Guidelines for Authors

Terra et Aqua is a quarterly publication of the International Association of Dredging Companies, emphasising “maritime solutions for a changing world.” It covers the fields of civil, hydraulic and mechanical engineering including the technical, economic and environmental aspects of dredging. Developments in the state of the art of the industry and other topics from the industry with actual news value will be highlighted.

- As Terra et Aqua is an English language journal, articles must be submitted in English.
- Contributions will be considered primarily from authors who represent the various disciplines of the dredging industry or professionals, who are associated with dredging.
- Students and young professionals are encouraged to submit articles based on their research.
- Articles should be approximately 10-12 A4. Photographs, graphics and illustrations are encouraged. Original photographs should be submitted, as these provide the best quality.
- Digital photographs should be of the highest resolution.
- Articles should be original and should not have appeared in other magazines or publications. An exception is made for the proceedings of conferences which have a limited reading public.
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- Authors are requested to provide in the “Introduction” an insight into the drivers (the Why) behind the dredging project.
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Maritime infrastructure construction is not possible without dredging. That is the long and short of it. At the core of every port expansion or coastal engineering achievement lies the bedrock of dredging operations and the skills of the dredging industry. Over the years these skills have reached new heights – and depths – that could hardly have been predicted 50 years ago.

One of the notable persons who was present at the dawn of the modern era of coastal engineering and dredging was Dr. Eco Wiebe Bijker, Professor Emeritus at the Netherlands’ Delft University of Technology. In February of this year he passed away at age 87, leaving a legacy that started when he joined and later led the renowned Delft Hydraulics Laboratory in De Voorst, Marknesse, the Netherlands. There he was involved in the research that laid the foundation for the Delta Project, protecting the Southern Netherlands Delta against flooding, the response to the disastrous destruction of the dykes and consequent loss of life in 1953. His research resulted in the first theoretical and practical formulation of wave effects in alongshore sediment transport, the Bijker formula. In the 1950s and ‘60s he taught and inspired both international students at IHE in Delft and Dutch students at Delft University of Technology as Chair of the Coastal Engineering department. Until his retirement in 1992, he continued teaching with remarkable and appreciated results, motivating generations of students to pursue the study of coastal processes. His contributions in the field of coastal engineering remain legendary.

These types of study and research continue today at IHE, TU Delft and a select number of universities worldwide and this is clearly reflected in the subjects in *Terra et Aqua*. One of the articles in this issue was written by the International Association of Dredging Companies Young Author Award winner, who received his masters from UNESCO-IHE. He is presently studying at Leichtweiss-Institut, Technische Universität, Braunschweig, Germany. A second article is by authors who have received or are working on degrees at TU Delft. In both cases, the tradition of original research and innovative thinking in the fields of coastal engineering and dredging studies at these technical universities are still clearly a priority. The practical application of these studies is also essential: The first article examines the engineering properties of Geotextile Sand Containers and their effect on the hydraulic stability of GSC structures and the second is an analysis of technical and financial feasibility of flexible design concepts for an ongoing port project in Rotterdam. Finally, this issue includes an update on the marine works operations and environmental considerations for the Fehmarnbelt Fixed Link which will connect northern Europe and Scandinavia. This too is a project that has been and continues to be thoroughly vetted with extensive research about environmental impacts and practical construction solutions.

Pioneers in the industry like Professor Bijker can be proud that their ground-breaking work continues to inspire and be built upon. The role of the dredging industry also continues to evolve with new approaches such as “Building with Nature” and “Early Contractor Involvement”. Keeping pace with these new concepts are innovative dredging technologies and vessels, and, most importantly, a growing group of well-educated, highly trained individuals. Many of the present-day top executives and managers in the dredging industry studied with Professor Bijker and his successors. They were inspired by him as a teacher and his influence continues to be seen in their professionalism and commitment as they go forth in their companies.

Koos van Oord
President, IADC
ABSTRACT

As a result of their numerous advantages, Geotextile Sand Containers (GSC) are getting increasingly popular as an alternative to conventional hard (e.g., rock, concrete) coastal structures. Nevertheless, GSCs still represent an emerging technology – even though the first GSC application in coastal engineering was in the 1950s. Despite the considerable development of GSC since then, no proper design guidelines are available for the design of GSC structures on a sound scientific basis. This on-going research study focuses on developing simplified formulae and a computational tool for the design of GSC structures. The significance of important engineering properties such as the type geotextile material, the sand fill ratio, the interface friction, and their influence on the hydraulic stability of GSC structures will also be evaluated. For this purpose and in order to better understand the effects of these properties on the hydraulic stability of GSC structures, a series of systematic laboratory experiments were conducted. This article contains some of the most important findings from these experimental investigations including the implications for the design practice. This article originally was published as part of the PIANC COPEDEC VIII Proceedings in Chennai, India, February 2012 and is reprinted here in an adapted version with permission.

Financial support provided for the first author by German Academic Exchange Service (DAAD) is acknowledged with great thanks. Leichtweiss Institute, Technische Universität Braunschweig, Germany, and NAUE GmbH & Co. KG are also gratefully acknowledged for their financial support to conduct the laboratory investigations.

INTRODUCTION

The need for cost-effective, environmentally friendly and more sustainable solutions to mitigate the risk of disasters caused by coastal erosion and floods related to the impact of climate change in coastal zones is urgent. In this context, more versatile materials and innovative solutions are required for the design of new shore protection structures as well as for the reinforcement of existing threatened coastal barriers and structures, including dune reinforcement and scour protection (Oumeraci and Recio 2010). The use of Geotextile Sand Containers (GSC) is a low-cost, soft and reversible solution and has a history of more than 50 years in hydraulic and marine applications. A range of successful coastal protection structures using GSCs (Figure 1) has been constructed in many parts of the world (e.g., Heerten 2000, Saathof et al. 2007).

Above: With their numerous advantages, Geotextile Sand Containers are being used in many situations as an alternative to conventional hard (e.g., rock, concrete) coastal structures. Shown here Busselton Jetty, a well-known tourist destination in western Australia (Photo courtesy of Geofabrics Australasia and ELCOROCK®).
Lawson 2008, Oumeraci and Recio 2010). Most of these failure modes are influenced by the engineering properties of GSCs. This study will therefore discuss the significance of important engineering properties of GSCs and their influence on hydraulic stability of GSC structures.

**ENGINEERING PROPERTIES OF GEOTEXTILE SAND CONTAINERS**

The most important engineering properties of GSCs are the mechanical properties of the geotextile material (e.g., friction, tensile strength and so on), the sand fill ratio, type of the fill material and the interface friction, in fact most of these properties will affect the deformation of GSCs and the movement of sand inside the container. More importantly, these properties are interrelated (Figure 3). The importance of these aspects has been highlighted by many authors worldwide. However, the knowledge about the influence of the properties of GSC listed in Figure 3 on the hydraulic stability of GSC structures is still very poor.

Based on a comprehensive literature survey and the analysis of previous model tests on the stability of GSC revetments, the decision was reached that some new experiments are needed to study the influence of the engineering properties of GSCs on the hydraulic stability of GSC structures and to obtain the required parameters for modelling, to clarify some processes and to validate the numerical models which are being performed.

**Sand Fill Ratio**

The sand fill ratio of GSCs was identified as an important parameter for the hydraulic stability of GSC structures (e.g., Oumeraci et al. 2007, Oumeraci and Recio 2010). It affects the deformability of containers, the internal movement of sand, and the resistance against sliding, which directly affect the hydraulic stability of a GSC structure. Oumeraci et al. (2007) have performed a systematic study to determine the optimum fill ratio for the GSC used for scour protection of offshore monopiles subject to storm waves in a large wave flume (GWK), Hannover, Germany. According to their findings, the stability increases with increasing sand fill ratio. A similar behaviour of GSCs was reported by Wilms et al. (2011) based on another series of large-scale experiments in GWK. Therefore, not only the weight of the container but also the fill ratio significantly influences the hydraulic stability of a sand container lying on the seabed.

Therefore, Oumeraci and Recio (2010) recommend more systematic research to investigate the influence of the sand fill ratio on the mechanisms responsible for the hydraulic failure of GSC. Moreover, the sand...
The fill ratio considerably influences the long term performance of GSC structures. Hence, the future research should be essentially directed towards the definition of an optimal sand fill ratio by accounting for the deformation properties of the geotextile and by balancing the advantages and drawbacks of high and moderate sand fill ratios. Ultimately, because of its considerable effect on the hydraulic stability and the long-term performance, future standards and guidelines should explicitly address the issue of the sand fill ratio of GSC (Oumeraci and Recio, 2010).

Even though the sand fill ratio is found to be a key factor governing the hydraulic stability of GSCs, none of the exiting stability formulae for the design of GSC structures accounts for the sand fill ratio. Moreover, existing definitions for the sand fill ratio are very vague. In order to overcome the drawbacks of existing definitions of sand fill ratio, a new definition was developed based on the initial volume of an inflated geotextile bag and dry bulk density of sand. The shape of the geotextile bag is initially flat and two dimensional. Once it is filled, it becomes a three-dimensional pillow. This final shape of the filled GSC has a complicated geometry which is difficult to idealise by a simple shape. Therefore, the calculation of the maximum volume of a geotextile container fully filled with sand is challenging (see Figure 4).

In this article, the sand fill ratio was calculated based on the theoretical maximum volume estimated using the formula of Robin (2004). The dry bulk density of sand (1480 kg/m$^3$) was used to calculate the required mass of the sand to achieve a desired sand fill ratio. During the small-scale experiments, it was found that the 0.5 m long model GSCs can be filled up to 120% of this initial theoretical maximum volume as a result of the elongation of geotextile material, even if the GSCs are filled carefully to avoid excessive elongations.

**Friction between GSCs**

Not only during laboratory tests, but also in the real life projects, “pullout” of GSCs has been observed (Oumeraci 2003, Jackson 2006). Recio (2007) experimentally and numerically investigated the process of pulling out containers from a GSC revetment caused by wave attack and concluded that the interface friction between GSCs considerably affects the hydraulic stability of GSC structures. Furthermore, the formulae suggested by Recio (2007) already account for the interface friction between GSCs. However, the effect of interface friction properties is still not fully clarified and/or experimentally verified.
Interface friction mainly depends on:
- friction properties of geotextile material (both short term and long term),
- contact area between two containers,
- the overlapping length (seaward slope),
- the sand fill ratio (shape of the GSCs),
- the type of fill material, and so on.

