ANNOUNCING:
The New Interactive Terra
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GENERAL PORT WITH SPECIFIC GOALS
five-year environmental plan for Lisbon

AVOID DISPUTES, COSTS AND DELAYS
define survey means and methods early

READY FOR RAPID LAND RECLAMATION
combine converter slag and dredged soil
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 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 A4s. 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 by the editor.
- Authors are requested to provide in the “Introduction” an insight into the economic, social and/or environmental drivers behind the dredging project by the editor.
- An emphasis is placed on articles which highlight innovative techniques and applications.
- By submitting an article, authors grant the IADC permission to publish said article in both the printed and digital versions of Terra et Aqua without limitations and remuneration.
- For the digital version, authors are requested to provide extra material such as additional photos, links to reports from which articles have been excerpted or short videos. These can be embedded in the digital version under the same provisions as above.
- The digital version will contain a link to the LinkedIn page of the author. In case the author does not agree, please inform IADC (rauwerda@iadc-dredging.com).
- 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.

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COVER
Dredging at the Port of Lisbon. In order to obtain five-year environmental licences which would expedite the regular and systematic dredging of the beds of its access channels and manoeuvring and anchorage basins, the Port of Lisbon Authority developed new strategic plans for dredging and monitoring within the Tagus estuary (see page 5).
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## SEMINARS / CONFERENCES / EVENTS

IADC’s Seminar in Brisbane, Australia is ready to go in March. June conferences set for San Francisco and Toronto and a new Call for Papers from the Hydrographic Society.
In the world of dredging nothing stands still. And so it is that 2014 has already seen a number of developments and changes. In the work of the IADC member companies as well as at the IADC itself.

Despite the ongoing economic crisis, the flexibility and foresight of the major dredging companies has led the way in the industry. As well, the dedication of the well-educated personnel and the investments in continuing research and development for improved equipment have kept the IADC member companies at the forefront of maritime construction for major infrastructure projects.

Diversification and innovation are the driving motors and help keep these companies working globally. By adding other marine-related activities such as oil and gas, offshore wind projects, marine services and marine related civil works they continue to make themselves indispensable. A number of projects in South America and Australia in the last few years have been extremely important. But the tide is turning again and the opportunities are starting to emerge in Singapore and neighbouring countries.

Of course, conditions caused by climate change are also presenting new challenges in the Arctic areas. These are an indication of the future as seen in both the dredging works for a new LNG port in the northernmost regions of Russia, as well as the opening of the almost 5000 km long Northern Sea Route for shipping. Such conditions also prevail in the northern reaches of Canada. Though we are often a ‘hidden’ underwater operation, dredging plays a significant role in all major maritime projects, from Fehmarnbelt in Scandinavia to the warm waters of Southeast Asia.

The IADC has also been changing as it finds new ways to fulfil its mission to keep stakeholders, government agencies and port authorities well informed of the state-of-the-dredging art. New tools for the digital age for reaching this audience are being adopted. Recently the decision was made to create an interactive online Facts About. The print edition has been replaced by an enhanced digital version that will continue to be published quarterly. The first issue of 2014 on trailing suction hopper dredgers can be found at http://tinyurl.com/mctwoba. And this issue of Terra et Aqua has been simultaneously published in print and in an enhanced digital edition at www.terra-et-aqua.com.

*Terra et Aqua* remains determined to seek articles that represent this forward-looking, problem-solving attitude. As dredging is global, so are the articles. This issue reaches out to three countries on three different continents – to Japan, to Portugal and to the USA – with three very different subjects. In each of the articles, a useful aspect of dredging’s challenges, techniques and advances is described – from the social and economic forces that drive the need for dredging, to the importance of accurate data prior to the start of a project, to the beneficial use of dredged materials.

Diversity is the key to the growth in the dredging industry and as well to the excitement of the contents of *Terra et Aqua.*
ABSTRACT

The Port of Lisbon borders almost a dozen municipal districts and shares territory under its jurisdiction with national, European and international organisations in an extremely sensitive environment. Yet, owing to its site on an estuary, the Port of Lisbon Authority (Administração do Porto de Lisboa, APL) must regularly and systematically dredge the beds of its access channels and manoeuvring and anchorage basins.

This article explains the strategy adopted by the Port of Lisbon to obtain five-year environmental licences by presenting a dredging plan and a monitoring plan and procedures report on the environment. It described the existing situation in detail, presenting proposals for the sinking of dredged sediment and providing information on future projects. It also includes projects of the APL in partnership with local municipal districts and the Ministry of the Environment to recover river bank areas and combat erosion. Finally, it focusses on current projects to adapt the Port of Lisbon as to assure that the port has the capacity to handle increasingly large ships, resulting from the continuing changes in the world shipping fleet prior to the opening of the Panama Canal in 2015. These changes call for the available sea beds to be adapted, not only at the hub ports that will receive these ships, but also at other ports, such as the Port of Lisbon.

This article was originally presented at the 20th World Dredging Congress and Exhibition (3-7 June 2013, Brussels, Belgium) and published in the Congress Proceedings. It is reprinted here in a slightly revised version with the permission of WODA, the World Organisation of Dredging Associations.

INTRODUCTION

The Port of Lisbon borders 11 municipal districts and shares territory under its jurisdiction with the following protected areas: at a national level, the Tagus Estuary Nature Reserve; at a European level, a Special Protection Area, Site of Community Interest and Corine Biotype; and internationally, the Ramsar Convention. It is an area that is extremely sensitive from an environmental point of view and yet, owing to its site on an estuary, the Port of Lisbon Authority (Administração do Porto de Lisboa, APL) regularly and systematically dredges the beds of its access channels and manoeuvring and anchorage basins.

The Port of Lisbon therefore adopted a strategy to obtain five-year environmental licences by presenting a dredging plan and a monitoring plan and procedures report to the environment. This described the existing situation in detail, presented proposals for the sinking of dredged sediment and provided information on future projects. In addition, the projects of the APL in partnership with local municipal districts and the Ministry of the Environment to recover river bank areas and combat erosion are described as well as current projects to adapt the Port of Lisbon so as to assure that the port has the capacity to handle increasingly large ships, resulting from the continuing changes that are being noted in the world shipping fleet prior to the opening of the Panama Canal in 2015. These changes call for the available seabeds to be adapted, not only at hub ports that will receive these ships, but also at other ports, such as the Port of Lisbon, which are prepared to see how the regular shipping lines that use them replace their fleets with larger vessels.
June 2012, Lisbon was the scene for one of the world’s most important yachting events, a final stage of the Volvo Ocean Race.

A total of 2,641 ships entered the Port of Lisbon during 2012. Sea cargo traffic reached a total of almost 10.350 million tonnes in the same year, and between January and December 2012, 314 cruise ships carrying a total of 522,604 passengers stopped in the Port of Lisbon. For cargo activities, the Port of Lisbon is considered an important link between the Mediterranean and northern Europe, functioning as a turntable for international trade between Europe, America and Africa. For years it has maintained a national leadership in the bulk food sector. Lisbon moves almost 70% of the food products entering Portuguese ports (Figure 1).

The Port of Lisbon is a large European port on the Atlantic coast, with a geo-strategic position that gives it an outstanding status in international trade logistics chains and on the main cruise circuits. The Port of Lisbon hinterland extends to the Portuguese regions in the centre of the country, Lisbon and the Tagus Valley, the Alentejo and the Algarve, as well as to the Spanish regions of Extremadura and Andalusia, with even further possibilities as can be combined with the extension of this hinterland to Castile la Mancha and Madrid thanks to existing transport and logistics projects.

The Port of Lisbon is a general port in which many segments co-exist, with containers, bulk food and cruise ships especially dominant, but also with areas dedicated to leisure, pleasure craft, water sports and marine tourism together with the river transport of passengers, cargo and fishing. For instance, in

Container traffic is especially important for Lisbon, which has regular coastal shipping services with other European countries as well as a large number of direct intercontinental services by the main shipping lines. APL has four marinas on the north bank of the River Tagus with a capacity for more than 1,100 boats. The Port of Lisbon is therefore an important engine for the social and economic development of the Lisbon and Tagus Valley regions and in general for all of Portugal, directly or indirectly generating almost 5% of the region’s GDP and helping to maintain almost 40,000 jobs.

The Tagus estuary, in which the Port of Lisbon is located, is on the western coast of Portugal, with access to the Atlantic Ocean. It is one of the largest estuaries in Western Europe, stretching for almost 80 km and with a total area of 320 km2. The Tagus estuary is a meso tidal system with a half-day tidal period. The average amplitude in the centre of the estuary is 3.2 m with spring tides and 1.5 m with neap tides, reaching up stream levels of up to 3.6 m and 1.6 m, respectively, with spring and neap tides (Figure 2).

The hydrodynamic conditions and generation of waves with wind that prevail in the centre of the estuary lead to a differentiation in the sectors next to the right and left banks relating to the sedimentation of fine matter. Their deposits thus tend to concentrate on the right
bank where the most important container, cargo and cruise ship terminals, as well as the marinas, are located. This causes a strong sedimentation throughout the area, against the existence of inter-tidal zones, cut by the tidal channels, which allows the development of important areas of marshland on the left bank. The APL’s jurisdiction extends over 11 riverside municipalities on both banks of the Tagus estuary, including the city of Lisbon (Figure 3).

The Tagus estuary is one of the largest and richest estuaries in Europe, in which the values of nature are respected. Of the almost 320 km² of this estuary, approximately 40% are in the intertidal areas, located especially in its central and upper areas (Figure 4). The great morphological diversity of the Tagus estuary is the origin of a considerable diversity of habitats and species. Thus, large extents of silt banks and marshland can be found as a result of the smooth slopes of the banks and the high tide level. The estuary banks also contain important salt flats and reed beds and, on the surrounding land, cork oak woods.

The Tagus estuary and its adjacent land areas contain 35 species of mammals, 194 regularly present species of birds as well as nine species of reptiles and 11 of amphibians. There are also references to the overall presence of 101 species of fish in the estuary, although the number regularly present at one time does not exceed 40.

Also, after an “absence” of almost half a century, the Portuguese oyster will be able to return to the Tagus estuary. An agreement was signed in February 2012 to undertake a pilot project to investigate the viability of breeding oysters in the River Tagus and to determine the suitability of the water quality for the commercial production of molluscs. Likewise, the Tagus Estuary Management Plan, in the final phase of preparation, also identifies aquaculture as one of the potentials that must be developed. In this context, a large part of this estuary, and therefore the area under the jurisdiction of the port authority upstream of it, is protected by various nature conservation statutes:

- At the national level, as a protected area: the Tagus Estuary Nature Reserve.
- At the European level, as Red Natura 2000 landscape, because of the interest in conserving it, and of the presence of the species described in the directive Birds – Tagus Estuary Special Protection Area and of the existence of habitats that must be
preserved within the framework of the directive Habitats – Areas of Community Interest, and also as a place that forms an integral part of the Council of Europe Network of Bioenergy Reserves.

