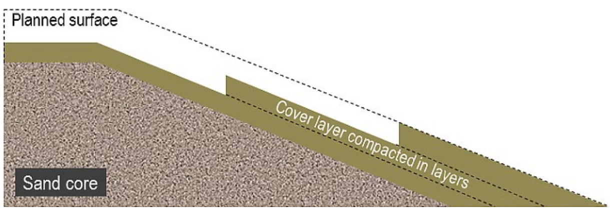

Fig. 5. Standard way of installing a cover layer on a sand dike core in layers of 20–50 cm

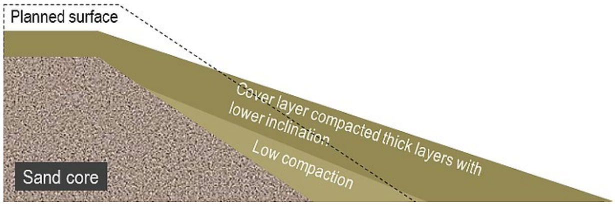

Fig. 6. Steep sand core with installed cover layer in lower inclination and lower compaction at the dike toe

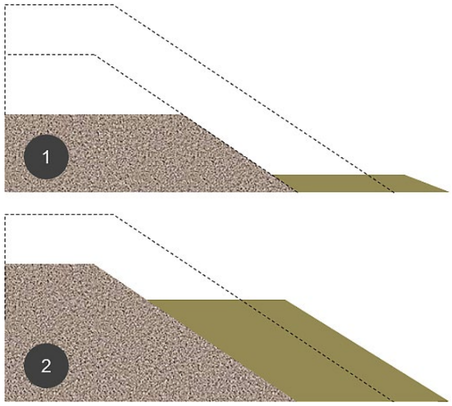

Fig. 7. Steep sand core with horizontal installation of cover layer in layers of 20–50 cm beside the sand core. Step 1: sand core 1 m, 3 layers of cover material. Step 2: sand core full size, finishing of cover in layers of 30 cm

On the Eastern dike of polder 1 a different technology was chosen: The sand core was only installed up to 1 m height and the cover material was then placed on both sides in horizontal layers of 30 cm (Fig. 7). This method was repeated until the crest was reached.

In polder 2 the cover material was installed in layers of 30 cm on top of the sand core. The installation with a caterpillar was easy and the compaction with a roller compactor was possible, at least in relatively dry conditions (Fig. 5).

4.2. Comparison of different compactors

Three different compaction methods were used in the installation tests (Fig. 8): a sheep's foot roller compactor with vibrator (12.5 t), a standard roller compactor with vibrator (12.5 t), and a standard caterpillar (13.0 t). The evaluation of all compaction data gathered showed only small differences between the compaction results (Table 3 and Figs 9–11).

Initially it was supposed that the compaction results after caterpillar compaction only would be considerably lower than those after installation with roller compactors. Data evaluation shows a 6% lower DOC (mean values) for M1 when compacting with the caterpillar only, which is significant. For M2 a 2.5% lower DOC was observed, which is not significant with respect to the data population.

Also, a higher risk of non-uniform compaction was assumed initially, which would result in larger standard deviations. However, there is a lower spread of the caterpillar compaction data for M1 and a slightly higher spread for M2. Both are not significant. Thus the assumption could not be verified.

Fig. 8. Compactors used for the technology comparison

Table 3. Results of the DOC analysis from the test dike

	Roller	Caterpillar
M1		
Number of values	23	27
Mean value	78.6%	72.4%
Standard deviation	6.33%	4.61%
M2		
Number of values	28	27
Mean value	84.2%	81.7%
Standard deviation	6.35%	8.27%