Until recently, the test results obtained by means of direct shear stress tests were the only available data to assess the friction between GSCs and only a few studies have been carried out in order to understand the interface shear strength of a pile of sand bags (Krahn et al. 2007, Matsushima et al. 2008).

Krahn et al. (2007) conducted large-scale interface shear testing of sand bags and other dike materials. Also Matsushima et al. (2008) carried out full-scale loading tests with soil bags. These works provide more insight into interface shear properties of geotextile sand/soil containers. The most promising finding of the research study of Krahn et al. (2007) is that the interface shear strength between sand filled bags is greater than that of the geotextile material alone. Furthermore, those studies show that the estimations of interface friction between sand bags using the direct shear test with geotextile samples are not accurate.
Important Engineering Properties of Geotextile Sand Containers

enough. Therefore, more investigations should be conducted to understand the friction between GSCs and its effect on the hydraulic stability of GSC structures.

EXPERIMENTAL STUDIES

As a result of an extensive review and analysis of the literature on the engineering properties of GSCs and on the hydraulic stability of GSC structures, the conclusion was drawn that laboratory testing represents the most feasible and appropriate option to study the effect of the engineering properties of GSCs on the hydraulic stability of GSC structures.

Therefore, a series of laboratory investigations were conducted. The influence of the sand fill ratio, the friction between GSC (by varying the type of geotextile material) and some geometrical parameters such as the stacking method (tandem or staggered) on the hydraulic stability were studied through two types of model tests; pullout tests (Figures 5 and 6) and wave flume tests (Figures 10 and 11).

PULLOUT TESTS

The main objective of these tests is to study the effects of engineering properties of GSCs on the pullout forces of GSC structures, with a special attention to the sand fill ratio. In order to achieve this goal, the effects of the following factors on the pullout forces were examined through a series of scale model tests:

- sand fill ratio of GSC,
- friction properties of geotextile material,
- seaward slope (overlapping length), and
- stacking method of GSC.

Apart from the determination of the influence of engineering properties of GSCs on the pullout forces, the specification of the required parameters for the numerical modelling of submerged GSC structures was the other main objective of the pullout tests.

GSC models were constructed with different sand fill ratios; 80% (mass = 11.18 kg), 90% (mass = 12.58 kg), 100% (mass = 13.98 kg), 110% (mass = 15.39 kg), 120% (mass = 16.80 kg) and with different geotextile material (woven and nonwoven). Since nonwoven geotextile has higher elongation properties, containers can be filled up to 120% of the initial volume, whereas containers with woven geotextile materials can be filled up to 110% because of their limited elongation capability.

The tests were conducted by constructing different GSC structures in the 1-m-wide wave flume (1 m wide and 1.25 m height) of the Leichtweiss-Institut (LWI). The heights of GSC structures were varied depending on the model configuration. GSCs were pulled using an electric motor that has a capability to adjust the pulling speed (Figure 5). GSCs were modified by attaching a horizontal pipe made of the same geotextile material at the front side of GSC, which can accommodate a steel rod. This rod and the electric motor were connected using lightweight steel cables.

The pullout forces were measured using a force transducer (Figure 5) connected to the cables and GSCs were tested only for steady pullout forces. The movement of GSC under the pullout forces was measured using a displacement transducer (Liner Variable Differential Transformers, LVDT). The LVDT was connected with a lightweight sliding frame attached to the rear side of the container. This attachment provided more precise measurements of the movement of the container and the measurements are
assumed to be free from errors caused by the deformations of the GSC caused by pullout force.

GSCs with sand fill ratios; 80%, 90%, 100%, 110%, and 120% were tested in 48 different testing scenarios. Each test configuration was repeated five times and all the results were taken into consideration during the analysis. In most cases, there were variations in the measured pullout forces. However, the general trends were clearly visible. A non-dimensional parameter was introduced as a relative pullout force. This is the ratio between pullout force and the weight of the crest GSC. According to the results, sand fill ratios of 90%~100% needed a higher relative pullout force than for other sand fill ratios (Figure 7). In general, the sand fill ratio clearly affects the deformation (shapes) of GSC and, consequently, the interface friction forces. Therefore, there will be a significant difference in terms of hydraulic stability for different sand fill ratios.

A comparison of the slope GSC and the crest GSC shows that the slope containers have at least 130% higher (average value) resistance than the crest GSC (Figure 8). Two types of geotextile, a woven and a nonwoven material, were used for the construction of the GSC models. As a result of the underwater direct shear tests with standard shear box, friction angles \( \Phi = 13.33^\circ \) (\( \tan \Phi = 0.237 \)) and \( \Phi = 22.62^\circ \) (\( \tan \Phi = 0.417 \)) were obtained for woven and nonwoven geotextile, respectively. These two materials showed a clear difference in their pullout resistance, which is roughly proportional to the friction coefficients obtained from direct shear tests. Then the relative pullout forces were calculated to find out the relationship between friction properties of geotextile materials and the interface friction properties of GSC. According to the results, both types of geotextile showed more than 30% higher relative friction forces than the corresponding theoretical relative friction forces based on direct shear tests. This is important when comparing GSCs made of woven and nonwoven material in terms of stability against pullout, and thus hydraulic stability under wave attack.

Additionally, GSCs structures with nonwoven geotextile can be further optimised as they showed nearly 50% higher relative friction forces than the estimated values using direct shear test results for sand fill ratios between 90% and 100%. Stacking methods, however, did not show any important effect for either nonwoven or woven GSC.

**WAVE TESTS**

Wave tests (Figures 9 and 10) were conducted in the 2-m-wide LWI wave flume to investigate the effect of the above-mentioned engineering properties on the processes that govern the hydraulic stability.

Approximately 350 model tests were performed while varying wave parameters, geometrical parameters and properties of GSC such as the sand fill ratio, the type of geotextile material, and so on. During model tests, incident and transmitted wave parameters, the behaviour of the structure (high speed video records), the flow velocity around the structure, and the pressure variations at the crest of the GSCs structure are systematically recorded.

Since the existing damage classification for conventional coastal structures (e.g., rubble mound breakwaters) is not applicable to GSC structures, a new method of damage classification was introduced:
- If a GSC displaces less than 10% of its length or shows an angular motion less than 10\(^\circ\), then it is considered as “stable”;
- If a GSC shows a greater displacement than 10% of its length or greater angular motions than 10\(^\circ\) then it is considered as either an “incipient motion” or a “displacement” depending on the magnitude as shown in Table I.
By considering the critical GSC layers of a GSC structure, the level of damages were then classified into five categories (see Table I).

**Effect of crest freeboard on hydraulic stability of GSC structures**

Early GSC structures were designed using the hydraulic stability formulae for stone armour layers such as Hudson’s formula (1956). Only the weight of GSCs was considered similar to any other conventional coastal structure. Later Wouters (1998) proposed a new stability formula (see Equation 2) for GSCs based on the Hudson’s formula and the previous experimental data.

This formula contains a modified stability number ($N_s$), which was developed explicitly for GSC sloping structures. Oumeraci et al. (2003) then proposed two different hydraulic stability formulae for crest GSC and slope GSC of a revetment using the stability number proposed by Wouters (1998).

According to Oumeraci et al. (2003), hydraulic stability of crest GSCs depends more on the relative freeboard whereas that of slope GSCs depends more on the surf similarity parameter.

The data from the current experimental results, however, showed that even the crest GSCs of submerged and low crest structures are strongly dependent on both the crest freeboard and the surf similarity parameter. Therefore, stability curves for different crest freeboards were developed based on one damage category; “incipient motion” when the damage category = 1) as mentioned in Table I.

$$N_s = \frac{H_s}{(\rho_{GSC} / \rho_W - 1) \cdot \frac{C_{wp}}{\sqrt{\xi_0}}} \cdot D,$$

(Equation 2)

Where,
- $N_s$ = stability number [-],
- $H_s$ = incident significant wave height [m],
- $\rho_W$ = density of water [kg/m$^3$],
- $\rho_{GSC}$ = density of GSCs [kg/m$^3$],
- $C_{wp}$ = empirical parameter derived from the stability number $N_s$ [-],
- $D$ = thickness of armour layer [m],
- $\xi_0 = \tan(\alpha)/(H_s/L_0)^{1/2}$ [-],
- $\alpha$ = slope angle of structure slope [°],
- $L_0 = g \cdot T^2/(2\pi) = \text{deep water wave length calculated using the mean wave period [m]}$.

Ideally, a single hydraulic stability curve should be found which can describe the behaviour of submerged/low crested GSC structures with different positive and negative crest freeboards. Vidal et al. (1992) showed a relationship with the relative freeboard and the stability number ($R_{c*} = H_s/D_{50}$) of low-crested rubble mound breakwaters by considering four different damage categories. The possibility of developing a similar relationship for the submerged/low crested GSC structures was also examined in the current research study.

Based on the above-mentioned new damage classification (Table I), new non-dimensional hydraulic stability curves were developed (e.g., Figure 12). Furthermore, different regions were demarcated in order to assess the expected damages to GSC structures, when design wave conditions are exceeded. For the quantification of the effect of the sand fill ratio and the type of geotextile material on the hydraulic stability, test results of different test series were compared by considering nonwoven 80% filled GSCs (series: NW80H / Rc = 0) as the basis (Figure 13). For each test scenario, “incipient motion” curves were plotted (damage category DC 1), as described in Table I.

**Effect of sand fill ratio on hydraulic stability of GSC structures**

In Figure 14, the “incipient motion” curves for 80% and 100% filled GSCs are comparatively...
the differences between woven and nonwoven GSCs are reduced in terms of hydraulic stability, mainly because of different dominant failure mechanisms.

When submergence depth is small, GSC structures failed as a result of sliding caused by overtopping waves, whereas in relatively larger submergence depths, overturning and “uplift and drift” were commonly observed. For overturning and “uplift and drift” failure mechanisms, the impact from the friction between GSCs is relatively trivial. However the progress of the damage was much rapid in woven structures compared to nonwoven structures.

Effect of the type of geotextile material on hydraulic stability of GSC-structures
Effects of the type of geotextile material used for the construction of GSC on the hydraulic stability of the GSC-structure were studied by using a nonwoven (series: NW80H) and a woven (series: NW80H) material (Figure 15).