• At the international level, as a place on the Ramsar list of conservation areas relating to marshlands of international importance, especially as a habitat for water wildfowls.

**STRATEGIC AND TERRITORIAL FRAMEWORK**

The strategic policy and territorial management based on the system of territorial management is organised in three ambits (national, regional and municipal) within a framework of coordinated interaction. In this context and with regard to the port activity and the territorial area of the Port of Lisbon, the following instruments are noteworthy.

**National ambit**

The Strategic Transport Plan (PET) – Sustainable Mobility – Horizon 2011-2015 has been valid since 2011, because of its effects on marine and port development. This instrument combines a set of public and private investment initiatives in the port sector, both underway and/or in the study phase, that could contribute to increasing the competitiveness of the Portuguese economy, especially the “study for the concession and building of the new Trafaria container terminal (...) with a view to the concession of the new Trafaria container terminal with draughts of -16.5 m and an annual potential traffic of up to 2 million TEUs”.

The planning and spatial management of sea-related activities is one of the strategic pillars on which the National Sea Strategy is based. Additionally, it is one of the main measures proposed by the Inter-Ministerial Commission for Sea Matters in the ambit of the European Union Integrated Maritime Policy. The Maritime Space Management Plan (POEM) arose within this context. This plan is designed to guarantee the sustainable use of resources, their preservation and recovery, in order to enhance the efficient use of marine space and to encourage the economic, environmental and social importance of the sea. This plan is in the approval phase.

The Tagus Estuary Management Plan (POE Tagus) arose in the sequence of transposing the Water Framework Directive and the publication of the Portuguese Water Law, aimed at the management of the estuary and its banks by suitably making compatible the multiple uses and occupations of the territory with the objectives of protecting and valuing water resources, ecosystems and associated natural values. This plan is in its final preparation phase and awaits public debate.

**The Tagus Estuary Nature Reserve**

The Management Plan (PORNET) has been in force since 2008. It sets the regimes for safeguarding resources and natural values and sets the uses and management regime that must be applied in its area of intervention to guarantee the conservation of the nature and biodiversity, as well as to maintain and value the properties of the natural and semi-natural landscapes, and encourage the maintenance of the natural vocation of the Tagus Estuary Nature Reserve as a habitat for migratory birds.

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**Table I. Calendar and estimate of volumes for dredging.**

<table>
<thead>
<tr>
<th>Area</th>
<th>Area of action (ha)</th>
<th>Annual volume (m³)</th>
<th>Levels (zh) (m)</th>
<th>Number of annual interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 VTS</td>
<td>2</td>
<td>30,000</td>
<td>-4.0</td>
<td>1</td>
</tr>
<tr>
<td>2 Alcântara area</td>
<td>16</td>
<td>200,000</td>
<td>Between -5 and -15.5</td>
<td>from 3 to 4</td>
</tr>
<tr>
<td>3 Santa Apolónia area</td>
<td>29</td>
<td>450,000</td>
<td>Between -7.3 and -1.5</td>
<td>from 3 to 4</td>
</tr>
<tr>
<td>4 Entrance bar channel</td>
<td>Variable</td>
<td>250,000</td>
<td>-17.5</td>
<td>1</td>
</tr>
<tr>
<td>5 Marine</td>
<td>32</td>
<td>100,000</td>
<td>Between -4 and -8.3</td>
<td>1</td>
</tr>
<tr>
<td>6 Cala das Barcas</td>
<td>10</td>
<td>50,000</td>
<td>-3.5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>89</strong></td>
<td><strong>1,080,000</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Areas subject to maintenance dredging. The numbers correspond to Table I.
Regional ambit
The Regional Territorial Management Plan defines the regional territorial development strategy, integrating the options set at the national level and considering the municipal strategies for local development, forming the reference framework for preparing the municipal plans for territorial management. The Lisbon Metropolitan Area Regional Territorial Management Plan (PROT AML), valid since 2002 and in the revision phase, applies to the area of the Port of Lisbon.

Municipal ambit
The municipal territorial management plans set the regime for the use of land and define the models of the forecast development of human occupation and the organisation of the urban systems, and according to a suitable scale, the parameters for land use and for guaranteeing environmental quality. The APL’s area of jurisdiction covers 11 municipalities, the plans of which are being revised, except for the municipalities of Vila Franca de Xira, Moita and Lisbon, which finished the revision in 2009, 2010 and 2011, respectively.

Other plans
The Port of Lisbon Strategic Development Plan (PEDPL, 2007), for which the APL is responsible, is a sectorial and strategic document that identifies the objectives and main actions to be taken to achieve a sustainable development model for the Port of Lisbon. This plan therefore presents the re-ordering and physical development of the APL jurisdiction area in its maritime component, integrated and sustainable management in economic terms and the management of the Tagus estuary and the short, medium and long term planning of the development of infrastructures and installations as its main objectives to be able to guarantee its suitability to the development of the search for traffic and new technological, legal and environmental requirements. The time horizon of the plan is 2025. The plan covers three large strategic business areas, cargo, cruise ships and leisure craft.

The Integrated Plan for the System of Support Infrastructures for Leisure Craft in the Tagus Estuary (PIRANET, 2010), for which the APL is also responsible, has as its main objective the creation of an “integrated system of support infrastructures for leisure craft, suitable for the territorial properties, diversified in type and adapted to the needs of the demand, complemented by a qualified offer of activities and support services that contribute to the development of nautical leisure activities in optimum conditions and with sufficient safety, based on criteria of environmental, social and economic sustainability, to stimulate the intensification and expansion of the nautical sector, which will benefit the region and the country socially and economically”. The PIRANET has been integrated into the POE Tejo (Tagus) as a sectorial instrument.

APL Dredging Plan (2010-2015)
In the realm of the obligations arising from the transposition of the EU Water Directive Framework to Portuguese legislation, the APL prepared its maintenance dredging plan for the five year horizon (2010-2015) for which it intends to obtain environmental permits for carrying out the dredging necessary for the port’s operation, avoiding as far as possible administrative procedures. This conforms to the proposed conditions and takes into account a programme that may be set by the environmental authorities, developing the plan subject to approval. The POE Tejo also took this plan into account, revealing its innovative concept.

This plan contains the biophysical and social and economic frameworks of the Port of
Lisbon. It details the geographical features regarding its environmental aspects, the matter of marine accessibility and development and the economic situation and legal and administrative framework of the port authority. The plan identifies the existing port structures as well as the system of maritime accesses including the port entrance channels and the system of navigation channels in the estuary, giving a detailed classification of all the areas subject to dredging. It sets calendars and an estimate of the volumes to be dredged in each place, as shown in Figure 5 and summarised in Table I.

The plan also details the dredging procedures implemented by the APL and for the immersion of sediments especially regarding the checking of the correct positioning of the dredger and of the immersion, as well as checking the project and determining the dredged volumes. Supported by studies by the LNEC (national laboratory of civil engineering), the Port of Lisbon, proposed to immerse class 1 and 2 sediments in the estuary in the areas marked in red.

The blue area was proposed to immerse dredged sand from the entrance channel when these are not reused for beaches. This area was also chosen using hydrodynamic studies, which highlighted the importance of maintaining the shallower depths of the submersed banks that line the entrance channel. Later, as an addition to the dredging plan, the port promoted hydrodynamic and ecological studies that concluded that there was a possibility to use the green areas to immerse class 3 sediments. This was approved by the environment authorities with the condition that the port follow a plan to monitor water quality and biota (Figure 6).

It also explains the dredging methods used by the APL with examples describing the types of dredgers as well as the forms of contracting and the estimated costs. Another chapter explains the places used in the immersion inside and outside the estuary and the technical bases giving rise to the relevant selection.

Finally, the plan covers the matter of the environmental procedures during the dredging work, describing the existing situation, breaking down the actions promoted by the APL and proposing a water quality monitoring plan which must be implemented in the dredging areas and in the places planned for the immersion. It also includes a programme for the prior classifying of the sediments, differentiating the historically uncontaminated sediment areas from those in which there are contaminated sediments. It also describes the form of contracting and the estimated costs.

The APL plan proposes to present periodic reports to the environmental authorities on the progress of the dredging and the environment monitoring plans as well as the environmental classification being carried out. The plan concludes with the description of the dredging plans for the period 2010-2015, most of which is subject to an environmental impact assessment.

The approval of this plan by the environmental authorities within eight months was seen as a strategic element with which the APL could carry out, in a regular way, maintenance and stabilised dredging, with proper attention on the one hand to the complexity of the environmental framework and the territorial implication and, on the other, to the maintenance frequency of most of the moles (with an average of three times per year) as well as taking into account the irregularity of the areas to be dredged (Figure 7).

STRATEGIC COOPERATION WITH MUNICIPALITIES
The Port of Lisbon understands that, given the framework in which its activity is carried out, the plan can only be viable and have perspectives for development if a strategy of proximity and cooperation is set up with the other organisations in the Tagus estuary. This strategy must be one of taking an active role in the sustainability and the maintenance of the balance of the various factors that contribute to the estuary’s quality and the quality of life of the people who live around it. For this reason the attitude of the APL has
been that of studying and developing projects for rehabilitating the banks to improve the populations’ quality of life in collaboration with municipalities and environmental organisations. Examples of this policy are the recent actions carried out in the municipalities of Barreiro and Moita (Figure 8).

Barreiro is a town on the south bank with a long history (Figure 9). In the Middle Ages, part of this area had been used for setting up salt flats and there is documentary proof that these were then converted into piers for installing tidal flow mills, some of which were operating up to the first quarter of the 20th century. With the arrival of windmills built on the white sand areas around the area of As Caldeiras, the tidal flow mills went into decline. In the 1960s the area was the site of much heavy industry. Over time this type of industry declined and in the 1990s an environmental recovery was started, designed to improve the quality of life of its inhabitants. Natural waterside bands were maintained but are also undergoing a process of recovery for the population’s leisure use.

With the introduction of modern catamarans to replace the old “cacilheiros” (ferries crossing the River Tagus), used for the transport of passengers between the river banks, these beaches started to erode as a result of the catamarans’ wash. APL has developed a project to recover these beaches that includes the artificial supply of approximately 25,000 m³ of sand in the area and a later supervision plan. This work is also designed to safeguard the cultural heritage of the area by protecting the historical mills and piers. This artificial supply of sand has been monitored regularly by the APL by surveying. Currently the beach is also used by persons practicing water sports, taking advantage of the catamarans’ wash.

Another town in which the APL has undertaken dredging, including a wider project to assess the watersides, and in accordance with the wishes of the municipality itself, was Moita, located on the southern bank of the river with a strong tradition of fishing and the use of leisure craft (Figure 10).

The old centre of this town is located on an arm of the estuary, into which a water line with a small flow is discharged. The area at the top of this arm of the estuary contained large accumulations of sediments with the resulting negative environmental impact for the town centre (Figure 11). Together with the municipality, the APL studied and developed a solution to maintain a permanent area of water in the end of the river arm opposite the old centre of Moita, that consisted of dredging an access channel in this area and building a dyke with sluice gates which would function with the tidal cycles to dredge the channel by itself. This action also included the environmental regeneration of the area. The involvement of the APL consisted of dredging the area of the pier over an area of approximately 35,000 m² to the +0.6 m zh level and dredging an access channel to the +1.0 m zh level for the old Moita mole, with 25 m width and approximately 850 m long. A total of 96,300 m³ of sediments were dredged and returned directly to the old marinas near the area of action.