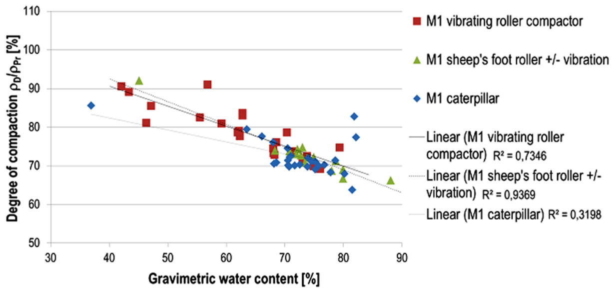

Fig. 9. DOC for M1 and different compaction technologies

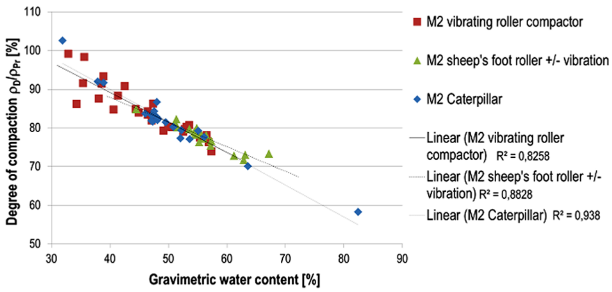

Fig. 10. DOC for M2 and different compaction technologies

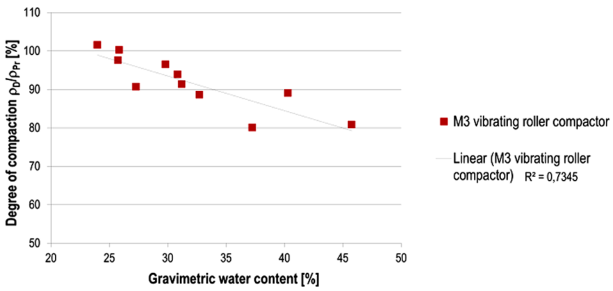

Fig. 11. DOC for M3 with roller compactor

As a result the compaction with a caterpillar only was chosen for installation efficiency due to the small deviations in the compaction results. This was possible particularly because of the crumbly state of the ripened dredged material. For material with larger loam or clay clots the method would have to be revised.

4.3. Installation of geosynthetics

There are four different types of geosynthetics installed in the research dike. A geosynthetic clay liner GCL was installed as a lower hydraulic boundary condition (Fig. 12). The GCL was rolled out and the overlappings were glued together using a bentonite paste. In this way the vertical seepage is minimized.

The geosynthetic drainage composites used to control the seepage line in cross-section H and at the toe of the western dike covers could be easily placed (Fig. 12). They were rolled out in dike longitudinal direction, using the full width of 5.0 m, which will be the most practical way in a real project. Thus, the cross-machine transmissivity is relevant for the design.

The geogrids for reinforcement were planned to be installed in both the slopes of 1:2 and 1:3 inclination. However, since an installation of 30 cm layers of cover layer material was not possible on the 1:2 slopes, the proposed system of geosynthetic reinforcement could not be applied. The reinforcement was only installed in the cover layers with a 1:3 inclination (Fig. 13). Therefore, the first layer of 30 cm was installed and compacted on top of the sand core, then the geogrid was placed on top of it, pulled tightly and fixed at the ends. Then more dredged material was quickly placed on top of the grid and a layer of 0.4 m was installed and compacted before another layer of geogrid was wrapped over the whole surface. Finally a final layer of 30 cm of dredged material was installed on top of the geogrid.

Fig. 12. Installation of the geosynthetic clay liner and drainage composite

Fig. 13. Geogrid installation

Fig. 14. Installation of the erosion control product

The geosynthetic erosion control product was placed over the finished dike surface and then covered with a few centimetres of crumbly dredged material of the same kind as in the cover layer underneath (Fig. 14). The product was fixed to the ground with 0.4 m long steel rods, approximately 2 per square metre. During installation it seems to be of importance to fix the material on one side of the dike first and then pull it tight so that the product will not stretch and deform when it is necessary to walk over it, e.g. while installing the fixation rods. Walking on the material may also be necessary when covering the materials with soil, seeding and moving the freshly developed turf. Also then the RECP should be kept in place with as much contact to the subsoil as possible.