Both types of GSCs were filled 80% and have approximately the same weights under buoyancy. During the tests series, when \( \text{Rc} = 0 \), stability numbers of nonwoven GSCs were almost twice as those of woven GSCs for “incipient motion” cases (damage category DC 1). As the submergence depth increases, the differences between woven and nonwoven GSCs are reduced in terms of hydraulic stability, mainly because of different dominant failure mechanisms.

When submergence depth is small, GSC structures failed as a result of sliding caused by overtopping waves, whereas in relatively larger submergence depths, overturning and “uplift and drift” were commonly observed. For overturning and “uplift and drift” failure mechanisms, the impact from the friction between GSCs is relatively trivial. However the progress of the damage was much rapid in woven structures compared to nonwoven structures.
**CONCLUSIONS**

This research study is one of the first attempts to systematically quantify the effect of the engineering properties of GSC on hydraulic stability. First, pullout tests were conducted to quantify the effect of the sand fill ratio, the type of geotextile material, seaward slope of GSC structures (overlapping length), stacking pattern, and so on, on the underwater pullout forces. From the five different tested sand fill ratios, the pullout forces are increased when the sand fill ratios (or increment of the weight of GSC) are increased. In order to determine the optimum sand fill ratio, a non-dimensional parameter was introduced as a relative pullout force. Fill ratios between 90%~100% are found to be optimal in terms of the resistance against pullout of the GSC. Only the amount of sand filled into GSC was varied here, but not the size of the empty bag (thus keeping the amount of geotextile used for a GSC unchanged). All the GSCs show 30%~50% higher pullout resistances than what was estimated based on the interface friction properties of materials. This will contribute to further optimisation of GSC structures.

Second, wave flume tests were conducted on low-crested GSC structures with both positive and negative crest freeboards. GSCs show different failure mechanisms for different submergence depths and the importance of engineering properties of GSCs also varies depending on the dominant failure mechanism for a particular GSC structure and for a particular freeboard. For most of the low-crested structures, the crest GSCs are clearly the critical elements. The hydraulic stability of these crest GSCs is a function of both relative crest freeboard and the surf similarity parameter. For the tested conditions with a zero freeboard, GSCs constructed with woven geotextile with an approximately 50% lower friction coefficient than nonwoven geotextile resulted in 40% less stability numbers, when the incipient motions of crest GSCs are considered.

Even though most of the existing studies on the construction of GSC structures recommend a sand fill ratio of 80%, 100% filled GSCs show a 36% higher stability number when the surf similarity parameter is 5, compared to 80%. Future research and design guidance should address the definition of an optimal sand fill ratio by accounting for the elongation properties of the geotextile and balancing the advantages and drawbacks of high and moderate sand fill ratios.

In addition to the hydraulic stability improvements achieved by higher friction angle between GSC and high sand fill ratios, these parameters also significantly influence the damage progression of GSC structures over the entire storm duration – the conditions which start damages to a GSC structure, the development of the damage and the different damage levels caused by different factors.

These results will be used for the validation of the numerical modelling system and of the hydraulic stability of GSC structures which is being developed. After validation, it will be used for a more detailed parameter study.

**REFERENCES**


ABSTRACT

The present volatile environment continues to place new functional requirements on port infrastructure. As a result, the useful life of port infrastructure has been reduced in recent years. Flexibility in infrastructures makes it possible to adapt them for new or changed use. The use of flexible and sustainable-solutions infrastructures needs to be promoted – though initially more costly, these may prove economical over their whole life cycle. The approach taken here was to carry out a real-life case study which entailed an investigation into the technical and financial feasibility of flexible design concepts for an ongoing port project in Rotterdam.

This exercise has led to insights into the suitability of flexible infrastructures for various uses and situations. The benefits of a flexible design concept were monetised and included, so that the resulting business case was viable. The study also served to highlight some barriers to the design, planning, and implementation of flexible infrastructures.

The authors wish to acknowledge that this research was carried out within the framework of Port Research Centre Rotterdam-Delft and Next Generation Infrastructures and sponsored by Water Research Centre Delft and Public Works Department of Rotterdam.

INTRODUCTION

Ports have a design life of several decades that must accommodate today’s needs as well as those of tomorrow. They also represent a major infrastructure investment. The present volatility, and the complex and dynamic nature of ports create new challenges for port planning and design. In order to cope with the many uncertainties, the traditional systems of engineering practices try to incorporate fundamental properties such as flexibility, versatility and adaptability into their plans and designs.

Flexibility in design of civil infrastructures such as quay walls, jetties, basins and approach channels, makes it possible to adapt them for new or changed use. An extended lifetime for infrastructures means not only a greater chance of returns on investments, but it also contributes towards sustainability through efficient use of resources. In the last few years, various flexible concepts for quay walls have been proposed. These concepts however have been seldom applied in practice. The common reasons cited for this are: a lack of long-term vision resulting in implementation of short-term solutions, lack of innovative spirit and institutional barriers.

How to shift focus from short-term profit to long-term vision, how to incorporate life cycle considerations into design of infrastructure, and how to encourage collaboration on innovative projects, which have an uncertain outcome, are some of the key challenges in the port sector.

OBJECTIVES

The objective of this research is to promote use of flexible and sustainable infrastructures – though initially more costly, in view of the uncertainty, they may prove more economical over their entire life cycle. Therefore, a real-life case was examined as a part of an MSc study (Ros 2011). The case entailed an investigation into the technical and financial feasibility of flexible design concepts for an ongoing port project. This was expected to give insights into
the suitability of flexible infrastructures for various uses and situations and also to highlight the challenges encountered during design, planning and implementation of flexible infrastructures. These challenges and issues could be addressed during future research.

CASE STUDY: INNOVATIVE USE OF TEMPORARY INNER LAKE AT MAASVLAKTE 2
Description and research approach

The Maasvlakte 2 (MV2) project, an expansion of the existing Port of Rotterdam (PoR) into the North Sea, is a venture of the Port of Rotterdam Authority (PoRA). The land reclamation began in 2008; 400 ha is already contracted in the first phase, and the first ship will be received in 2013. The construction for the second phase will begin in response to client demand and it is only in 2033 that MV2 will be fully operational. This means that, in between the phases (time uncertain), a large area of water – protected by an expensive sea defense – is not in use (Figure 1).

This situation offers a unique opportunity for the PoRA to generate extra revenues by carrying out commercial activities (of a temporary nature) in this area. This possibility was explored in a study, the details of which can be found in Ros (2011).

Site description and boundary conditions

Figure 2 shows the 500 hectare inner lake divided into parcels – the size, water depths and the approximate time that the parcel is expected to become available are also indicated. The container terminals of RWG, APMT, and Euromax, presently under construction in phase 1 of the MV2 project, are also indicated. A temporary dike divides the area into an open and closed lake. Based on the Master Plan (PMR 2010), which guides the development of MV2, the availability of the inner lake is determined as being about 7 years.

The various steps of the study are described briefly in the following sections:
- an inventory of activities suitable for the inner lake (not necessarily related to cargo handling);
- an inventory of infrastructure design concepts (traditional and flexible) and proposals for preliminary designs for each activity based on a cost analysis;
- a life cycle analysis to establish the viability of various activities in various scenarios;
- a detailed analysis to examine the financial viability of the selected alternative;
- drawing of conclusions over all aspects of the case study, with a focus on flexibility.
Certain activities are beneficial for the existing or future clients of PoR; others can benefit the image of the port, yet others could represent future opportunities for the port.

Figure 3 displays the seemingly most promising activities in the inner lake. Some cargo related activities are:

- ship-to-ship transshipment of liquid bulk using buoys or dolphins saves intermediate storage and requires cheaper facilities than ship-to-shore transshipment; also safer because of its mild wave conditions and patrol vessels nearby;
- storage of construction materials, e.g., granite blocks transported from Norway to the Benelux;
- mooring facilities for inland vessels and feeders which have to wait since seagoing vessels have priority because they generate more revenues and have service time agreements;
- a common terminal as a central transshipment hub for inland vessels (barges) which obviates the need for hopping of inland vessels through the port (CBT);
- assembly of structures such as caissons or offshore platforms;
- assembly of offshore wind turbines are transported in components to ports, assembled in ports and transported by sea, big market to meet European Union’s renewable energy targets.

Under non-cargo related uses, the inner lake could also be used for:
- the generation of wind energy;

The inner lake water depth varies from 14 metres in the south-east to 17 metres in the north-west. The planning objective is to select amongst various commercially viable, temporary activities for this area. The selected function or activities for the inner lake, should fit within the policy of site allotment of the PoRA, and not hinder other building or operational activities at MV2. Regulations related to safety and the environment, such as the European Bird and Habitat Directive, the Dutch spatial planning law, and the Dutch water law, limit the activities the that can be carried out at the inner lake. The requirements set out in the zoning plan (IGWR 2008) and the Environmental Impact Assessment reports (PMR 2007) are also applicable.

**Inventory of potential activities**

In order to formulate alternatives, a brainstorming session was organised with participants from PoRA, Delft University of Technology, and Municipality of Rotterdam (PoRA 2011).

Innovative ideas and out-of-the-box thinking were encouraged. The activities were not limited to cargo handling (although these generate the largest revenues in the form of port dues and contract income for PoR). The inner lake also offers a unique location for carrying out pilot projects of innovative character, e.g., realisation of flexible infrastructures or new activities.

Certain activities are beneficial for the existing or future clients of PoR; others can benefit the image of the port, yet others could represent future opportunities for the port.

Figure 3 displays the seemingly most promising activities in the inner lake. Some cargo related activities are:

- ship-to-ship transshipment of liquid bulk using buoys or dolphins saves intermediate storage and requires cheaper facilities than ship-to-shore transshipment; also safer because of its mild wave conditions and patrol vessels nearby;
- storage of construction materials, e.g., granite blocks transported from Norway to the Benelux;
- mooring facilities for inland vessels and feeders which have to wait since seagoing vessels have priority because they generate more revenues and have service time agreements;
- a common terminal as a central transshipment hub for inland vessels (barges) which obviates the need for hopping of inland vessels through the port (CBT);
- assembly of structures such as caissons or offshore platforms;
- assembly of offshore wind turbines are transported in components to ports, assembled in ports and transported by sea, big market to meet European Union’s renewable energy targets.