**COOPERATION WITH THE ENVIRONMENTAL AUTHORITIES – SUSTAINABILITY POLICY**

The most important and longest involvement of the APL takes place in the area of the Bars of the River Tagus, a complex system of sandbanks and channels at the mouth of the River Tagus, most of which are no longer in the area administered by the port authority but in an area under environmental management (Figure 12).

In the vast area stretching from SãO Julião da Barra to the north and to Trafaria and...
In the area of supervisory tasks, the APL systematically and regularly undertakes hydrographical surveys of the bars’ areas to monitor the development of their bottoms in the entrance channels and on the sandbanks so that it can act when necessary.

For a better and more objective view of the maritime movement conditions, the APL has also maintained, since 2003, a wave measurement buoy that transmits data on line and that can be seen on the APL Web site, www.portodelisboa.pt. The supervision of the area of the entrance bars, as well as the adjacent coast, is therefore more important since it provides observational data on the rising sea level to worrying values throughout the Portuguese coast.

According to the studies made by Professor C Antunes of the University of Lisbon, based on the functioning tide gauges, the current situation can be seen in Figure 13.

Also in the area of climate change, and because of the greater frequency of extreme phenomena such as storm surges, the APL has kept a record of the most important incidents in the Tagus estuary, which it shares with the environmental authorities (Figure 14).

**FUTURE PROJECTS**

**Lisbon Cruise Ships Terminal**

The new structure of the Lisbon cruise ships terminal, the nearest to the city centre, with a total area of 7,790 m², has been developed in phases; the first two phases ended in 2011. They were related to the main work for rehabilitating and reinforcing the moles between Santa Apolónia and the Jardim do Tabaco, including the backfilling of an old dock. With this project the Terminal has 1500 m of quay and can receive up to 5 cruise ships with -8.0 m to -12.0 m of draught.

The next phase will be the construction of the cruise ships terminal building and the conditioning of the exterior areas. The design of this building and the exterior conditioning were the subject of an international request for tenders to provide a new structure for Lisbon with a “friendly” concept, taking into account aspects such as comfort, accessibility, flexibility and the speed of the services provided to passengers in a suitable way for acting more sustainably with the most recent scientific innovations.

The main ideas arising from the set of studies carried out to date show the importance of the Cachopo north for the stability of the entire area. The maintenance of this bank is also considered a determining factor in the protection of the bank of Municipality of Oeiras and of the beaches at Caparica, given that it dissipates most of the waves that reach this area. Because of this, the APL placed the sand from dredging the southern bar channel in this area to help reinforce it. The resulting monitoring shows positive results that must be interpreted as a trend.

The concern shown by the APL over time for maintaining the hydrodynamic balance of this area has led it to manage dredging and the sand from this dredging in a way that is in accordance with the principles of environmental sustainability. The sand from dredging the channel is deposited on the beaches on the coast of Estoril, on the beaches of the Costa de Caparica, as well as the immersions in the Cachopo north, always giving priority to its placement in the area of the entrance bars system. It is clear that the reality of the area of the entrance bars and all the dynamics of erosion and the build-up of sandbanks is much more complex than was thought in the past, so that firm investment in the supervision of the entire area as well as continuing in-depth studies is important.

According to the studies made by Professor C Antunes of the University of Lisbon, based on the functioning tide gauges, the current situation can be seen in Figure 13.

Also in the area of climate change, and because of the greater frequency of extreme phenomena such as storm surges, the APL has kept a record of the most important incidents in the Tagus estuary, which it shares with the environmental authorities (Figure 14).

**Cascais – Mean Sea Level Variation**

![Figure 13. Increase of average level. http://webpages.fc.ul.pt/~cmantunes/hidrografia/NMML_Cascais.JPG](http://webpages.fc.ul.pt/~cmantunes/hidrografia/NMML_Cascais.JPG)

![Figure 14. Aerial view of the mouth of the Tagus estuary with natural sand banks in the foreground.](http://webpages.fc.ul.pt/~cmantunes/hidrografia/NMML_Cascais.JPG)
current and future traffic, so that Lisbon could achieve a significant increase in cruise ships departing and arriving at it.

Of the 37 bidders, including 12 from abroad, the first prize was awarded to the architect João Carrilho da Graça, with a project with an overall investment of almost €20 million. As well as the advantages of urban insertion, this new location makes it possible to reduce dredging together with an increase in the ship reception capacity, taking into account the environment and sustainability concerns in the new port extensions.

Tagus Marina
In 2011 and 2012, the APL reclassified the Pedrouços dock on the Lisbon riverside to host the planet’s most demanding regatta, the Volvo Ocean Race (VOR) (Figure 15).

The reclassifying of this dock consisted of the recovery of the berths and walls in the dock as well as the demolition of buildings, the tidying of the surrounding area and the dredging of the interior area and mole accesses, with an approximate area of 330,000 m³ of sediments at -5.0 m level. Before dredging, the sediments were classified; almost 85% were uncontaminated and were immersed in the estuary and the 15% of slightly contaminated sediments were immersed outside the estuary. This set of actions allowed the environmental recovery of the area. After undertaking this work and after the Volvo Ocean Race was held, the APL held an international public request for tenders for the conversion and operating concession of the Tagus Marina, This comprised the Pedrouços dock and the Bom Sucesso dock, to make it a reference for excellence in leisure boating in Portugal, in order to enhance tourist promotion in the Tagus estuary and in the region of Lisbon and to prepare to host international events such as the VOR regularly, maintaining the draughts in the dock within the levels required for the VOR.

The intention of this request for tenders is that the areas around the docks will become an attractive pillar for supporting nautical activities and for trade, tourism, cultural, sporting and animation services as a complement and accessory to these types of activities.

CONCLUSIONS

- In a scenario of strong environmental demands and urban pressure such as at the Port of Lisbon, the difficulties that threaten the port’s existence can be overcome only by maintaining a permanent dialogue and active cooperation with all the other organisations in the estuary, both local and environmental authorities, which are the territorial planning authorities as well as with the help of the representatives of local communities.
- With regard to the types of uses in the estuary, the APL has included engineering techniques and projects in the choice of solutions that conciliate the achieving of sectorial objectives with the conservation of the estuary’s environmental and social and economic balances to minimise the inconveniences to it.
- In an increasingly restrictive economic framework such as is taking place in Europe, it is increasingly essential to find solutions planned not only with the help of other organisations and users, but also with a perspective of balancing existing resources that are compatible with cheaper and more sustainable actions.
- The solutions for actions must increasingly be chosen from the perspective of an integrated community in the framework of the strategic European orientations for the next framework of community support.

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ABSTRACT

Despite advancement in dredging and survey technology, contract disputes over increased costs continue to plague dredging contractors and stall owners’ time-sensitive projects when after-dredge surveys fail to produce accurate, repeatable results. The challenges of many of today’s projects, such as deeper channels, tighter dredge envelopes and environmental restrictions, put contractors and owners at ever increasing risks. One of these risks – and one of the more critical components of any dredging project – is the no longer simple process of measuring the completed work to be sure that it complies with the design intent. It is often unrecognised that the ever increasing complexity of this measuring (survey) presents challenges of its own that can often make or break the entire process. Weaknesses and ambiguity in data streams collected by very sophisticated multibeam systems coupled with varying interpretations of the governing Engineering Manuals also commonly lead to disputes over survey methodology, quality control procedures and operational protocols.

This article is based on a study of industry trends, advancement in dredging and survey technologies, and the underpinnings of historical dredging disputes in order to present a streamlined approach to minimising claims and maximising efficiency and profitability. The basic techniques explored here are:

1. Early project communication and participant buy-in of dredging and survey means and methods;
2. Proactive requests for contract clarification and the implementation of protocols to maximise information sharing;
3. Understanding and reconciling the interplay between error budgets and regulatory limits;
4. Expert, in-the-field review of raw survey data to determine shoal validity; and
5. Increased communication between contractors, surveyors and project management personnel.

Both practical legal and engineering guidance on ways to implement offensive strategies for project success are offered.

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INTRODUCTION

Because dredging is vital to both socio-economic development and environmental health, the dredging industry is uniquely situated at the heart of the world’s largest and most complex infrastructure systems. Owing to the size and difficulty of such projects, the long lead time that often exists between initial design, project funding and actual construction, as well as the rise in environmental restrictions, dredging projects are inherently susceptible to increased disputes arising out of project tolerances and limitations that are often incongruous with the technology being used to measure success. As our waterways have been one of the hardest hit areas of pollution, the rise in environmental awareness has led to increased conservatism amongst regulators and, in turn, heightened regulatory restrictions for dredging projects. These restrictions may not
growth demands on waterways and ports, conditions have become compounded by new construction industry spectrum. These difficulties of maritime construction are available to meet project needs. Specifications, experience or equipment the position of not having adequate routine variety suffer as designers are put in technology does get close to catching up, dealing with such changes. When the fails to buttress innovative solutions for outdated even by a couple of years – often placed on maritime construction, the As new restrictions are increasingly being technology on projects – if outdated even by a couple of years – often fails to buttress innovative solutions for dealing with such changes. When the technology does get close to catching up, projects that are more difficult than the routine variety suffer as designers are put in the position of not having adequate specifications, experience or equipment available to meet project needs. The difficulties of maritime construction are therefore at the extreme end of the construction industry spectrum. These conditions have become compounded by new growth demands on waterways and ports, where deeper and wider channels are required to handle larger and larger ships. This, in itself, generates more challenges for technology as deeper waterways in many cases require removal of rock or rock-like material, which is extremely difficult and expensive to dredge. Additional clearances then have to be considered because harder bottom materials are unforgiving and therefore increase the potential for contaminant releases.

This is the complicated backdrop against which many modern dredging projects must be performed. On very large projects with complex funding structures, design often takes place years before construction causing a range of factors to shift such that the basic design specifications are likely outdated by the time construction actually begins. This means that many of the projects currently underway in the market were designed when certain technologies, like multibeam, were in their infancy and when funding requirements and environmental restrictions were vastly different. If the specifications for such projects have not been updated (and likely they have not as design budgets have undoubtedly long since been exhausted), the specifications may reflect decade-old technology and methodology.

Compound this with the potential disconnect that may occur between the owner’s/designer’s survey team and its design/project management groups, along with a growing demand on ageing survey vessels and project managers who may not be intimately aware of the project design criteria: The potential for conflict and claims is multiplied exponentially.

Such impasses often occur on complex dredging projects and claims have, in turn, become all too common in the industry. This does not mean to say that disputes on dredging projects cannot be avoided. Claims on dredging projects can be avoided: Simple techniques for increasing project buy-in by key participants, enhancing communication throughout all levels of survey and construction, training survey and construction personnel about ways to recognize survey inaccuracies in the field and an appreciation during the design stage for incongruities between restrictions and required performance standards will result in enhanced project success.