5. Discussion

The installation and compaction tests showed a better compaction result with the use of roller compactors compared to the caterpillar tracks only. However, for material M2 the difference was quite small, presumably due to the lower water content during installation compared to that of M1. To be sure to receive a good and homogenous compaction a roller compacter should thus be used, however, for efficiency the compaction with a caterpillar only is also possible, particularly on slopes with inclinations flatter than 1:3.

Still, the achievable degrees of compaction with the material as it comes directly from the ripening heaps are lower than originally requested. Therefore, laboratory tests with homogenized material were performed which showed an increase of optimal density OD after the dredged materials when the soil was tilled in the field and then mixed in the lab. This leads to the assumption that a certain processing using an in situ tilling before installation could improve the compaction of the fine-grained dredged material. This will be subject to investigation in the near future. This effect also shows, however, that if the material will not be homogenized or processed in another way before installation the laboratory tests – particularly the OD determination – will have to be performed also with the unprocessed raw material. Then again, the reliability of the achievable DOC value highly depends on the homogeneity of the material investigated. Dredged materials usually possess a high variability (Grubb *et al.* 2008) with respect to grain-size distribution, organic content distribution and often even some stochastically distributed gravel and clay clots. Finally, a higher compactor weight or a lower layer thickness may increase the compaction. This will also be investigated in the upcoming field tests.

First results regarding the geosynthetic reinforcement of the cover layer to reduce cracking show a positive effect of the reinforcement. Generally there is less seepage water recorded for the reinforced cross-sections. This will be subject to further investigations, such as excavations on the slopes, climate chamber experiments to study the different cracking behaviour of reinforced and non-reinforced samples. After the construction was finished in May 2012 there was a dry period of nearly three months with no considerable precipitation. Drying effects at the dike surfaces lead to shrinkage and associated cracks. The analysis of the crack development is difficult now that the vegetation covers the dike surfaces. However, to further mitigate the cracking another technology may be useful: Levacher and Liang (2013) found out that stabilised dredged material with insufficient strength can be further strengthened using biodegradable fibres. This technology may also have an effect on the initial shrinkage and associated cracking. Together with the necessary mixing technology and thus a kind of homogenisation the improvement of achievable compaction may be a positive side effect.

Regarding the correct installation of the erosion control products used there seems to be an issue with the correct filling of the erosion control product in practice: generally, the mat would be filled with crumply soil material, only just covering the product. However, when putting the soil over the mat there will be some areas with thicker layers. These areas seem to be critical with respect to overflowing resistance shortly after seeding when the grass roots have not yet reinforced themselves into the RECP and thus leading to a defined shear plane on top of the RECP. Both in lab flume experiments and full-scale flume experiments on the inner slopes of the research dike this effect could be found when the soil layer on top of the RECP was comparably thick and/or the roots were not fully developed. To reduce this effect, exact installation and quick grass germination to minimize material movement on the embankment seem to be necessary. This will also be subject to further investigations.

Abbreviations

DOC – Degree of compaction, computed by dividing the actual dry density by the optimal dry density OD;
OD – Optimal dry density from Proctor's test;
RECP – Rolled erosion control products.

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Conclusions

The Rostock research dike built in the frame of the DredgDikes project gave opportunity to investigate installation and compaction issues regarding the dredged materials and geosynthetics used.

1. The best compaction was achieved when installing the dredged materials with a caterpillar in layers of 0.30 m and compacting them with a roller compactor. Still, the degree of compaction was lower than originally demanded (around 80% OD instead of 90%), only partly because of the high initial water contents. Thicker layers compacted with a roller as well as the installation and compaction with a caterpillar only generally showed lower degrees of compaction. Still, for efficiency, the latter technology may be feasible on dike embankments with an inclination flatter than 1:3.
2. The use of the DOC as a quality control measure is problematic due to the inhomogeneities of the materials. There is usually one single OD value which is determined in the lab and which may not be representative for the whole dike cover material. Also it is not practicable to determine the soil type at every DOC sample. Other values, such as the initial shear strength or a load bearing capacity, may be more practicable control variables.
3. Installation tests of the erosion control products showed that it is essential not to cover them with too much top soil so that the grass roots can cling into the material even in an early stage of turf development shortly after germination. Also, it is necessary to stretch the materials over the slopes while fixing them to the surface so that they stay flat during further steps of construction and maintenance (covering with soil, seeding, mowing, etc.).