Under non-cargo related uses, the inner lake could also be used for:
- the generation of wind energy;
- mussel farms to cope with increasing demands;
- a pilot project for algae farming (algae can be used as biofuel in the future);
- installing a hotel for the workers at MV2 (as many as 2500 workers are expected between 2010 and 2035);
- a fast ferry for 10,000 commuters to the MV2;
- a temporary nature reserve which can help the flora and fauna, many kinds of water sports;
- a dolphinarium.

Selection of flexible constructions and preliminary designs
Infrastructure facilities are required to facilitate various activities. Some activities require waterside or landside access, others require extensive berthing, mooring, transshipment, or storage facilities, and yet others require no facility.

The inner lake will exist for a limited time and most traditional fixed infrastructure, owing to the long payback periods, is financially non-viable for this situation. Three options were available:

- Traditional fixed designs: a sheet pile wall, buoys or dolphins are relatively inexpensive, and can be reused; a jetty is also relatively inexpensive.
- Design for a shorter technical lifetime (in order to match the short economic lifetime): Containerland with a lifetime of 8-10 years is a possibility.
- Flexible designs that can be adapted for reuse: an L wall, Maxisteck, a barge, or caissons can be employed.

Structure selection is based not only on the immediate functional requirements of an activity, but on long-term considerations that include reuse. These structures can be seen in the first column of Figure 4, which also shows their reuse possibilities (in the port or otherwise). Most quay wall types, except for Containerland (CUR 2006) and Maxisteck (IGWR 2000), are well known (Figure 5). These two innovative concepts were a result of an initiative of PoRA, whereby the market was encouraged to come up with flexible concepts for infrastructures. In spite of pilot studies, these concepts have not been applied.

Each activity has its infrastructural and logistic requirements. Figure 6a and 6b show the alternative activities with the required facilities and the proposed location. The preliminary designs, i.e., dimensioning of the structures is carried out based on reference projects.

The technical lifetime of the structures differs as do the investment, operational, demobilisation, replacement and demolition costs. Reuse at another location is possible in all cases (in the case of Containerland the uncoated containers need to be replaced after 10 years).

The technical lifetime of Containerland is assumed to be 10 years, a sheet pile 25 years, and for the remaining structures 50 years. Investment costs are based on reference projects. Rough assumptions are made over the demobilisation, transport, demolition, storage and assembly costs.

Since the period of use is short, and revenues are not likely to differ irrespective of the structure, life cycle cost is used as a criterion for selecting the type of structure for each activity. This results in the following choices:

- Jetties are suitable for hotel at work and the fast ferry. A short jetty on a protected slope is cheaper than a longer jetty on a natural slope.
- Mooring structures are required for liquid bulk transshipment, as well as for mooring inland shipping and feeders. Piles are slightly more costly than buoys, but preferable.
- CBT requires a quay. Containerland is most cost effective because of the limited availability of the inner lake (at most 20 years).

The containers, with a lifetime of about 10 years can be replaced, or alternatively they can be protected from corrosion.

- Wind mill assembling and dry bulk storage require a quay. The existing quay wall of the contractor can be used instead of creating costly dedicated facilities.

Life cycle analysis
The financial viability of the activities needs to be examined in a business case. This requires an estimation of all relevant costs and revenue over the anticipated life cycle, the rest value and the possibility of reuse. This is also given the name Life Cycle Analysis. The alternative with the lowest net present value is commercially most attractive.

The revenues of Port of Rotterdam Authority consist of port dues, land rent and mooring dues. The port dues cover the use of the nautical port infrastructure. The dues paid by seagoing vessels are related to the volumes handled. Most inland vessels have annual contracts and pay a relatively small amount irrespective of the number and duration of calls. Figures 7a and 7b show an estimate of the revenues generated per year through each activity using reference projects. The contribution of the port and mooring dues as well as the contract income from land rent can be distinguished for each activity in the figure.

However, not only the future costs and revenues, but the useful lifetime of an alternative is uncertain. Therefore, various scenarios are developed by varying the number and duration of useful service life/lives.
of the infrastructure. The service life of various alternatives depends on development of MV2 – the expected availability is about 7-10 years. The site is expected to remain idle for at least two years and activities with cancellation periods of 1-2 years are favoured. The service life of the quay is assumed to be 10 years. Two sets of alternatives are distinguished here: a) employing structures with 50 year technical lifetime (revenues come in the case of scenarios 2-5); b) employing no structures (no revenues in all scenarios).

Figures 8a-8c show the Net Present Value (NVP) of the activities (using the selected structure) on the Y axis plotted against the lifetime of the activity. For each activity, when the break-even point is reached is visible (i.e., NPV=0). For the activities requiring no structure, the cash flow is positive in the first year itself.

The activity with the largest NPV is liquid bulk transshipment followed by dry bulk storage and wind energy generation. Wind mill assembling is also financially viable if the existing quay wall can be used. The common barge terminal, evaluated on the same basis, is non-viable (the next section uses a more rational approach leading to a different result). A dolphinarium, fast ferry, and mooring facilities for inland shipping and feeders are not financial viable.

Water sports do not generate revenues, but create a positive image for PoR. Hotel at work will generate small revenues, could reduce commuter traffic and support other activities at MV2. A floating hotel requires seaside access as well at a certain distance from port activities. The fast ferry generates small revenues and is only useful with activities such as a dolphinarium, hotel at work or an amusement park. A nature reserve has a positive impact on the environment through an increase in biodiversity. Mussel and algae farming, both in the pilot project phase, require little investment and can generate small revenues. Hotel at work has a positive NPV. Liquid bulk transshipment can take place at Maasvlakte 2 with Suezmax vessels (150,000 DWT, 200 m LOA of about 200 m, a draft of 14.5 m). For larger vessels the inner lake has to be deepened locally, and Very
Large Crude Carriers (VLCC) cannot be received in Yantzehaven. Currently, LNG transshipments take place in the North Sea (Figure 9). Ship-to-ship transshipments are more costly at the inner lake but, because of mild wave conditions and patrol vessels nearby, safer than in the North Sea. Still, a larger number of vessels on the inner lake could increase the chance of encounters and minimum safety distances to other activities are required as well. The common barge terminal, a concept that provides flexibility for all the parties (and coincidently, the only activity which employs a non-traditional quay wall), is discussed in detail in the next section.

**COMMON BARGE TERMINAL: CONCEPT**

A common barge terminal (CBT) is a central point for inland vessels to pick up and drop off cargo instead of hopping among several container terminals. It requires a quay to berth vessels and handle cargo and preferably is located close to the terminals. It has to be accessible via road for the employees, suppliers, emergency services and internal transport of cargo to other terminals. The transport to and from to the terminals is carried out by 25 TEU or 50 TEU vessels. The concept is illustrated in Figure 10 (Malchow 2011).

The market success of the common barge terminal depends on the collaboration between the container terminal operators RWG, APMT and Euromax (CTO), the terminal operator of CBT (CBTO) and PoRA. In the current Master Plan, though a barge feeder terminal is planned at MV2, a part of the quay will be used for handling inland ships.

The container terminals too, will be realised in phases in response to market demand. According to the current forecasts, even in the worst case economic scenario, an increase of 3.5% per year is expected in the container throughput, and on average 6%. When the sea terminals are nearing capacity, a CBT can help in reducing congestion. A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the CBT concept was carried out to evaluate the strengths, weakness, opportunities and threats of the concept (Table I). Viewing Table I, the left column (Strengths and Opportunities) outweighs the right column and is evidence of the overall benefits of the concept.

![Figure 7a: Revenue from cargo-related activities.](image-url)

![Figure 7b: Revenue from other activities.](image-url)

![Figure 8a: Net Present Value (NVP) for activities requiring no structures.](image-url)

![Figure 8b: Net Present Value (NVP) for activities requiring structures (low NVP).](image-url)

![Figure 8c: Net Present Value (NVP) for activities requiring structures (high NVP).](image-url)
Result of Financial Analysis of a CBT

PoRA invests in the quay wall and infra plus; CBTO invests in the equipment and additional transport. CTO incurs the cost for transport and container handling of the barges at the CBT in order to relieve congestion at its terminals when they near capacity. The benefit is postponement of investment in infrastructure expansions, without loss of cargo, and its competitive position. Shifting small call sizes to the CBT makes it possible to handle large call sizes as well as a larger number of sea vessels at the container terminals. Handling sea vessels instead of barges increases the productivity, thus in a way a CBT creates extra capacity at the sea terminal (Zuidegeest 2009).

The costs and benefits of this concept need to be monetised in a business case for all individual parties -- the container terminal operators RWG, APMT and Euromax (CTO), the operator of CBT (CBTO) and PoRA. This financial analysis is based on many uncertain factors, e.g., container throughput and terminal productivity which together determine the capacity of the container terminals and when it is exceeded; call sizes of barges at the container terminals and the percentage of small call sizes; the logistic concept selected by the CBT operator; the future port tariff structure; handling and internal transport costs and so on. In this analysis assumptions were made in consultation with experts in order to arrive at estimates of these variables in the business case.

The analysis concluded that the CBT was a viable option for the PoR, if the business cases of CBT, the container terminal operators and PoRA are taken into account. Thereby, the eventual savings from postponed investment in container terminal expansions could be treated as income in the individual business cases of PoRA and CTO. The indirect benefits for PoRA in the form of greater efficiency at the sea terminals were, however, not included. CTO benefits most from this concept, and a concrete business case helps in negotiations for mutual sharing of the benefits from this concept.