CLAIMS AVOIDANCE MADE SIMPLE
Employing the adage that history is the greatest teacher, examples of prior disputes are shared below to assist industry participants in avoiding common project pitfalls. Further guidance is offered so that claims can be avoided through the implementation of certain key dispute avoidance techniques.

Have Contractors Made Early and Thorough Requests for Contract Clarification and Do All Parties Concur on the Means and Methods for Gauging Project Success?
Ask:
• Do all project participants have a clear understanding of what work the contract requires and how the work will be measured?
• Has the contractor performed a careful review of the project requirements to ensure compliance?
• On public projects, have the means and methods of before-after-dredge survey measurement been clearly and expressly stated in the bid documents?
• If possible, have all parties to the agreement come to consensus regarding the particular technology and methodology to be used on the project?

The basis for any project is the signed contract between the owner and the contractor. Any disputes that arise between contractors and owners will ultimately be resolved in light of the contract, and the language of the contract will control. Thus, it is axiomatic that contractors must have a complete understanding of their duties, rights, and obligations under the agreement that outlines the project. This includes a clear comprehension of exactly what the contract requires of each party, and how the work to be performed under the contract will be measured. The latter point is especially important in dredging disputes where miscommunication and ambiguities in terms can lead to costly problems.

When bidding on or entering into a project, parties should be mindful of even the most
innocuous contract provisions. In one project example, the contract was clear about the required dredge depth but was ambiguous with respect to precisely how and under what processing methodology the owner would measure and verify the contractor’s work. It became clear during the performance of the after-dredge surveys that the contractual term used to describe the survey methodology to be employed (simply: “acoustic sweep survey”) was inherently ambiguous. It could have referred to one of four common processing methods, each of which may have yielded different results. The contractor, assuming that the Owner intended to use average sounding analysis method, itself used the average method when performing its pre-acceptance surveys. In contrast, however, the owner used the minimum depth processing method for acoustic sweep surveys.

While such information should have been made clear at the outset of the project, it was not. As a result, there were discrepancies between the contractor’s surveys and the owner’s after-dredge surveys resulting in a claim for excess shoaling.

**Contract language**
Given the immense importance of contract language as it relates to the rights and obligations of the parties, contractors must take certain proactive steps to ensure that they understand precisely what they are signing up for before they actually do so and before their contractual duties take effect. For example, contractors should be practiced at proactively issuing a Request for Information (RFI) in the pre-contractual stage to clarify any ambiguities in the contract language.

Even where the contract language appears to be clear on its face, as above, contractors would be well served to review the documents with an eye toward practical implementation of the requirements listed, to determine whether there are actually any terms or conditions that might cause confusion when the time comes for performance. This is especially important because often contractors and owners rely on standard form contracts with “boiler-plate” language, and as a result may not analyse the contract terms as carefully as is necessary.

Early, thorough analyses of contract language with an eye toward real-world implications of the terms used, aided by substantive requests for clarification from contractor to owner, will help ensure that the types of misunderstandings illustrated above are avoided.

**Consensus on technology and methodology**
Relatedly, it is critical that owners and contractors understand and, if possible, come to a consensus regarding the particular technology and methodology to be used.

Because of the wide range of survey methodologies available, as well as the ever-changing technology in the field, contractors and owners must be sure to familiarise themselves with the chosen protocol. Failure to reach understanding or consensus regarding survey methodologies can and does lead to costly delay when problems occur.

Achieving project participant buy-in prior to the start of a project ensures that each party is fully aware of the risks and benefits inherent in the chosen survey methodology, and helps to foster a sense of mutual collaboration on the project as well as ownership of the methods chosen. This ensures that parties begin projects as partners rather than adversaries (Figure 1).

In another illustrative case, the problem of repeated rejection of acceptance requests was determined to be the result, in part, of improper tide readings. The owner, using a manual tide gauge as opposed to an electronic tide gauge, had been measuring the contractor’s work in oftentimes imperfect conditions. Although the use of an electronic tide gauge was, at the time, the widely preferred method for making tide readings and was, in fact, what the contractor expected was being used to measure its work, the owner's reading were negatively impacted by choppy water, excess boat traffic and poor weather.

While there was no contract requirement that the owner use an electronic tide gauge on the project, in light of the inherent risk in operating a manual tide gauge, the contractor should have been made aware that the owner was not using the most accurate, up-to-date technology. As such, the owner’s failure to educate or gain consensus regarding the tide gauge to be used eventually subjected it to claims from the contractor when the manual method gave inaccurate results that in turn tainted the survey readings. If the owner had identified its methodology prior to the project start date, then both parties could have evaluated the efficacy of said methodology or at least entered into the project with full knowledge of the attendant risks of utilising a manual measurement system.

How, then, can contractors and owners best...
act to prevent issues like those illustrated above from adversely impacting their projects?

- First, contractors should note whether owners are using commonly accepted, “tried and true” survey methodology, or whether they are pushing the limits of these standards. This may require that contractors actually bring in outside “peer reviewers” who are familiar with the latest technology to evaluate the efficacy and reliability of the proposed methods.

- Second, contractors should be watchful for obsolete procedures and specifications that may hamper progress. Although some might argue that determining what is an “appropriate” survey protocol is an inherently subjective decision, external standards that all owners and contractors can use to measure the acceptability of a chosen protocol are available.

**Has the Interplay Between Error Budgets and Dredge Limits Been Fully Explored and, if Necessary, Reconciled?**

**Ask:**

- Does the contract include a dredge depth limitation beyond which the contractor may be sanctioned for over-dredging?
- Are there any specific site challenges that will inhibit the accuracy of survey systems (i.e., rough bottom, ship traffic, fast or erratic currents, floating debris from outfalls).
- Are such over-dredge design restrictions compatible with standard error budgets or does the interplay between these two factors create an impossible situation for the contractor?

For all of the aforementioned reasons, it is essential that contractors familiarise themselves with a project’s chosen survey methodology prior to entering into an agreement with a project owner. In addition to the above examples, contractors should also be sure that they comprehend the survey technology to be used – especially in those cases where the project owner has prescribed a dredge limit – so that any irreconcilable differences in the interplay between the equipment capability and the dredge depth precision can be easily identified, addressed and fixed early.

**Case study over-dredging**

One recent project provides an excellent example of how irreconcilable differences between dredge limits and survey technology can lead to disputes. On that project, the contract restricted the contractor to a 0.61 metre (2 foot) over-dredge envelope (e.g., the required dredge depth was -10.7 m (-35 ft) MLW with an allowable over-dredge limit of -11.3 m (-37 ft) MLW). Key there was not the tightness of the 0.61 m (2 ft) range, but rather that over-dredging beyond the 0.61 m (2 ft) pay limit actually carried adverse legal consequences and severe financial penalties according to applicable environmental laws.

This was a significant restriction given that a number of environmental conditions of the subject site commonly created error budgets within the owner’s surveys that actually ranged from 0.18 m (0.6 ft) to over 0.61 m (2.0 ft). Thus, the contractor was prohibited from over-dredging more than 0.61 m (2 ft) beyond the contract depth, but the surveys used to evaluate the contractor’s work measured to a standard of accuracy incompatible with the contract design.

It is noteworthy that based on the version of the Engineering Manual in effect at the time, the projections were that most survey product variations could be expected to be less than 0.27 m (0.9 ft). Thus, even if the owner’s survey accuracy met the commonly accepted 0.27 m (0.9 ft) standard variation, the contractor was in reality held to an envelope much smaller than 0.61 m (2 ft). Moreover, because of the inaccuracy of the owner’s surveys that led to variations of over 0.61 m (2 ft), in some cases the contractor’s margin of allowable error was actually below zero. As such, even if the contractor was successful in keeping within the 0.61 m (2 ft) envelope, when that same dredged area was surveyed by the owner, the final survey plots would have randomly shown shoals of up to 0.15 m (0.5 ft) or more.

**Performance of the project within such incompatible extremes thus becomes the equivalent of either a defective design or a tacit agreement by the owner that the measure of the finished work product can and will be done to a compatible tolerance. As all contractors should, the contractor in the above example had the right to expect consistent, uniform and accurate deployment and operation of whatever survey system the owner used. The contractor also had a right to expect a degree of survey accuracy that was compatible with the environmental restrictions inherent in the contract. As is clear from the case study, neither of these conditions were met, and delays and disagreements ensued.

While this may sound like an extreme example, situations such as this are, unfortunately, more common that one might expect. This points out a very common survey problem within the industry: Field conditions and the behaviour of a waterway can be very unfriendly towards even the most sophisticated survey system. To make matters even more difficult, conditions within certain waterways can change dramatically by something as common as the change of tide or a major rain event. Such conditions dramatically affect the sound velocity in water and can introduce survey errors of over a foot as the survey vessel traverses from bank to bank.

More often than not, designers and specifiers may be totally unaware of such conditions and the survey crew, who deal with such problems on a routine basis, may not understand the importance of communicating their difficult experiences to the design teams while a particular project is in the design or permitting stages.

Contractors who are considering entering into an agreement that specifies over-dredge penalties cannot take for granted that the contractually mandated over-dredge limits will actually square with the survey technology as employed and operated. What does this mean for contractors evaluating new project opportunities?

First, contractors should pay close attention to any restrictions on over-dredging, particularly where legal or financial penalties are involved, as this turns an already imprecise process into a risky endeavour that carries the weight of potential liability. As environmental awareness grows and project owners place more and more conservative measures on their projects, this issue will likely occur with more frequency.
Compounding the problem is the fact that owners (or their representatives who are tasked with writing the terms of the contract and overseeing the design process) sometimes do not have a thorough understanding of the ramifications of these restrictions and the interplay between their survey methods and project realities. Thus, contractors themselves should ensure that they have a clear understanding of the survey methodology/technology to be used by the owner to evaluate their work, so that both parties can identify, at the outset, any inconsistencies or incompatibilities between the error budgets and dredge limits. If necessary, contractors should seek out the advice of industry experts to identify potential conflicts and determine how best to handle their resolution.

**Have Both Parties Engaged in Expert, In-the-Field Review of Raw Survey Data to Determine Shoal Validity?**

**Ask:**

- To the greatest extent possible, are all after-dredge surveys being performed using best practices so that operational, environmental and equipment-based survey error is minimised?
- Has the contractor requested the owner’s raw data files to make such determinations on its own?
- Is the contractor aware of the signs it should look for in the data to determine that best practices are being followed?

One of the most important ways that parties can protect themselves from unnecessary and costly disputes is by learning how to identify potential errors and anomalies in the raw survey data. Particularly, contractors should ask owners not only for the after-dredge survey results, but also for the data that underlies those results. In so doing, contractors will place themselves in a stronger position in the face of owner requests for costly shoaling that might not actually be necessary or appropriate.