4. The effect of cover layer reinforcement to reduce shrinkage cracking can be detected. Since there are only results from four tests with two variations each this is, however, rather a tendency which will have to be further investigated.

References

Apitz, S. E. 2010. Waste or resource? Classifying and scoring dredged material management strategies in terms of the waste hierarchy, *Journal of Soils and Sediments* 10(8): 1657–1668. http://dx.doi.org/10.1007/s11368-010-0300-9

Beyer, K.; Grabe, J.; Kaschel, G.; Timmers, V. 2012. Development of a large-scale environmental chamber to investigate the dessication behaviour of flood embankment profiles, in *Proc. of 12th Baltic Sea Geotechnical Conference*, 244–250.

Cantré, S.; Saathoff, F. 2011. Design method for geotextile tubes considering strain, *Geotextiles and Geomembranes* 29(3): 201–210.
http://dx.doi.org/10.1016/j.geotexmem.2010.10.009

Cantré, S.; Saathoff, F. 2013. Investigation of dredged materials in combination with geosynthetics used in dike construction, *Procedia Engineering* 57(2013): 213–221.
http://dx.doi.org/10.1016/j.proeng.2013.04.030

Cantré, S.; Große, A.-K.; Neumann, R.; Nitschke, E.; Henneberg, M.; Saathoff, F. 2013. Fine-grained organic dredged materials for dike cover layers – material characterisation and experimental results, in *Proceedings of the World Dredging Congress WODCON XX,* Brussels, 3–7 June, 2013, session 4/3. 14 p.

EAK 2002/2007. Empfehlungen für die Ausführung von Küstenschutzwerken durch den Ausschuss für Küstenschutzwerke der Deutschen Gesellschaft für Geotechnik e.V. und der Hafenbautechnischen [German Recommendations for the design of coastal protection constructions], *Die Küste* 65. 589 p. (in German).

Grubb, D. G.; Cadden, A. W.; Miller, D. D. 2008. Crushed Glass-Dredged Material (CG-DM) blends: role of organic matter content and DM variability on field compaction, *Journal of Geotechnical and Geoenvironmental Engineering* 134(11): 1665–1675.
http://dx.doi.org/10.1061/(ASCE)1090-0241(2008)134:11(1665)

Große, A.-K.; Saathoff, F. 2013. Soil mechanical aspects in characterizing fine grained organic dredged material from the Baltic Sea area, in *Proceedings of the GeSed Conference*, Caen, 10–12 April, 2013.

Gröngröft, A.; Gebert, J.; Berger, K.; Maaß, B. 2005. Verwendung von Baggergut als Material für die Dichtung von Deponien, den Deichbau, zur Verfüllung und zur Bodenverbesserung [Use of dredged material for landfill capping, dike construction for backfilling and soil improvement], *Hamburger Bodenkundliche Arbeiten* 56: 209–223 (in German).

HELCOM 2011. Report on disposal of dredged materials at sea [online]. Available from Internet: http://meeting.helcom.fi/web/monas

Henneberg, M. 2000. Erste Ergebnisse aus Praxisversuchen zur Verwertung von gereiftem Nassbaggergut als Bodenverbesserungsmittel in der Landwirtschaft [First results from practice experiments about the re-use of ripened dredged materials as a soil improvement measure in agriculture], *Rostocker Agrar- und Umweltwissenschaftliche Beiträge* 8: 375–386 (in German).