Table I. SWOT Analysis Common Barge Terminal Concept.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
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<tbody>
<tr>
<td>- increased efficiency and productivity at sea terminals (thus creating extra capacity in the terminal)</td>
<td>- initial capital investment by PoR and CBTO operator</td>
</tr>
<tr>
<td>- faster loading/unloading of inland shipping by dedicated barge cranes</td>
<td>- requires co-operation amongst involved parties (CBTO, CTO, PoRA)</td>
</tr>
<tr>
<td>- cost savings for PoR owing to phased investment in civil infrastructure</td>
<td>- logistics of barge transport need optimisation</td>
</tr>
<tr>
<td>- cost savings for CTO owing to phased investment in terminal equipment, no additional rent, personnel and operational costs</td>
<td>- shorter sailing distances in the port</td>
</tr>
<tr>
<td>- shorter sailing distances in the port</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>- delay investment in phase 2 MV2, use resources elsewhere</td>
<td>- conflicts between parties</td>
</tr>
<tr>
<td>- modal shift to inland transport owing to available infra</td>
<td>- each party wants its own barge feeder terminal</td>
</tr>
<tr>
<td>- reduced congestion at terminals, better relations with CTO, better image for the port, more clients for phase 2 of MV2</td>
<td>- inland shipping rates rise making it non-viable</td>
</tr>
<tr>
<td>- pilot project for flexible structures</td>
<td>- new forms of competitive transport (faster and environmentally friendly) appear</td>
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</table>
CONCLUSIONS

This case study dealt with utilisation of the inner lake at Maasvlakte 2 in Rotterdam for commercial purposes, using flexible infrastructural facilities. This was seen as a unique opportunity for the PoRA to generate extra revenues. Since the inner lake has a temporary existence in between the two phases of the MV2 project, the infrastructural facilities were meant to be suitable for temporary use. The choices lay between a civil structure with a short lifetime (thus suitable to be demolished), or a flexible infrastructure (easy to dismantle, transport and assemble), that could be to be reused at another location.

The study involved a selection of potentially viable activities in the inner lake, preliminary designs of required infrastructural facilities, as well as a selection of suitable location based on the logistics and safety considerations.

The viability of these concepts was examined.

One of the promising concepts, i.e., the Common barge terminal (CBT) was evaluated in a detailed business case. The case study offered many insights related to both engineering and financial aspects of a port project. The following conclusions could be drawn over flexible infrastructures:

- Constraints from the surroundings, such as ongoing construction and operational activities, limit the choice of activities and infrastructure for the inner lake. Similarly, institutional bottlenecks (such as the Master Plan which forms the basis for the Environmental Impact Assessment, and based on which the construction permits have been granted) also restrict the possibilities.
- The selection of the type of structure is determined by the functionality it offers, and the short- or medium-term financial viability. In general, traditional infrastructure associated with minimum costs and risks (since the designs and construction methods have been optimised during multiple projects) is selected and preferred. Long-term viability is seldom examined.
- A capital-intensive concept has a small chance of being selected amongst available alternatives, despite the benefits that it may offer in the long-term future. Flexible solutions, such as a floating terminal, could help PoRA seize many such opportunities in the future, but the huge capital investments and unproven viability means that it will not be realised.
- When a non-traditional design concept does form an option (just as in the present study), the choices are limited to the existing concepts which have been well researched in pilot studies, through experiments or computer simulations. This fact signifies that collaborative research on innovative flexible concepts must continue, so that planners and designers have a variety of infrastructural solutions at their disposal.
- The study concluded that the CBT was a viable option for the PoR, taking into account the business case of CBT, the Container Terminal Operators and PoR. In this manner, the added benefits (such as savings resulting from postponed investment in container terminal expansions and a significant increase in efficiency and productivity at the sea terminals) could be taken into account in individual business cases of PoR and CTO. CBTO benefits most from this concept and a concrete business case helps in negotiation with the CTO for mutual sharing of the resulting benefits.
- Thus, a CBT provides additional flexibility to phase investments in container terminal expansions, both by PoR and CTO; the value of this flexibility has been included in the business case to support decision-making over the commercial use of the inner lake. A valuable lesson from the exercise is that phasing infrastructure expansion offers monetary advantages for all the parties through postponing investment and allows PoRA to keep their options open.

REFERENCES


ABSTRACT

The Fehmarnbelt Fixed Link will connect Scandinavia and continental Europe with a combined rail and road connection between Denmark and Germany. It is planned to cross the Fehmarnbelt between Rødbyhavn, located some 140 km south of Copenhagen on the island of Lolland in Denmark, and Puttgarden, located on the island of Fehmarn on the north coast of Germany.

Important challenges for the realisation of this project are: a world-breaking distance of 18.5 km, a water depth of 30 m and crossing a busy navigational channel.

After a comprehensive comparison between a bridge and an immersed tunnel solution the decision was reached that an immersed tunnel should form the basis for the continuous planning of the project including the environmental impact studies. However, alternative technical solutions are still being considered. The start of the construction is expected to commence in 2015 and the link is scheduled to be opened for traffic in 2021.

This article will present some key points of the conceptual design of the marine works aspects in general, and focus on the dredging process more specifically. The global picture of key dimensions and volumes will be included as well.

INTRODUCTION

Description of the Immersed Tunnel Project

The alignment for the immersed tunnel solution is shown in a plan in Figure 1. The route passes east of Puttgarden, Germany, crosses the Fehmarnbelt in a soft curve and reaches Lolland east of Rødbyhavn in Denmark. The alignment and landfall locations were chosen in a process which considered environmental and technical factors in addition to costs and the practical issues of connecting to the existing infrastructure. A number of alignments were investigated and optimised to fit the spatial resistance factors identified for the project area.

The major features of the immersed tunnel solution include:

- An immersed tunnel approximately 18 km in length.
- Cut and cover tunnels at each landfall bringing the tunnel up to the surface.
- Portal structures, at the entrances to the tunnel.
- Ramps for the road and rail on the approaches to the tunnel.
- Approach highway and railway linking to existing routes.

Figure 1. Conceptual Design alignment (road shown in blue and rail shown in red).
Reclamations areas at both coasts (the great majority at the Lolland coast) for the re-use of material dredged from the tunnel trench.

**IMMERSED TUNNEL SOLUTION**

The tunnel elements consist of a combined road and rail cross-section all at one level, contained within a concrete structure. There are two types of tunnel elements: standard elements and special elements as shown in as shown in Figures 2 and 3. Standard elements represent the cross-section for the majority of the immersed tunnel (79 standard tunnel elements). All standard elements have the same geometric layout and are, to a high degree, interchangeable. Each standard element is approximately 217 m long and is constructed from a chain of smaller segments which, for transportation and immersion, are temporarily connected longitudinally using a post-tensioning system which is cut after the tunnel elements are placed on its foundation.

There are also 10 special elements, one every 1.8 km along the length of the immersed tunnel that provide space within the tunnel to house the mechanical and electrical equipment associated with the tunnel’s operations systems. Each special element is unique and cannot be interchanged with other elements. They provide maintenance access via the ground floor to all areas of the tunnel with the minimum of disruption to operation.

Many sorts of tunnel technical installations in the tunnel – such as fire suppression systems, tunnel drainage, lighting, communication system, Intelligent Transportation System and SCADA – will ensure that the future users enjoy a safe journey from coast to coast through the tunnel.

The tunnel elements are placed in a trench dredged into the seabed, as shown in Figure 4. A bedding layer of gravel forms the foundation for the elements. A combination of locking fill and general fill is at the sides, while at the top is a protection layer which is in general 1.2 m thick, but can vary depending on the location on the alignment. The function of the locking fill is to lock the tunnel element into position in the trench and prevent any movement as a result of hydraulic loads or the placement of the general fill.

The protection layer ensures against any damage from grounded ships or falling and dragging anchors.

The standard tunnel elements are 97% of the total length of the immersed tunnel. In the
Reclamation areas are planned along both the German and Danish coastlines that will accommodate the dredged material from the excavation of the tunnel trench. These areas will be landscaped into green areas. The size of the reclamation area on the German coastline is relative small. Two larger reclamations are planned on the Danish coastline on both sides of the existing harbour which will absorb the majority of the dredged material from the trench excavation.

MARINE CONSTRUCTION WORKS

The marine construction works activities comprise all the coast-to-coast marine construction activities which are needed to create the immersed tunnel for the Fehmarnbelt Fixed Link. The marine construction work phases are described in the following sections.

Phase I: Temporary works

The temporary works comprise the construction of two temporary work harbours (one on the German side at Puttgarden and one on the Danish side at Rødbyhavn), the dredging of the portal areas and the construction of the containment dikes.

The work harbours will be used to provide a safe haven for marine construction equipment, to facilitate the transport of personnel, and to provide facilities for supply, stockpiling, and load-out of materials and equipment. These harbours will be integrated into the planned reclamation areas and upon completion of the tunnel construction works, they will be dismantled/removed, backfilled and landscaped.

To meet the stringent requirement for the opening date, a total of 8 production lines, which will construct 79 tunnel elements, are foreseen. The high production rate for the concrete will result in a high demand for materials to be delivered on site. Deliveries to the site are expected to take place by means of trucks, but the main materials for the concrete production (cement, sand, aggregates and reinforcement) will be delivered by vessels.

The tunnel portal buildings are both located behind the newly constructed coastline and the main features of the portal building and ramp area are as follows:
- Ramps for road and rail
- A cut-and-cover tunnel section including a lightscreen structure
- Portal buildings
- Sea defences.

Table I below gives an approximation for some of the main resources that will be required to construct the Fehmarnbelt Fixed Link tunnel. These quantities are subject to variation at detailed design.

<table>
<thead>
<tr>
<th>Quantities</th>
<th>Units</th>
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<tbody>
<tr>
<td>Concrete in tunnel elements</td>
<td>2.5 million m³</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>300,000 tonnes</td>
</tr>
<tr>
<td>Ballast concrete, total</td>
<td>0.4 million m³</td>
</tr>
<tr>
<td>Structural concrete, portal buildings, ramps and cut and cover</td>
<td>0.2 million m³</td>
</tr>
<tr>
<td>Total volume dredged from tunnel trench, access channel, harbours</td>
<td>19 million m³</td>
</tr>
<tr>
<td>Trench backfill volume</td>
<td>6.4 million m³</td>
</tr>
<tr>
<td>Total reclamation area</td>
<td>350 ha</td>
</tr>
<tr>
<td>Total area Production site</td>
<td>120 ha</td>
</tr>
</tbody>
</table>

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**Table I. Resource requirements.**
Phase III: Installation of the tunnel elements and backfilling the trench

The installation of tunnel elements and the backfilling of the trench is also a sequence of Marine Works activities. As there may be a period of time between dredging of the tunnel trench and immersion of the tunnel structure, the operation will start with a clean sweep operation. Any undesirable sedimentation which has been deposited within the trench can, for instance, be removed with a trailing suction hopper dredger. This will ensure the trench is suitably clean for placing the gravel bed layer and subsequently the immersion of the tunnel elements.