By way of background, a multibeam sounding system is a device that marries a series of single acoustic measuring beams into an “inverted fan” arrangement (Figure 2). Simply put, the soundings produced in modern sweep surveys are little more than a complex array of signals generated in rapid succession, from which the sounding system measures the quality of the signal return over time. That time interval increases as water depth increases, and thus the time duration of the signal can be used to calculate the water depth with relatively consistent accuracy. In order for an electronic signal to be accurate in this measurement process, the variables that affect the speed of sound in water must be accounted for. In “tank test” conditions the water temperature and salinity are usually uniform and consistent, thus the calibration adjustments for these figures can be manually entered into the system computer and the computer will adjust the output accordingly.

These same variables in a navigable waterway must be accounted for by calibration methods known as sound velocity probe casts, as well as physical measurements to check the electronic sound velocity data. These are known as “bar checks”, “ball checks” and “blunder checks” and are performed using equipment and measuring devices designed specifically for that purpose. Failing to diligently carry out these tests will radically reduce the quality and accuracy of the survey results.

A sampling of the various problems with survey accuracy that may occur as a result of a party’s failure to properly administer the appropriate quality checks required by the multibeam sounding technology are described below.

**Identifying problems with sound velocity casts**

Looking back over the past century of dredging, multibeam survey represents a relatively new technology that is continually undergoing rapid advancements. A typical modern multibeam system represents the cutting edge of hydrographic technology, and most of the components represent highly sophisticated electronic systems and components. Nevertheless, the unfortunate fact remains that this sophisticated equipment is also subject to an abundance of potential problems that can quickly and dramatically degrade overall system accuracy, only some of which include equipment malfunctions. As such, it has become extremely important that a level of constant and diligent interrogating of system quality take place during the performance of survey work. Without such diligence, erroneous data will be introduced and may go unnoticed or, worse yet, be ignored or manipulated in post-processing.

Field interrogations of the system consist of a series of prescribed testing and calibration procedures that measure the output of the system against known standards. In theory, if a survey party follows these prescribed procedures, the end result will be a reasonably accurate work product. That, at least, is the theory. And it holds reasonably true as long as the survey crew remains diligent in their duties and applies a level of common sense with respect to the overall site conditions, which also includes voiding obviously bad survey passes and re-scheduling and/or cancelling the conduct of surveys when environmental conditions (such as satellite availability, weather and vessel traffic) are outside of reasonable parameters.

In field deployment an abundance of potential issues with multibeam systems remain, especially with respect to the accuracy of the outermost beams of the array, their propensity to “bend”, and the ability of these very small beams to identify and properly record the variability of bottom materials. The true accuracy of the outer beams of the system array can be seriously affected by common variations in water temperature and salinity within the water column. This is generally corrected to more acceptable levels of accuracy by the use of the SV-Probe data, which is also subject to an abundance of potential problems.
which records samples at regular intervals from the surface to the bottom and then uses this data to correct the beam deflection. Aside from the “bending” issue, the importance of the proper application of the sound velocity data itself can also not be emphasised enough.

By way of example, the variation in sound velocity from the water surface shown in Figure 3 ranged from 1482 m/s (4860 ft/s) at the water surface to 1489 m/s (4885 ft/s) at the bottom. Failure to account for, or a significant change in, this variation alone would introduce up to 0.15 m (0.5 ft) of depth error into a survey at the center beams and a minimum of 0.21 m (0.7 ft) at the outer (45˚) beams.

Figure 4 is an example of what can happen to the outer beams of a multibeam array when sound velocity is not properly tuned. This section view shows multiple passes of the same area (yellow, blue, red, etc.) using inadequate velocity probe data. Note how the ends of each pass (denoted by extreme end of color band) are turned up – resembling “smiley faces”. This is erroneous data that can be seen as a disparity of up to 0.46 m (1.5 ft) “hatched” areas, which indicate that the data disparity between high and low soundings in the same bin, with blue being near zero and the difference increasing to yellow at 0.46 m (1.5 feet) as the colours proceed down the column. The vertical thin strips represent “swath” groups from the multibeam fan. Where the vertical strips are blue, there is good agreement within the “bins”; however, where there are typical non-blue streaks, the agreement is poor and show over 0.46 m (1.5 ft) difference in places.

Figures 5 and 6 show how steep, head-on seas produce an irregular bottom that resembles the sea surface (less some buffering from the HPR sensor). The typical false wave height in the bottom in these figures is about 0.24 m (0.8 ft) in the areas indicated by the arrows.

When steep waves or wake hit the bow or stern of a survey vessel at an angle and throw it off course, triangular patterns of irregular soundings occur. As shown using the arrows in the 3-D image, Figure 7 demonstrates in a survey area footprint how “quartering” waves and wakes produce the typical triangular “hatched” areas, which indicate that the survey vessel was subjected to rapid course change from the waves hitting it at an angle.

**Identifying problems with wave disturbances**

The introduction of errors attributable to wave and wake disturbances while a survey is in progress is an issue of serious concern with respect to the conduct of surveys that are expected to be precise. Areas with heavy weather exposure and vessel traffic may make a survey area subject to considerable potential wave action.

Devices known as HPR compensators are the industry standard for electronically adjusting a vessel’s position in the computer when its “steady state” is disrupted by waves or wakes. Modern HPR sensors are very efficient, but they still have corrections problems, especially when the survey vessel’s “steady state” is thrown off rapidly, such as regularly occurs with large regular waves or wakes that hit the bow of the boat at an angle.

Most manufacturers’ specification data indicate that, in theory, the HPR can handle almost any sea state. In practice this is not the case, which clearly shows the effects that wave action can have on the accuracy of survey data.

The graphics in Figure 5 illustrate what happens to a multibeam survey performed with a state-of-the-art multibeam system in choppy seas. The colour legend bar is the depth error into a survey at the center beams and the disparity between high and low soundings in the same area (yellow, blue, red, etc.).

**Identifying scatter**

Scatter refers to a general disagreement of data points within a cell. Figure 8 shows an example of scatter and demonstrates that in a 0.91 m x 0.91 m (3 ft x 3 ft) area data points are scattered over a depth of 0.73 m (2.4 ft). This is typical of problems caused by the “gain” and “power” settings of the system, and can be the result of floating or bottom debris.

While one could argue that the spread of points within the cell merely represents a rough bottom condition, as shown in Figure 9, extreme bottom roughness only appears when multiple survey passes are overlaid. Here red, yellow, blue, green and white represent multiple passes by a survey vessel over the same location. Note that the average extremes of data within one pass are from 0.061 to 0.122 m (0.2 to 0.4 ft). However, when overlaying the data from multiple passes over the same location, the data disparity expands to 0.3 to 0.46 m (1.0 to 1.5 ft) –
Are Internal Controls in Place for Communication between Engineering, Survey and Construction Personnel?

Ask:
- Does the contract require internal reporting between engineering, survey and construction so that all project participants are communicating effectively?
- Is the contractor aware of what questions to ask in order to illicit helpful answers from the owner?

Beyond recognising the need for frequent and clear communication, discussed above, owners, contractors and other project participants should ensure that actual policies and programmes are in place to facilitate such communication. By ensuring that formal avenues exist by which project participants can either prevent misunderstandings from occurring or address misunderstandings once they occur, owners and contractors will place themselves in the best position possible to avoid costly delays and litigation.

The project discussed in the first section of this article provides a helpful illustration of the ways in which a lack of internal controls can exacerbate miscommunications between project owners and contractors. As set forth above, the issue between the owner and contractor centered on the acceptability of the method used by the contractor to perform its pre-final acceptance surveys:

- The contractor used the average sounding method, believing that to be the best way to determine actual bottom surface conditions owing to inherent inaccuracies reaching 0.61 m (2 ft) in places. Figure 10 is a visual overview of what happens to the quality of data in the finished work product based on conditions such as the ones shown in Figure 9. Note how the smooth surface becomes rippled (representing erroneous data) as successive survey passes are overlaid on the original data display (lines and notations added). To further expound on this point, by way of comparison, in the isometric view in Figure 11, unfiltered “sounds” show up as rake-like ridges (or as rough panicles in the extreme case).

Compare the survey results in Figure 11 with the survey results in Figure 12, which came from a different, but similar, project. A dramatic difference in the two work products is clearly visible. This also speaks to the attained level of operator skill that must be required in “fine tuning” the multibeam settings to produce a dramatically better and more consistent, as well as precise, finished work product.

**Proactive remedies**

These illustrations are not meant to be exhaustive, but rather to show some of the problems evidenced by reviewing survey data instead of merely accepting survey results. They are intended to give some impression of the type of information with respect to survey quality that can be gleaned merely by examining the raw data as it comes in.

While the actual survey methodology used will differ across projects, contractors can still use these guidelines as a starting point towards better educating themselves about the indicia of reliability that should be present in the data.

Additional proactive steps that contractors can take to prevent unnecessary disputes include establishing, in conjunction with the project owner, a clear protocol by which contractors may review an owner’s survey results once they are available and verify that said results are acceptable prior to engaging in costly shoaling.

Beyond recognising the need for frequent and clear communication, discussed above, owners, contractors and other project participants should ensure that actual policies and programmes are in place to facilitate such communication. By ensuring that formal avenues exist by which project participants can either prevent misunderstandings from occurring or address misunderstandings once they occur, owners and contractors will place themselves in the best position possible to avoid costly delays and litigation.
present in the equipment that devalued the reliability of the “highest” and “lowest” promulgated points.

- The contractor notified the owner of the survey method it planned to use and identified the use of the average sounding method on several of its submissions to the owner.

- In addition, over a two-month period, the contractor sent multiple letters to the owner identifying its method of data processing and seeking guidance or direction when its surveys were repeatedly not being accepted. Likely because such communication was being directed to the owner’s construction personnel, the owner’s survey department neither commented on, objected to nor corrected the contractor’s activities; nor did the owner voice any type of concern with regard to the use of the contractor’s chosen survey method.

How could the use of internal controls have prevented these problems from occurring? One way that the owner and contractor could have pre-empted the communication issues that led to such a massive misunderstanding is by setting up a protocol under which parties would be contractually required to respond to RFIs in a timelier manner.

Contracts should be written to ensure that policies, procedures, timing, and acceptance protocols are clearly spelled out and strictly enforced. For example, the parties could have included a stipulation in the contract that, prior to submitting its first pre-final acceptance survey, the contractor would be required to obtain the owner’s written approval for the method to be used and to confirm that it would use the same method so as to promote consistency in after-dredge surveys.

By writing into the contract policies designed to foster communication between owners and contractors, project participants protect themselves against the danger of miscommunication down the line when the project reaches a more critical juncture. While disagreements with respect to chosen project methodologies may still exist, disputes will be minimised by the requirement that contractors and owners timely and accurately, based on good information, communicate their views to identify and address major points of contention contemporaneously with the work being performed. Owners and contractors must also ensure that
controls exist to facilitate communication between engineers and other project participants. For example, the above-referenced project would have benefited from a policy requiring construction field personnel to connect the owner’s surveyors, and possibly with the initial project designers, and with the contractor when design and survey methodology was questioned.