Levacher, D.; Liang, Y. 2013. Use of fibres waste in sediments stabilization/solidification, in *Proceedings of the World Dredging Congress WODCON XX*, Brussels, 3–7 June, 2013, session 14/1. 12 p.

Morscheck, G. 1992. *Standortkundliche Kennzeichnung, Bodenentwicklung und Nutzungsmöglichkeiten von in Spülfeldern abgesetztem Hafenschlick* [Characterisation, soil formation and application possibilities of harbour sludge processed in spoil fields]: PhD-Thesis. Universität Rostock (in German).

Netzband, A.; Christiansen, H.; Maaß, B.; Werner, G. 1998. Relocation of dredged material from Hamburg harbour in the River Elbe, *Water Science and Technology* 37(6–7): 241–248.
http://dx.doi.org/10.1016/S0273-1223(98)00204-2

Pohl, C.; Vavrina, L. 2008. New approaches for geotechnical design of Baltic Sea dikes, in *Proceedings of the 11th Baltic Sea Geotechnical Conference*, 1005–1012.

Quandt, T.; Henneberg, M. 2011. Deponierekultivierung mit gereiftem Baggergut am Beispiel der Siedlungsabfall-deponie Grimmen (M-V) [Landfill recultivation using ripened dredged material with the example of the landfill Grimmen], in *7. Leipziger Deponiefachtagung – Stilllegung, Nachsorge und Nachnutzung von Deponien*, 139–150 (in German).

Saathoff, F. 2003. Geosynthetics in geotechnical and hydraulic engineering, in *Geotechnical Engineering Handbook*. Berlin: Ernst&Sohn, 507–597.

Saathoff, F. 2006. Beispiele zur Sanierung und Ertüchtigung von Deichen mit Geokunststoffen [Examples for the reconstruction of dikes using geosynthetics], in *Symposium Sicherung von Deichen, Dämmen und Stauanlagen,* 9–10 February, 2006 (in German).

Saathoff, F.; Oumeraci, H.; Restall, S. 2007. Australian and German experiences on the use of geotextile containers, *Geotextiles and Geomembranes* 25(4–5): 251–263.
http://dx.doi.org/10.1016/j.geotexmem.2007.02.009

Sikora, Z.; Ossowski, R. 2013. Geotechnical aspects of dike construction using ash-soil composites, in *Proceedings of the 11th International Conference on Modern Building Materials, Structures and Techniques*, Vilnius, 16–17 May, 2013.

Triboutt, C.; Jusson, B.; Nzihou, A. 2012. Evaluation of treated polluted river sediments for road foundation, *Materiaux & Techniques* 100(5): 467–477.
http://dx.doi.org/10.1051/mattech/2012022.

Wang, D. X.; Abriak, N.-E.; Zentar, R. 2012. Co-valorisation of Dunkirk dredged sediments and siliceous-aluminous fly ash using lime, *Road Materials and Pavement Design* 14(2): 415–431. http://dx.doi.org/10.1080/14680629.2013.779309

Wang, D. X.; Abriak, N.-E.; Zentar, R.; Xu, W. Y. 2013. Solidification/stabilization of dredged marine sediments for road construction, *Environmental Technology* 33(1): 95–101.
http://dx.doi.org/10.1080/09593330.2011.551840

Weißmann, R.; Richwien, W. 2003. Ein Bewertungsverfahren für Klei im Deichbau, *Hansa* 140(7): 71–75 (in German).

Zdiri, M.; Abriak, N.-E.; Ben Ouzdou, M.; Neji, J. 2009. The use of fluvial and marine sediments in the formulation of Roller Compacted Concrete for use in pavements, *Environmental Technology* 30(8): 809–815.
http://dx.doi.org/10.1080/09593330902990097

Zhang, C. L.; Jin, W.; Wu, X. Y.; Wang, S. C. 2011. Properties of solidified dredged sediment used as subgrade construction material, in *International Conference on Electric Technology and Civil Engineering*, 2468–2470. http://dx.doi.org/10.1109/ICETCE.2011.5774642

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