A gravel or rock bedding layer is considered the most likely type of foundation which will be placed within the trench using a pontoon equipped with a fall-pipe and then levelled during placement with the fall-pipe or afterwards using a screeding pontoon.

Crushed rock will need to be delivered from a quarry somewhere in the region.

Expectations are that this will be done by self-unloading carriers which can moor alongside the placing pontoon and unload the rock onto a conveyor belt (via a hopper feeder) and the rock will be subsequently conveyed and fed into the fall-pipe.

Ramps section of works. These works comprise the dredging of the ramps and construction of temporary front and lateral dikes.

Before the reclamation takes place, containment dikes are to be constructed some 500 m out from the existing coastline at a depth of approx. MSL-4.5 to MSL-6.5 m (MSL = Mean Sea Level). The dikes will be built to a height of MSL+3m with an extended crest of some 7 m.

Phase II: Dredging and reclamation

A number of different types of dredging works need to be performed:

- Dredging to create the trench where the immersed tunnel can be placed
- Dredging to create sufficient depth for temporary harbours and access channels
- Dredging for the portals and ramps, reducing the need for land-base excavation prior to commencing the structural works.

The excavation of the tunnel trench between Lolland and Fehmarn represents the majority of the dredging works in terms of the quantity of dredged material and the associated construction time. All other dredging works (for work harbours, access channels and ramps) will be completed prior to the start of trench dredging. The total dredging quantity of in-situ soil that will be dredged for different parts of the works is 19 million m³.

An important goal for the project is to beneficially re-use the majority of the dredged material and at the same time give close attention to environmental issues and safety during the working process.

To prevent blockage of water exchange through the Fehmarnbelt the contours of the reclamation areas do not exceed the boundaries of the existing breakwaters of the ferry terminal.

The production facility is located inside the reclamation area Lolland East, where as a consequence, part of this area will temporarily be unavailable for the storage of dredged material.

The work harbour and basins will result in additional dredging because it will be deepened (and later filled again). This will also lead to a temporary storage of dredged material. Part of the temporary storage of dredged material is done by raising the surface level of the reclamation area Lolland East and the rest is stored on land in earth berms around the production site.

After the construction of the tunnel elements, the stored dredged material will be used to fill the work harbour and then the final landscaping will be done.
Phase IV: Landscaping

The expected dredging methodology will be described in the following section, where it is explained why it is most likely that a large part of the dredged material is mechanically excavated and transported with barges to the reclamation areas. Part of the materials (less than half) will need to be placed in the wet areas behind the containment dikes, and the other part is used for dry placement above the water level.

Most of the materials will consist of very hard clay till (approximately 12 million m³ in-situ values), which will be ideal to form the basis as main fill for the reclamation areas.

It is also expected to be suitable to use as construction material for the containment dikes around the reclamation areas. The rest of the material will consist of mechanically excavated softer soils such as sand, silt and clays (approximately 7 million m³ in-situ values).

Once dredging and reclamation for the tunnel is complete the reclaimed land are allowed to consolidate and then landscaped into their final design. The main goal for the landscape plans is to use the dredged materials beneficially to create natural landscapes and create added environmental, natural and recreational value to the project as shown in Figures 9 and 12.

This will be achieved with the following landscape elements:

- Beach and dunes at the outer corner of reclamation area Lolland West.
- Artificial pocket beach connected to a lagoon on reclamation area Lolland West which creates a recreational area.
- Armored dikes with higher lying land between the Rødbyhavn and the portal building.
- Coastal lagoons with wetlands on the eastside of the portal building, where the nature is allowed to develop naturally. There are two openings where brackish water can flow in and out of the area.
- A natural cliff on the far east side of reclamation area Lolland East, which is allowed controllably to erode and thereby supply the downstream coastline with sediments.

The immersion operation involves all activities concerning the preparation, immersion, and connection of the tunnel elements under water. Prior to immersion, the tunnel elements are stored in floatation next to their ultimate location. When ready for immersion the element is winched into position by the immersion pontoons fixed to the element. In near-shore locations tug boats may be used to help guide the elements. The immersion starts by filling the ballast tanks and to create the required negative buoyancy for the element to sink.

During the lowering, the tunnel element is supported from the immersion pontoons on suspension wires, as shown in Figure 7. The position of the pontoons is controlled with mooring wires.

During the immersion the tunnel element is gradually lowered towards the previously immersed element. The horizontal movement of the tunnel element is controlled using contraction wires. When the tunnel element nears its location it will be slowly lowered onto the gravel bed within the trench. The immersed element is pulled against the preceding element and the joint is sealed. Subsequently alignment adjustments are made if needed, with hydraulic jacks inside the immersion joint. Once the tunnel element is correctly positioned, the locking fill is placed.

Once a tunnel element has been installed on the foundation bed it will be necessary to backfill the trench with suitable materials and provide a cover layer for protection. The design of the locking fill, backfill and cover layer is such that it does not extend above the existing seabed level, except in the very near-shore areas.

To create sufficient horizontal stability against wave conditions a locking fill is placed on both side of the tunnel element. Crushed rock or gravel will typically be used for the locking fill, depending on the position along the alignment. The material will be brought from a quarry within the region. The general fill will be sand from a suitable marine source location. A small- to medium-size trailing suction hopper dredger is a likely option which can be used to source the sand and then place the fill via its drag arm into the trench.

For the protection layer, rock will be transported from its source, possibly using a pontoon tugged by a boat, and placed for instance by side stone dumping (pushing rock over the side of the pontoon) or by grabs mounted on the vessel itself.
Marine Works Operations and Environmental Considerations When Building the Fehmarnbelt Tunnel

25

The soils to be dredged on the German side are characterised by paleogene clay and some clay-till with boulders. The central basin comprises gyttja, sands, silts and clays and the soils to be dredged on the Danish side are dominated by thick deposits of clay-till. All dredged material is expected to be classified as clean, unpolluted soil.

From a pure technical point of view all dredging methods are more or less applicable in different parts of the crossing. However, to minimise the impact on the environment mechanical excavation by means of Backhoe Dredgers (BHD) or Grab Dredgers (GD) is expected to be the preferred method.

Mechanical dredging will minimise the adverse effects of dredging turbidity on the surrounding environment. The alternative of hydraulic dredging will be associated with relative higher turbidity levels, caused by the suction process or by overflow of a hopper.

The proposed methodology for trench dredging comprises mechanical dredging using Backhoe Dredgers (BHD) to a depth of MSL -25m and Grab Dredgers (GD) below that depth. A Trailing Suction Hopper Dredger (TSHD) is a proposed option to be used to pre-treat (rip) the clay-till below MSL -25m and the pre-treated material will subsequently be dredged by the GDs. The mechanically dredged material (excavated by GD and BHD)

Figure 9. Final landscape of Lolland Reclamation Area.

Figure 10. Longitudinal soil profile.
Creating natural reclamation areas

The reclaimed areas are designed and shaped in such a way that sufficient storage capacity is created while maintaining “zero blockage” of the flow of water.

Dredged material will be used to reclaim and create a natural recreational type of landscape with eroding cliffs, wetlands and beaches – each with a different nature and use. The different areas can be expanded or reduced, and the levels can be changed to provide the best conditions for wildlife and recreational activities.

On the Fehmarn coast (Figure 11) the reclaimed land behind the dike will be landscaped to create an enclosed pasture and grassland habitat. New paths will be provided through this area leading to a vantage point at the top of the hill, with views towards the coastline and beyond. The reclaimed land behind the dike will be landscaped to create an enclosed pasture and grassland habitat.

On Lolland (Figure 12), two reclamation areas will be located, one on either side of the existing ferry harbour. The reclamation areas extend approximately 3.7 km east and 3.5 km west of the harbour and project approximately 500 m beyond the existing coastline into the Fehmarnbelt.

The sea dike along the existing coastline will be largely retained and will continue to function as flood protection for the hinterland. A new dike to a level of +3.00 m will protect the reclamation areas against the sea. To the eastern end of the reclamation, this dike rises as a till cliff to level of +7.00 m. The erosion of the cliff will result in sediment releases during severe storms which will feed the beaches with sand on the east of the reclamation area.

Two new beaches are planned within the reclamation areas. There will also be a lagoon with two openings towards Fehmarnbelt and revetments at the openings to control the amount of wave energy passing into the lagoon area.

Minimising the footprint

The impact on the seabed is minimised by not reclaiming within protected natural habitats.
Obviously dredging contractors, who avail over backhoe dredgers that can reach a depth of 30 m or more, will only start with ripping after they have reached the maximum depth with their backhoe dredgers. This should be seen as a variation, not an alternative.

Another expectation is that the dredging contractors will look at the expensive elements in the dredging works and try to reduce the costs. The following elements are obviously from that point of view:

• The ripping of the clay till below MSL-25 m with a hopper dredger is a very costly operation, because a hopper dredger is a very expensive piece of equipment and if only used to rip, it is not employed to its full potential. Dredging contractors can be expected to look for ways to either utilise

### Description of Alternative Dredging Solutions

Although the preferred dredging methodology will be a feasible way to execute the works, it might not be the most economical solution. With an open tender the expectation is that the dredging contractors will also look into other solutions, which might be more economically feasible, taking into consideration the availability of suitable equipment.

### Stringent navigational measures

During the construction of the Fehmarnbelt Fixed Link there will be restricted working areas where marine activities will take place. The main offshore construction phases are the dredging of the tunnel trench and the immersion and backfilling operations, and they will be performed in a busy navigation route (T-route), where on an annual basis some 40,000 ships (year 2010) pass through the Fehmarnbelt. Ensuring that the risk of a vessel collision during this temporary situation is reduced to an acceptable minimum is of the utmost importance.

The total period for the dredging operation will be approximately 1.5 years and will take place as a continuous process. One disadvantage of the proposed dredging methodology is that it requires a relatively high number of dredging equipment working in the Fehmarnbelt. Based on the detailed planning of the immersion cycle, the conclusion is that the tunnel elements must be immersed from 2 fronts working from both shore lines towards the inner part of the Fehmarnbelt. The foundation and backfilling operations will run in parallel with the tunnel immersion operations.

The aggregates, sand, gravel and cement, for the concrete production for the tunnel element production site on Lolland will be brought in with 5,000 to 10,000 DWT bulk vessels. Vessels will enter the harbour basin through an access channel.