If such a protocol had existed, an informed dialogue could have occurred. As evidenced, project participants should place clear communication at the forefront of their project goals, and should fashion their contracts to reflect this priority.

First, early proactive Request for Information (RFIs) by contractors on specification and contract ambiguities, coupled with proactive responses by owners, will result in a smoother project. These should be treated as indicators of project success, rather than nuisances. Ambiguities or conflicting issues should be aired in this way during the pre-bid process, as it is far better and less costly to deal with such issues before bid time than after – even if it causes delays and even if additional design budget must be allocated to do so.

Second, if long periods of time have elapsed between initial design and advancing for bids, the project requirements should be subject to careful review to be sure that they are up to date. The challenges of deeper and wider channels, increased cost of in-situ (or contaminated) material removal, coupled with increased environmental awareness, should never be underestimated. Projects often require the use of cutting edge technology, potentially well beyond the expertise of the designer, to create a successful project. This may require bringing in outside contractors or equipment manufacturers who are familiar with the latest technology. Such expense should be viewed as a “value added” and not an unnecessary expenditure. Contractors should be mindful of obsolete procedures and specifications, while owners should not try to handle new issues brought on by new challenges with outdated technology.

Third, all parties should be trained to recognise when a difficult demand has been placed on the initial design from the regulatory review process. Parties should be proactive in advancing approaches to recognise issues and seek advice on their resolution from industry experts. The entire protocol chain of design should be looked at and, to the extent necessary, outside peer review/value engineering (VE) review on difficult or challenging projects should be instituted. This peer/VE review may need to occur at various milestones, especially when – as discussed above – long periods of time have elapsed between initial design and advancing for bids.

Fourth, contractors would be well served to educate themselves on the different manuals and/or published guidelines that may exist in relation to a particular project, and to familiarise themselves with the standards contained therein. By ensuring that they have a complete understanding, not only of what is expected and/or recommended in terms of survey protocol and methodology, but also whether and how the owner actually plans to implement these protocols, contractors will be in a better position to consent to specific courses of action prior to commencing work on a project. The reverse is also true: Owners should be sure to understand the technology to be used by contractors in performing measurements of their own work and should be clear with contractors about what methods they, in turn, will be using.

Fifth, contractors should request raw survey data instead of merely accepting survey results. All parties should be well trained in reviewing raw survey data to identify indicia of error during survey and not after claims or litigation have arisen.

Finally, communication, communication, communication: Contractors must notify owners when issues arise, even if such issues seem insurmountable. It is better that all parties know when problems arise so that key participants can work on resolving them. If necessary, parties should also consider bringing in outside mediators and experts early on, as fresh eyes can often see things that are not as apparent on the project “battlefield”. The cost of outside help will be far less than ending up in a protracted dispute. Parties are encouraged to work toward resolving issues, rather than stonewalling and placing blame. Even if there are cost ramifications from early dispute resolution, at the end of the day resolving disputes in the field is a great deal less expensive than resolving them in court.

CONCLUSIONS

The minimisation of disputes between contractors and owners will serve to benefit all parties, as unnecessary delay and increased costs effect everyone. In summary, the tips and techniques that all dredging contractors and project owners should observe are:

The cost of outside help will be far less than ending up in a protracted dispute. Parties are encouraged to work toward resolving issues, rather than stonewalling and placing blame. Even if there are cost ramifications from early dispute resolution, at the end of the day resolving disputes in the field is a great deal less expensive than resolving them in court.
ABSTRACT

In recent years, great quantities of dredged material have been removed in order to maintain the depth of channels and anchorages. In addition, a lack of land for the disposal/storage of dredged soil has become a problem. At the same time, converter slag that has properties such as wear resistance or hydraulic properties has been used as a civil works material in areas such as roadbeds.

With the reduction of public construction recently, however, the development of new usages is expected. Therefore, in coastal areas the utilisation of a Calcium Oxide (CaO) improved soil, i.e., dredged soil and converter slag (usually called “slag stabilised soil”) has been developed. From previous studies, characteristics such as hardening and a suppressed increase in pH is known. This improved soil is used as material for the “padding” of tidal flats and marine forests and for backfilling hollows where a large quantity of sand from the sea bottom has been placed for urban development.

Based on an experiment using a pneumatic flow mixing method where slag stabilised soil was used as a material for reclamation, large-scale rapid reclamation work was performed with the aim of satisfying an average strength of 50kN/m² (long-term curing). At the same time it was confirmed that there was no adverse influence on the water quality in the peripheral sea area during the reclamation period.

An article on this subject was first published in the Proceedings of the Western Dredging Association (WEDA XXXIII) Technical Conference and Texas A&M University (TAMU 44) Dredging Seminar, Honolulu, Hawaii, August 25-28, 2013 and is reprinted here in an updated version with permission.

INTRODUCTION

Great quantities of dredged soil have been produced from maintaining the depth of channels and anchorages and for harbour developments. This has previously been casted onto land designated for the disposal of dredged soil or in reclaimed areas. However, it has recently become difficult in some places to secure sufficient land whilst in other areas availability has decreased because of the recent developments in environmental conservation.

Converter slag is the granular by-product of steel production and is produced at an approximate rate of 10 million tonnes a year in Japan. It has properties such as wear resistance and hydraulic properties when being used as a civil works material in areas such as road beds. It is generally considered a useful way of recycling material. However, when converter slag is used in a marine area, particularly a place where it is directly in contact with seawater, it is necessary to consider its influence on the neighbouring environment because alkalinity levels are high in converter slag (Ref 1).

The slag stabilised soil increases the dredged soil’s strength and the combination of the two materials suppresses the liquidation of the alkali from the converter slag. It is thought that the mixture also adsorbs phosphorus contained in the eutrophic dredged soil. Because seawater does not circulate in the sea hollows, they become a degraded
environment with a lack of oxygen and a high density of hydrogen sulfide. It is possible for slag stabilised soil to be utilised as a possible material backfill for hollows and to create shoals and tidelands in marine areas.

In this report, the slag stabilised soil was examined for its hardening character and basic experimental data were collected while using it as a material for reclamation. The large-scale reclamation work was accomplished using the pneumatic flow mixing method, a first for the Japanese.

The reclaimed land formed by the slag stabilised soil was evaluated for its performance and construction properties so as to establish a technique for slag stabilised soil. At the same time the reclamation work was managed appropriately so as not to affect the neighboring environment (Ref 2).

**PNEUMATIC FLOW MIXING METHOD**

The pneumatic flow mixing method is characterised by the following steps. First, dredged soil obtained from grab dredging undergoes the addition of a stabilising agent as the soil is unloaded from a pneumatic conveying vessel. The dredged soil is mixed with a stabilising agent by utilising the turbulent effects caused by the plug flow that can be generated in a pneumatic conveying pipe.

Figure 1 provides an example of the configuration of the working fleet used for this process. The fleet comprises a grab dredger, hopper barge, pneumatic conveying vessel, cement supplier barge, and a placement barge (for underwater placement). Construction carried out using this method is primarily characterised by the preparation and placement of stabilised soil and is carried out by all these vessels working together (Ref 3).

**EXPERIMENT**

**Summary**

In the case of reclamation with slag stabilised soil, it was confirmed that the pneumatic flow mixing method was applicable to the mixing of dredged soil and converter slag, and work proceeded to acquire basic experimental data at the time of the large-scale reclamation. The mixing of the two materials and placement were the subject of experiments in September, 2010 in Tokai-shi, Aichi using the pneumatic flow mixing method with a pipe diameter of 100 mm and pipe length of approx. 100 m.

The basic layout summary for the experiment is shown in Figure 2. The experimental conditions assumed the water content ratio of dredged soil was 1.6 times the liquid limit of the soil, and the additional quantity of converter slag (grain size 25 mm or less) made up 30% by volume of dredged soil.

The placement on the ground was by an energy absorber and the water placement by using a tremie. This was performed in order to compare the influence of the mixtures using different placing methods. The situations in relation to the placement on the ground versus in the water are shown in Figure 3.

The uniaxial compression test on a sample of slag stabilised soil in each pit was done on the 28th day after placement. In addition, the depth distribution of strength for the slag...
Land Reclamation Using Calcium Oxide (CaO) Improved Soil in Japan

The stabilised ground at a 2-m depth was confirmed by carrying out a cone penetration test and a standard penetration test on the 28th day and six months after placement.

**Strength characteristic**

The results of uniaxial compressive tests of slag stabilised soil (at age 28 days) are shown in Figure 4. They show average uniaxial compressive strength ($q_u$) is 294.2 kN/m$^2$ and coefficient of variation is 0.18 in case of placement on the ground. An average $q_u$ of 184.6 kN/m$^2$ and coefficient of variation of 0.23 is the case for placement in the water and it was confirmed that dredged soil and converter slag were able to be mixed uniformly by the pneumatic flow mixing method. The $q_u$ was 279.1 kN/m$^2$ in the indoor test using the dredged soil was the same as the experiment.

The ratio for $q_u$ when placed on the ground and the indoor test was 1.05 and the one for water placement was 0.66. The ratio between ground and water was 0.63 (Ref 4). The ratio of $q_u$ was bigger and the coefficient of variation was smaller than the value shown in the technical manual for the pneumatic flow mixing method (ratio of $q_u$ (ground) 0.7, ratio of $q_u$ (water) 0.5, coefficient of variation 0.35) (Ref 5).

**Ground exploration**

With the slag stabilised ground, an electric cone penetration test, a standard penetration test and an automatic lamb sounding were done. The depth distribution of the point resistance $q_t$ of the cone penetration test, the uniaxial compressive strength $q_u$, the standard penetration test $N$ value and the automatic lamb sounding $N_d$ value of the 28th day after placing are shown in Figure 5. There was no material separation based on differences in specific gravity and deterioration of the quality owing to surface drying on the slag stabilised ground. It was also confirmed that the ground where the depth distribution of strength was undertaken had formed uniformly (Figure 6). In addition, from these results, the expression of relations of uniaxial compressive strength $q_u$ and corn index $q_c$ was $q_c = 12.1 \times q_u$ (Ref 6).

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There was mostly silt and clay in dredged soil I, and there was mostly sand in dredged soil II and III.

b) Normal management test of dredged soil

Water content and wet density, flow value (JHS A 313) of the dredged soil in every hopper barge were measured. Dredged soil I had low wet density and high water content, but flow values tended to become smaller (around 100mm) regardless of water content and wet density ratio. Dredged soil II had a high wet density and the flow value was changed greatly according to the change of water content ratio. Dredged soil III had high water content and low wet density, and the flow value was small (around 100mm) regardless of water content ratio.