Measures like a Vessel Traffic System (VTS), well-defined boundaries for working areas, buoys and guard vessel control are included in the design and reduce the risk of a collision to an acceptable level. The channel will be marked by navigation aids. The accessibility of the work harbours is dependent on the weather conditions. Storms will from time to time create downtime for the supply of materials. To improve the accessibility and reduce this downtime temporary breakwaters are foreseen. These breakwaters will be removed after the construction of the tunnel elements.

Figure 12. Extent of the proposed reclamation on Lolland (dashed white lines).
the full potential of the hopper dredger or make a special-built tool to rip the clay-till.

• Monitoring the spill will be a responsibility of the dredging contractor. Lessons learnt from the Øresund Link point out that the monitoring required there led to very high monitoring costs (approximately 10% of the dredging and reclamation project value). Therefore one can anticipate that solutions to reduce the costs of monitoring will be thoroughly considered.

Alternative options for hydraulic dredging

By not only ripping the clay-till but dredging it at the same time as well, hydraulic dredging will make full use of the trailing suction hopper dredger. Transporting this material up through the suction pipe from depths ranging between 25 and 50 m will require a high pumping power and large quantities of water. The fully loaded draft of the hopper dredger (assuming a hopper dredger with a hopper volume in the range of 10,000 – 15,000 m³) will be in the order of 10 m.

This means that the hopper dredger cannot place its load directly in the reclamation area, but will have to pump it into the reclamation area through a pipeline. A cutter suction dredger is an efficient piece of equipment to dredge harder material like for instance the clay-till. For this project it can only be considered when it can pump the dredged slurry directly into the reclamation area, because hydraulic loading of barges with clay will result in an unacceptably high spill percentage.

If the reclamation area is (partly) filled hydraulically instead of mechanically, measures have to be taken to take care of the discharge water. The fill soil consists mainly of clay with large amounts of silt. As result of the mixing with water, pumping and subsequent transport through a pipeline of several kilometers in length, part of the clay will be dissolved in the water, resulting in very dirty water, with high concentrations of fines.

This discharge water can obviously not be released directly into the surrounding sea, but has to flow through a series of settlement basins in which the fines can be collected.

At the moment the effects of the alternative options for hydraulic dredging and its effects on the environment are under investigation, including the measures which might need to be undertaken for such options.

REMARKS

This article gives an impression of the marine operations and their associated marine equipment spread for the conceptual design of the Fehmarnbelt Fixed Link project. It goes without saying that the contractors are challenged to come with their own construction methods during tendering, of course, within the boundaries which are set in the Contract.

Besides minimising the environmental impact by setting stringent requirements during both construction as well as the operational phase, the project also takes up the opportunity to create added value to the environment.

By using the dredged material from the trench to form and shape reclamation areas, valuable recreational and natural resources will be created.

Coastal zone management is often associated with densely populated areas, but the Fehmarnbelt Fixed Link project will demonstrate the positive contribution of such a large-scale project to the natural system in a rural area.

REFERENCES


Valuing Ecosystem Services: The Case of Multi-functional Wetlands
BY ROBERT KERRY TURNER, STAVROS GEORGIOU AND BRENDAN FISHER

That many of our ecosystems have been ignored and consequently been degraded is hard to dispute. According to the authors, part of the problem is that the debate over the valuation of ecosystems is complicated: To address this, they have developed a system called “Ecosystem Services Approach” or ESApp to appraise the full value of “ecosystem services” to the economy and society. Multi-functional wetlands are used as a case study for implementation.

In each of six chapters the authors put their ESApp system in a perspective that applies to policy and project appraisals and management as well as legal decision-making:
- Ecosystem Services Approach to Natural Resource Management. A general definition that “ecosystem services are the aspects of ecosystems consumed and/or utilised to produce human well-being” allows room to introduce the concept of organisation, operations and outflows utilised by humans.
- The Ecosystem Services Approach: Valuation of Multi-functional Wetlands. Wetlands, with their biodiversity and wide range of benefits to humanity, are a complex but pertinent example of applying the ESApp through which their benefits (“service outcomes”) that can then be monetised.
- Economic Valuation of Wetland Ecosystem Services in Practice. Socio-economic benefits are evaluated considering risk, uncertainty and irreversible changes, with a focus on wetland benefits defined as hydrological (water-related), biochemical (nutrients and soil minerals) and ecological (habitat maintenance).
- Valuation of Multi-functional Wetland: Case Studies. Concrete examples of the valuation of nature conservation, recreation and other at-risk economic interests are given.
- Conclusions and Future Prospects. Although ESApp is applied to wetlands, the authors point out their research methods can provide generic guidance to a variety of other systems.

Three appendices round out the book: Appendix A: Economic Valuation Techniques offers various valuation methods such as market demands and market-based transactions, production functions, the Hedonic Price Method and Travel Cost Method. Appendix B: Wetland Ecosystem Services: Overview of Empirical Studies is an extensive literature survey of specific studies (primarily in the UK and the USA), most of which took place in the 1990s. Appendix C: Case Studies Used for Policy Review and Survey categorises by type of study and country 34 case studies (with worldwide cases from every continent) giving the policy relevance of each.

Valuating Ecosystem Services takes a broader view of what ecosystems truly mean to society than previous studies. The book gives guidelines that suggest how to better determine what “valuable” actually means. For public policy decisions and governance this is of great importance.

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FACTS ABOUT SELECTING A DESTINATION FOR DREDGED MATERIAL
INTERNATIONAL ASSOCIATION OF DREDGING COMPANIES
An Information Update from the IADC – Number 1. 2012. 4 pp. Available free of charge online and in print.

Selecting a destination for dredged material has provided innumerable concerns, challenges, discussions, debates and sometimes delays of projects. Therefore determining the nature of the dredged material and its potential use or placement early on is crucial. These choices can have enormous environmental, as well as direct economic, impacts on a project. In this Facts About the practicality of the most common options – for use, for open-water placement and for confined disposal – are examined. New methods such as “flexible disposal strategy” are presented, and the responsible parties for determining the destination are defined with a brief description of regulations governing these options.

Clarification
Please note that a sentence on page 3 under the heading “How are the placement and/or disposal of dredged material regulated?” has created some in-depth discussions amongst various experts. Although some feel that it is clear and correct as is, to avoid misunderstandings, IADC clarifies the sentence further by adding the phrase in italics: “In June 2008 the European Parliament adopted compromise wording for a new Waste Framework Directive (WFD) which excluded non-hazardous dredged material that is relocated in surface waters from the Directive’s jurisdiction and aligned the EU with international law as specified in the London Convention (LC)”.

Facts About are published periodically by the IADC as part of a series of concise, easy-to-read executive summaries on specific dredging and maritime construction subjects. A full list of titles and downloadable PDFs are available at the IADC website: www.iadc-dredging.com. Printed copies can be ordered by contacting the IADC Secretariat: info@iadc-dredging.com
SEMINARS / CONFERENCES / EVENTS

IADC INTERNATIONAL SEMINAR ON DREDGING
JUNE 18-22, 2012
DELFT, THE NETHERLANDS

Each year the International Association of Dredging Companies (IADC) organises its Seminar on Dredging and Reclamation in Delft as well in other cities around the world. This year’s Delft Seminar will be presented in June at UNESCO-IHE. The week-long Seminar covers such subjects as: overview of the dredging market and the development of new ports and maintenance of existing ports; project phasing (identification, investigation, feasibility studies, design, construction, and maintenance); descriptions of types of dredging equipment and boundary conditions for their use; state-of-the-art dredging and reclamation techniques including environmental measures; site and soil investigations, designing and estimating from the contractor’s view; costing of projects and types of contracts such as charter, unit rates, lump sum and risk-sharing agreements; design and measurement of dredging and reclamation works; and early contractor involvement.

An important feature of each Seminar is a site visit to a dredging project. In June the visit will be to Maasvlakte 2 (the new port of Rotterdam) and to the dredging yard of IADC member Van Oord. Participants will have the opportunity to see dredging equipment in action and to gain a better understanding of the extent of a dredging operation.

The fee for the week-long Seminar is € 2250.- (including VAT). This includes all tuition, seminar proceedings, workshops and special participants’ dinner, but excludes travel costs and accommodations. Assistance with finding hotel accommodation can be given.

For further information and registration:
For the brochure with details and the registration form visit:
• Email: dhollander@iadc-dredging.com

THE FUTURE OF DREDGING IN LATIN AMERICA
AUGUST 28-29, 2012
RIO DE JANEIRO, BRAZIL

Officially supported by WEDA, IADC, ABD and EuDA, and produced by Quaynote Communications, this new international conference will bring together dredging companies and their customers, oil and gas majors, ports, land reclamation companies, offshore and wind project companies, consultants, policy-makers and industry regulators. The conference will target senior players within the Latin American and global dredging industries and its primary emphasis will be on business development, networking and debate. The main objective is to provide a forum for delegates to meet and discuss hot issues with their peers and clients. The Future of Dredging will provide the perfect environment for exploring business opportunities, with a strong programme that features roundtables and case studies rather than academic papers. Topics will cover a review of projects in Mexico, Argentina and Brazil, dredging finance, the demand for new vessels, early contractor involvement, environment issues and regulations, lessons to be learnt from elsewhere and the constraints on dredging projects.

For further information about participating as delegates, speakers or sponsors contact:
Lorna Titley or Alison Singhal
Tel.: +44 203 560 8154
• Email: lorna@quaynote.com; alison@quaynote.com

RUSSIAN STATE HYDROMETEOROLOGICAL UNIVERSITY
OCTOBER 3-4, 2012
TUAPSE, BLACK SEA COAST, RUSSIA

CEDA was delighted to accept the invitation to co-operate with the Russian State Hydrometeorological University (RSHU) in organising a two-day technical programme on dredging as part of the one week International Coastal Conference “Coast, Evolution, Ecology, Economy” in Tuapse, Black Sea coast, Russia. The official languages of the event are Russian and English. Simultaneous translation will be provided. The dredging sessions, comprising talks equally divided between CEDA and Russian experts, will take place on 3-4 October 2012, whilst the whole event will run from 1-6 October 2012. A Young Professionals’ Session, a Questions and Answers Session to a selected Panel as well as a half-day technical visit will complete the dredging component of the programme.

Numerous significant projects in the region involving dredging create the demand for an international scientific and technical exchange between researchers and practitioners. These include the following: Works relating to the Winter Olympics 2014 in Sochi; Deepening and expanding the Sochi port; creation of a deep-sea harbour; Reconstruction of the Sochi embankment; Imeretinsky harbour (works are ongoing and close to finishing); Coastal protection Imeretinsky area – Kertch harbour (under construction) – one of the largest projects in the region, Tuapse port reconstruction (with oil terminal) and Port Taman (new large port) South Stream gas pipeline.

The registration fee for the event is € 100. For registration details and further information please visit www.cedaconferences.org/tuapse2012.

For further information contact:
Polite Laboyrie
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• Email: H.Laboyrie@witteveenbos.nl

Anna Csiti, General Manager CEDA
Tel.: +31 15 268 2575
• Email: csiti@dredging.org
Dredging 2012
OCTOBER 22-25, 2012
SAN DIEGO, CALIFORNIA, USA

Dredging 2012 is a four-day technical specialty conference on dredging and dredged material disposal, organised by PIANC USA and the Coasts, Oceans, Ports and Rivers Institute of American Society of Civil Engineers (COPRI ASCE). Since it has been almost 10 years since the last specialty conference was held in Orlando, Florida, in 2002, many new issues have emerged. Information will be presented regarding best practices and innovation in North and South America, Europe, and Asia. This will be an international forum bringing together professionals and practitioners from developed and developing areas of the world.

The Overarching Theme of the Conference is: “40 Years of Dredging and Environmental Innovation” and will include topics such as:
State of engineering practice; Dredging contracting and management innovations; Environmental dredging (remediation/ restoration); Safety; Current engineering dredging research; Integrating dredging and dredged material reuse with environmental restoration; Working with Nature; Site characterisation and survey; Sediment resuspension/ residuals; Sustainable sediment management; Dredged material management; Ports/navigation – case studies (coastal/inland); and Regulatory challenges and solutions.

For more information see:
http://dredging12.pianc.us
La Rue Forrester
Tel.: +1 410 544 6710
• Email: larue@wwsc.us or dredging@pianc.us

HYDRO12
NOVEMBER 13-15, 2012
SS ROTTERDAM, PORT OF ROTTERDAM, THE NETHERLANDS

The International Federation of Hydrographic Societies’ 17th European conference will be held in Rotterdam from 13-15 November organised by the Hydrographic Society Benelux. To be held aboard SS Rotterdam, the former Holland-America liner now permanently moored at the Port of Rotterdam, in the Netherlands, the three-day event is aimed at a wide international audience drawn from all sectors of the hydrographic and related professions. “Taking Care of the Sea”, the main theme of the conference, will be supported by a major exhibition of equipment and services as well as practical demonstrations, technical workshops and a series of social activities.

For further information contact:
David Goodfellow
• Email: dvd.goodfellow@virgin.net

CEDA DREDGING DAYS 2012
DECEMBER 12-13, 2012
ABU DHABI, UAE

On December 12-13, CEDA Dredging Days 2012 conference and exhibition will take place in Abu Dhabi, UAE. An optional technical visit will be organised on the second day of the conference. Theme of the conference is “Virtue, Venture and Vision in the Coastal Zone”. “Virtue” in this context is environmental awareness. “Venture” is the development of the coast for commercial purposes, benefiting the local and regional economies. “Vision” is the long-term planning development for aesthetic reasons, creating a sustainable future which supports those living and working in the coastal zone.

CEDA Dredging Days is one of the premier technical forums for presenting and debating new ways of thinking, innovative approaches and cutting-edge dredging tools and technology. Representatives of contractors, consultants, universities, research institutes and public authorities working in the fields of dredging, offshore oil and gas production, infrastructure development and trade, and sustainable energy production will be present to discuss these issues.

The topics of interest include but are not limited to: the offshore oil and gas industry,sustainable energy technologies and infrastructure and trade development. A technical exhibition will be located next to the technical session room. The central location of the exhibition area will provide organisations with an excellent opportunity to present their products and services. Companies who wish to participate in the exhibition should contact the Conference Secretariat.

A technical visit will be organised to one of the many interesting projects in Abu Dhabi on Thursday December 13, 2012 in the afternoon, hosted by National Marine Dredging Company (NMDC).
The accompanying persons’ programme will include visits to places of interest in Abu Dhabi. A reception is planned for Thursday evening.

The conference is aimed at practitioners, engineers and scientists representing: coastal, port, water management and environmental authorities; dredging industry; oil and gas industry; regulators; and environmental organisations and conservation bodies.

For further information visit:
www.cedaconferences.org/dredgingdays2012 or contact Sylvia Minten at the Conference Secretariat
Tel.: +31 6 1660 3947
• Email: sylvia@mintenprojectmanagement.nl

CALL FOR PAPERS

WODCON XX
JUNE 3-7, 2013
SQUARE-BRUSSELS MEETING CENTRE
BRUSSELS, BELGIUM

Organised by CEDA on behalf of WODA, which incorporates WEDA, CEDA and EADA, WODCON XX, entitled “The Art of Dredging”, will showcase some 120 technical papers over three days covering all aspects of dredging and maritime construction. All WODCON XX papers will be peer reviewed and provide up to date, relevant and high quality information.

The Congress will also feature a technical exhibition and technical visits. These technical programme elements will ensure a complete learning process, while various social events will allow participants to meet fellow professionals from all over the world in a friendly and inspiring atmosphere. The 2013 conference marks the 20th edition of WODCON and coincides with the 35th anniversary of the current WODA and its three component associations.

Topics of interest include but are not limited to the following broad areas: Method, Equipment & Techniques; Management of Sediments (clean and contaminated); Environmental Issues; Regulatory Issues; Management and Economics; Alluvial and Deep Sea Mining. Abstracts presenting both research and practical applications are encouraged. Papers must be original and should not have been published or offered for publication elsewhere. Purely promotional text will not be accepted. The Technical Papers Committee reserves the right to accept a submission as an oral or poster presentation. Authors must assign all copyright of the accepted papers to WODA. Prospective authors should submit titles and abstracts (maximum 300 words) online to be considered for the congress by 29 October 2012.

Interested CEDA authors (Africa, Europe and the Middle East) should submit their abstracts online on the congress website: www.wodcon.org. Please use the abstract guidelines on the website and contact: Aneta Trajkovska
Tel.: +32 (0)2 627 0166
• Email: wodcon20@congrex.com

Interested EADA and WEDA authors should e-mail their abstracts directly to the EADA or WEDA Technical Papers Committee members (see below). The submission must include the name, affiliation, telephone number and e-mail address of each author. The corresponding authors’ name must be identified. EADA region (Asia, Austral-Asia, Pacific).
Requested document format: MS Word
John Dobson
Tel.: +61 73262 3834
• Email: dobsoncj@hotmail.com

WEDA region (Americas). Requested document format:
MS Word or Portable Document Format – PDF
Dr Ram K Mohan (Chair WEDA TPC)
Tel.: +1 267 753 6301
• Email: rmohan@anchorqea.com

COASTS, MARINE STRUCTURES AND BREAKWATERS
SEPTEMBER 16-20, 2013
EICC EDINBURGH, SCOTLAND, UK

Following on from the successful 2009 event, the 2013 conference will once again be held at the EICC in Edinburgh, Scotland. In addition to the main session, the “Fringe” will give opportunities for presentations of recent news, continuing research, and developments in progress.

Workshops, short courses and technical visits will also be offered as part of the event. Prospective authors are invited to submit abstracts within any of the relevant themes or topics by August 1, 2012: Marine energy systems: offshore and nearshore; Sustainable construction, refurbishment and rehabilitation; Alternative procurement, economics and finance; Climate change and major storms: adaptation; Breakwaters, seawalls and jetties; Coastal threats, storms, tsunamis, climate change, erosion and flooding; Dredging and use of dredged materials; Environmental and social awareness; and more.

A full list of themes and topics as well as full abstract guidelines and a template are on the conference website. All abstracts must be in English, and submitted electronically at ice-breakwaters.com

For further information visit: ice-breakwaters.com or contact:
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Westminster, London SW1P 3AA, UK
Tel.: +44 (0)20 7665 222, Fax: +44 (0)20 7233 1743
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Covers

The reclamation areas on the Danish island Lolland (shaded white lines) are an essential part of the sustainable design for the proposed Frederikshavn Flood Link connecting Scania and continental Europe. The design ensures that the reclamation areas do not extend beyond the existing ferry harbor at Frederikshavn and do not impact the protected area at Hyllekrog (see page 20).

Guidelines for Authors

Terra et Aqua is a quarterly publication of the International Association of Dredging Companies, emphasizing "marine solutions for a changing world." It covers the fields of civil hydraulic and mechanical engineering including the technical, economic and environmental aspects of dredging. Developments in the state of the art and other topics from the industry with actual news value will be highlighted.

• As Terra et Aqua is an English language journal, articles must be submitted in English.
• Contributions will be considered primarily from authors who represent the various disciplines of the dredging industry or professions, which are associated with dredging.
• Students and young professionals are encouraged to submit articles based on their research.
• Articles should be approximately 10-12 A4. Photographs, graphics and illustrations are encouraged. Original photographs should be submitted, as these provide the best quality.

Digital photographs should be of the highest resolution.

• Articles should be original and should not have appeared in other magazines or publications.
• An exception is made for the proceedings of conferences which have a limited reading public. In the case of articles that have previously appeared in conference proceedings, permission to reprint in Terra et Aqua will be requested.
• All articles will be reviewed by the Editorial Advisory Committee (EAC). Publication of an article is subject to approval by the EAC and no article will be published without approval of the EAC.

• Authors are requested to provide in the "Introduction" an insight into the drivers (the Why) behind the project.

• By submitting an article, authors grant IADC permission to publish said article in both the printed and digital version of Terra et Aqua without limitations and remunerations.

• As Terra et Aqua is a quarterly publication of the International Association of Dredging Companies, emphasizing "marine solutions for a changing world." It covers the fields of civil hydraulic and mechanical engineering including the technical, economic and environmental aspects of dredging. Developments in the state of the art and other topics from the industry with actual news value will be highlighted.

Please address enquiries to the editor.

Articles in Terra et Aqua do not necessarily reflect the opinion of the IADC Board or of individual members.