Investigation results

In this report, only the results for ★ marks in Table II have been written down which are necessary for a performance evaluation of standard construction management items and the reclaimed ground.

a) Soil test

The dredged soil that was mixed with the converter slag used dredged soil I (11,323 m³), dredged soil II (7,949 m³), dredged soil III (4,763 m³). There was mostly silt and clay in dredged soil I, and there was mostly sand in dredged soil II and III.

b) Normal management test of dredged soil

Water content and wet density, flow value (JHS A 313) of the dredged soil in every hopper barge were measured. Dredged soil I had low wet density and high water content, but flow values tended to become smaller (around 100mm) regardless of water content and wet density ratio. Dredged soil II had a high wet density and the flow value was changed greatly according to the change of water content ratio. Dredged soil III had high water content and low wet density, and the flow value was small (around 100mm) regardless of water content ratio.

Investigation contents

The properties of the reclaimed ground and the strength of the slag stabilised soil which was placed in the eastern area to establish techniques for the material were investigated. An investigation components list is shown in Table II.
content of converter slag was bigger than the absorption water rate with an average of 8.3% (5.3% at the minimum and up to 10.5%).

(d) Mass per unit volume of converter slag
The mass per unit volume of the converter slag was measured twice a day using a 10L container. The measurements were distributed over the range of 1.86-2.12, the average was 1.95.

(e) Normal management test result
The slag stabilised soil in the vessel was sampled during a reclamation period and the measured wet density, flow value and uniaxial compressive strength measured once a day. The designed value of the uniaxial compressive strength was 30 kN/m² and the aimed for strength prior to the indoor test result (strength ratio 0.6 during ground and water placement) (Ref 4) was an average of 50 kN/m² (when placed on the ground). The results for wet density, flow value and uniaxial compressive strength are shown in Table V.

Adjustments were made by adding water through the axis, sealing water on the pneumatic conveying vessel at a minimum so as to achieve the aimed for strength and satisfactory strength in all dredged soil in the third month after placement. In the technical

Table III. Soil test results

<table>
<thead>
<tr>
<th>Item</th>
<th>Dredging site</th>
<th>Dredged soil I</th>
<th>Dredged soil II</th>
<th>Dredged soil III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of the soil grain</td>
<td>( \rho_s )</td>
<td>2.644</td>
<td>2.648</td>
<td>2.654</td>
</tr>
<tr>
<td>Consistency</td>
<td>Lightning limit</td>
<td>109.8</td>
<td>58.5</td>
<td>58.9</td>
</tr>
<tr>
<td>Plasticity limit</td>
<td>( w_P )</td>
<td>38.5</td>
<td>31.9</td>
<td>25.9</td>
</tr>
<tr>
<td>Plasticity index</td>
<td>( \Pi )</td>
<td>71.3</td>
<td>26.6</td>
<td>33.0</td>
</tr>
<tr>
<td>Grain size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>-</td>
<td>0.14</td>
<td>12.44</td>
<td>2.10</td>
</tr>
<tr>
<td>Sand</td>
<td>-</td>
<td>13.80</td>
<td>53.60</td>
<td>52.20</td>
</tr>
<tr>
<td>Silt</td>
<td>-</td>
<td>70.20</td>
<td>20.00</td>
<td>35.40</td>
</tr>
<tr>
<td>Clay</td>
<td>-</td>
<td>15.90</td>
<td>13.96</td>
<td>7.40</td>
</tr>
<tr>
<td>Max. grain size</td>
<td>-</td>
<td>9.5</td>
<td>26.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Wet density</td>
<td>( g/cm^3 )</td>
<td>1.303</td>
<td>1.636</td>
<td>1.719</td>
</tr>
<tr>
<td>Ignition loss</td>
<td>( Li )</td>
<td>11.6</td>
<td>8.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Soil suspension pH</td>
<td>-</td>
<td>8.0</td>
<td>8.8</td>
<td>8.3</td>
</tr>
<tr>
<td>Natural water content</td>
<td>( w_O )</td>
<td>171.3</td>
<td>73.3</td>
<td>63.0</td>
</tr>
<tr>
<td>Liquidity limit ratio</td>
<td>( w_O/w_L )</td>
<td>1.56</td>
<td>1.25</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Table IV. Test result of dredged soil.

<table>
<thead>
<tr>
<th>Item D.S.</th>
<th>Wet density ( g/cm^3 )</th>
<th>Flow value mm</th>
<th>Water content ratio %</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.S. I</td>
<td>1.301~1.525 1.380</td>
<td>90.0~115.0</td>
<td>99.0</td>
</tr>
<tr>
<td>D.S. II</td>
<td>1.500~1.812 1.715</td>
<td>86.0~143.0</td>
<td>113.5</td>
</tr>
<tr>
<td>D.S. III</td>
<td>1.530~1.692 1.621</td>
<td>113.0~211.0</td>
<td>166.6</td>
</tr>
</tbody>
</table>

(e) Normal management test result
The slag stabilised soil in the vessel was sampled during a reclamation period and the measured wet density, flow value and uniaxial compressive strength measured once a day. The designed value of the uniaxial compressive strength was 30 kN/m² and the aimed for strength prior to the indoor test result (strength ratio 0.6 during ground and water placement) (Ref 4) was an average of 50 kN/m² (when placed on the ground). The results for wet density, flow value and uniaxial compressive strength are shown in Table V.

Adjustments were made by adding water through the axis, sealing water on the pneumatic conveying vessel at a minimum so as to achieve the aimed for strength and satisfactory strength in all dredged soil in the third month after placement. In the technical
and qu7 because a positive correlation is seen between qu3, qu7 and qu28.

(f) Characteristic examination

Uniaxial compressive strength was measured for more than 20 specimens in each condition to confirm the change in the property of slag stabilised soil and the difference in dredged soil (Figures 13 and 14). The coefficient of variation of qu28 was up to 0.24 (April 25th) except in the early period of reclamation work and it was smaller than the 0.35 guidance figure given in the “the technical manual for pneumatic flow mixing method” (Ref 5).

(g) pH measurement

It was confirmed that the pH of slag stabilised soil was not beyond 9.0 which is the waste water regulation. Also once a day a check was made to see whether cloudiness occurred with natural seawater. The pH of the slag stabilised soil was on average 8.4. It rose around 0.2, but it was still less than 9.0. In addition, by measurements 30 minutes later, the cloudiness (separation of magnesium hydroxide) on the surface of the slag improved the soil and the cloudiness of the seawater could not be recognised (Figure 15).
(h) Elution examination, component examination
It was confirmed that slag stabilised soil complied with the bottom soil standard of the Marine Pollution Prevention Law and the quantity standard for elution and content of the Soil Contamination Countermeasures Act. The result of having carried out this component examination and an elution examination of the toxic substance using slag stabilised soil 28 days after placement as a sample showed that they were less than the standard for all items.

(i) Measurement of turbidity and pH
Turbidity and pH were measured once a day with a multi-parameter water quality meter. To comply with the water quality regulation the measured values for a background spot and a monitoring spot are shown in Figure 16 and Table VI. In regard to the cloudiness, turbidity was changed to SS by a correlative expression of the turbidity - SS which was carried out beforehand. The SS value went up and down under the influence of the rain, but because the value of background (BG) spot and the monitoring spot changed in the same way, and the pH was stable during the construction period. Both the pH and SS remained less than regulation values.

(j) Pressure in delivery pipe
Pressure sensors were installed in the pipe on the pneumatic conveying vessel and near the tip of the delivery pipe. These measured pressure in the pipe. The relationship between the flow value of slag stabilised soil and pressure incline, former experimental value (Refs 4, 10) and this measured value and value of the cement stabilisation (Ref 11) is shown in Figure 17. The remarkable rise in pressure was not seen this time in the pneumatic conveying of the slag stabilised soil (pipe dia. φ 800 mm x length 300 m) and it was confirmed that it had the same efficiency as the cement stabilisation.

Table VI. Quality of the water regulation and the measured value of pH and SS.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quality of the water regulation value</th>
<th>BG spot</th>
<th>Monitoring spot</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.0～9.0</td>
<td>7.9～8.2</td>
<td>7.9～8.2</td>
</tr>
<tr>
<td>SS</td>
<td>Below BG value+10mg/l</td>
<td>3.9～39.2</td>
<td>3.9～41.3</td>
</tr>
</tbody>
</table>

(k) Quantity of soil delivery, with added converter slag and added water
The quantity of dredged soil (in the barge) reclaimed by this construction equipment was up to 1456 m³ per day and up to 158 m³ per hour. The quantity of added converter slag was approximately as planned (25%) and was stable with an average of 25.2%, a minimum of 24.3% and up to a maximum of 25.7%. The quantity of added water at the axis seal...
of the pneumatic conveying vessel was given top priority for quality purposes and was reduced as much as possible to around 20 m³/h. The volume of slag stabilised soil became 1.48 times the quantity of natural ground soil after finally adding water and converter slag.

(l) Uniaxial compressive strength (sample at the placing location)
The slag stabilised soil was sampled before the second placement, molds were filled for measurements and sampled after the second placement by using polyvinyl chloride pipes and the strength development situation confirmed by a uniaxial compression test. The setting and the collection of the polyvinyl chloride pipes are shown in Figure 18. The comparison of the uniaxial compressive strength between the field sample and the mold sample is shown in Table VII. The mold sample results showed that the measurement result for the field samples became an equal or bigger value.

(m) Core penetration test and automatic lamb sounding
An electrical static core penetration test and an automatic lamb sounding in eight places on the slag stabilised ground were carried out in order to grasp its strength properties in the first month and third month after reclamation was completed. The core penetration test situation and the lamb sounding situation are shown in Figure 19. The test results that were measured are shown in Figure 20. Unevenness of the strength at each spot was seen, but strength increased according to the progress of the time and it was confirmed that the aimed for strength was reached to the same extent as the molded samples and the polyvinyl chloride pipe samples three months later.

Table VII. Result of uniaxial compression test.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.S. I</td>
<td>57.9~98.5</td>
<td>80.0</td>
<td>28.1~87.2</td>
<td>61.9</td>
</tr>
<tr>
<td>D.S. II</td>
<td>64.6~142.5</td>
<td>103.6</td>
<td>102.2~150.4</td>
<td>126.3</td>
</tr>
<tr>
<td>D.S. III</td>
<td>35.5~65.6</td>
<td>47.9</td>
<td>27.4~75.6</td>
<td>47.9</td>
</tr>
</tbody>
</table>

Figure 17. Relationship between flow value of slag stabilised soil and pressure incline.

Figure 18. Left, Setting situation of the polyvinyl chloride pipe; right, Collection situation of the polyvinyl chloride pipe.

Figure 19. Left, Core penetration test situation; right, Lamb sounding situation.

Figure 20. The ground findings.
CONCLUSIONS

During this construction work the following things about the materials and construction properties of the slag stabilised soil were grasped:

(1) The uniaxial compression test and cone penetration test were carried out and they confirmed that the slag stabilised ground met the predetermined strength.

(2) Because a) there was a positive correlation between wet density of the dredged soil and uniaxial compressive strength, b) there was a negative association between water content ratio of dredged soil and its strength, c) there was a positive association of strength between short-term curing and 28-day curing, d) measurement of wet density, water content and uniaxial compression strength on site (at 3 days and 7 days) made it possible to estimate the strength of material (at 28 days).

(3) When the slag stabilised ground was constructed using the pneumatic flow mixing method, the coefficient of variation was 0.23 (experiment) and 0.24 (construction), which was smaller than the value (0.35) for stabilisation with cement and good ground material was realised. In addition, the strength ratio of the indoor examination results and the placing to the ground/water was 1.05/0.63 which were bigger than the values (ground: 0.7, water: 0.5) of the cement stabilised soil.

(4) By examining the pH, elution components of slag stabilised soil its safety was confirmed. It did not affect the neighbouring environment during construction; confirmed by measurement of pH and SS in the monitoring spot.

(5) The technical manual for the pneumatic flow mixing method (revised version) states: “the dredged soil that included more than 50% sand and that deviated from the coverage (Ref 7) of 90 mm-100 mm or more was desirable for the flow value (Ref 8)”. However, the slag stabilised soil included more than 50% sand and flow value was around 80 mm, but it was still able to be conveyed. The particle size distribution shifts to a wider range by adding converter slag. However, for the slag stabilised soil, it is thought that conveyance was still possible even if the flow value is relatively small. The conveying efficiency, the quantity of adding water and the quality of slag stabilised soil are related closely and the most suitable set point in consideration of construction condition of the slag stabilised soil and quality of dredged soil must be developed.

Reclamation work in the western area is planned next, and the aim is to improve the quality and construction performance for this next area based on the results to date. In addition, the plan is to use a mixing method unlike the pneumatic flow mixing method.

Then, as more knowledge is accumulated through the acquisition of various data and development of new methods of mixing, new usages will be found for slag stabilised soil. The aim also is to test and further promote the use of slag stabilised soil.

REFERENCES

Puertos del Estado de España is a public body under the Ministry for Development that controls the effectiveness of the 28 port authorities in the Spanish ports system. In 1988 it published a Dykes Atlas containing information on the dykes built in Spain up to 1986.

During the 25 years that have elapsed since this publication, Spanish maritime technology has developed exceptionally. Its designs have gained in safety and reliability because of the advances in the knowledge of maritime climates, the optimising of methods for structural calculations, the scale model project tests in laboratories and the improvements in construction processes through the appearance of new equipment. As a result dykes have been built in the last decades at much greater depths and with much greater wave resistance. Dykes with a total length of 4,788 m (southern dyke in Barcelona), at depths of up to -48 m (southwest dyke in Escombreras), protected with blocks of up to 200/195 tonnes (Gijón / Langosteira) have already been built in Spanish ports.

These new constructions have encouraged Puertos del Estado to publish this new Atlas of Dykes (December 2012) to continue the story where the 1986 version ended. This new Atlas systematically describes and provides all the relevant information on the 63 dykes built in state ports between 1986 and 2011, with a total length of 73 km. It includes only the outer dykes, that is, those that are subjected to the direct action of the sea. It also contains only the dyke sections designed with a significant calculated wave height of more than 3 m and at a depth of more than 5 m.

The ports are grouped into eight maritime regions according to their geographical situations with similar coastal forms and common adjacent seas, giving information on the harbour walls in each port. For each port information is given on a double page spread containing:
- The location of the port
- An aerial photograph of the port
- Longitude and latitude
- Direction of the dominant and prevailing winds
- Maximum tidal range
- A plan of the port with bathymetry measurements, showing the dykes included in the Atlas.

It then provides information on the various dyke sections analysed, including:
- Schematic drawing of the dyke with the location of the various sections.
- Standard cross section of each section with the definition of its basic structural type (sloping or vertical) and showing all its elements: stone core, filters, beds supporting outer and inner protection layers and caisson foundations, skirt, sea bed, etc. In each case, data are provided on the weights and sizes of the various components.
- Geometrical data: length of each section, depths, levels of crown and foundations, slopes, sizes of caissons in vertical dykes, etc.
- Geotechnical data on the nature of the sea bed
- Design criteria: significant design wave heights, wave frequency, useful life in years, calculated return period, fault criteria, overflow experience, etc.
- Methods for verifying the cross section (mathematical formulas, numerical models, tests on physical models).

As with the 1988 edition, it is expected that the Atlas will be welcomed for its great usefulness since it will serve technicians in the port authorities as well as consultants, designers and contractors to approach the design of new dykes, considering the criteria set in each case described.

It remains only to thank Puertos del Estado for this publication and encourage this authority to start a similar initiative for the numerous quays and mooring lines in Spanish ports.

For further information see: www.puertos.es

ROBERTO VIDAL
USA SUMMIT ON DREDGING AND RECLAMATION
MARCH 31-APRIL 1, 2014
MIAMI, FLORIDA, USA

IQPC’s Dredging & Reclamation USA Summit is a global event that unites port authorities, engineers, port operators, construction companies, dredging contractors, and more in their quest to ensure the profitability and quality assurance of dredging projects. Experts will speak on the principles of dredging and reclamation projects with regard to architectural industry-waterborne trade, urbanisation, energy and climate change, beneficial use, federal and state regulations, environmental protection and more.

Subjects for discussion include:
The appropriations and contracting process, beneficial use of dredged material from capital dredging projects, how to implement strategic plans for port growth and evaluating the environmental risks

For further information contact:
http://www.dredgingandreclamation.com

SOUTH BALTIC CONFERENCE ON DREDGED MATERIALS IN DIKE CONSTRUCTION
APRIL 10-11, 2014
ROSTOCK / WARNEMÜNDE, GERMANY

The project DredgDikes was initiated by the University of Rostock and Gdansk Technical University to investigate the application of dredged materials, geosynthetics and different ash-composites in dike construction. The international cooperation project is part-financed by the EU South Baltic Cross-border Co-operation Programme 2007-2013.

For further information contact:
Universität Rostock, Chair, Geotechnics und Coastal Engineering
Prof. Dr. Ing. Fokke Saathoff
Tel: +49-381-4983701
Contact: Dr.-Ing. Stefan Cantré
• Email: stefan.cantre@uni-rostock.de
www.dredgdikes.eu

IADC SEMINAR ON DREDGING & RECLAMATION
MARCH 31-APRIL 4, 2014
NOVOTEL, BRISBANE, AUSTRALIA

For the first time ever IADC is happy to present its International Seminar on Dredging and Reclamation in Brisbane, Australia. Aimed at (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organisations who have to execute dredging projects, the IADC has organised the Seminar at numerous venues often in co-operation with local technical universities. Since 1993 this week-long Seminar has been successfully presented in Delft, Singapore, Dubai, Buenos Aires, Abu Dhabi, Bahrain and Brazil. As is appropriate to a dynamic industry, the Seminar programme is continually updated. In addition to basic dredging methods, new equipment and state-of-the-art techniques are explained.

To optimise the chances of the successful completion of a project, contracting parties should, from the start, fully understand the requirements of a dredging project. This five-day course strives to provide an understanding through lectures by experts in the field and workshops, partly conducted on-site in order to give the “students” hands-on experience.

Highlights of the programme are:
Day 1: Why Dredging? The Need for Dredging/Project Phasing
Day 2: What is Dredging? Dredging Equipment/Survey Systems (includes a site visit)
Day 3: Production of various types of dredgers (includes a visit to a dredging yard)
Day 4: Preparation of a Dredging Contract, Reclamation, Tender, Cost Pricing
Day 5: Contracts

An important feature of the Seminars is a site visit to a dredging project being executed in the given geographical area. This gives the participants the opportunity to see dredging equipment in action and to gain a better feeling of the magnitude of a dredging operation.

Each participant receives a set of comprehensive proceedings with an extensive reference list of relevant literature and, at the end of the week, a Certificate of Achievement in recognition of the completion of the coursework. Please note that full attendance is required for obtaining the Certificate of Achievement.

Group discount
The fee for the week-long seminar is AUD 4,400 (= € 3,100 inclusive VAT). The fee includes all tuition, seminar proceedings, workshops and a special participants’ dinner, but excludes travel costs and accommodations. Assistance with finding hotel accommodation is available. A Group Discount of AUD 400 (= € 280 per person) will be offered to groups and organisations wishing to register two or more delegates.

Other Upcoming IADC Seminars in 2014
• June 23 to June 27 (in co-operation with UNESCO-IHE), Delft, The Netherlands
• October 27 to October 31, Singapore (in co-operation with the National University of Singapore).

For further information contact:
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International Association of Dredging Companies
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www.iadc-dredging.com
XIV IBERO-AMERICAN COURSE ON PORT TECHNOLOGY, OPERATIONS AND ENVIRONMENTAL MANAGEMENT
MAY 19- JUNE 13, 2014
SANTANDER, SPAIN

This course is organised by Puertos de España, Spain in cooperation with the Inter-American Committee on Ports of the Organization of the American States (CIP-OAS). It will be given in Spanish only. Thanks to the support and cooperation of Puertos del Estado of Spain, the CIP is in a position to offer up to 20 scholarships for officials from the Americas.

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33RD PIANC WORLD CONFERENCE
JUNE 1-5, 2014
SAN FRANCISCO, CA, USA

Registration for the PIANC World Conference is now opened. The conference will have the theme “Navigating the New Millennium” and participants and presenters are sought from every continent regarding best practices and innovation. The PIANC 2014 Congress will include: Technical Short Courses, Plenary Sessions, Concurrent Technical Session Tracks, Industry Exhibition, Technical Tours, Networking Events, Accompanying Persons Cultural Tours. The Congress is held every four years and is open to members and non-members.

For further information contact:
Ms. Kelly J. Barnes
PIANC USA Deputy Secretary
USACE, Institute for Water Resources
Tel: +1 703 428 9090
• Email: Kelly.J.Barnes@usace.army.mil or pianc@usace.army.mil

WEDA 34/TAMU 45 CONFERENCE
JUNE 15-18, 2014
FAIRMONT ROYAL YORK, TORONTO, ONTARIO, CANADA

In June 2014 the Western Dredging Association and Texas A&M will be holding its next Annual Western Hemisphere Dredging Conference at the Fairmont Royal York in Toronto, Canada, one of the most renowned hotels in Canada since 1929. Registration is now opened. With the theme, “Expanding the Dredging World”, delegates will experience another interesting and educational technical programme that will promote the exchange of knowledge in fields related to dredging, navigation, marine engineering and construction, as well has the enhancement of the marine environment.

For further information contact:
Larry Patella
WEDA Executive Director
• Email: weda@comcast.net
www.westerndredging.org

CALL FOR PAPERS
22ND INTERNATIONAL FEDERATION OF HYDROGRAPHIC SOCIETIES’ CONFERENCE AND EXHIBITION
OCTOBER 28-30 2014
ABERDEEN, SCOTLAND

Abstracts of papers for presentation at the 22nd Conference are now invited for submission by the organisers, The Hydrographic Society UK. With its theme, Energy & Enterprise, the three-day event is expected to attract a wide international audience drawn from all sectors of the hydrographic and related professions. In addition to keynote addresses and paper presentations, the conference agenda also features an introductory Student Presentation Session for which there will be a prize of £500 for the best adjudged contribution. Other agenda items include a 60-plus stand exhibition, to workshops, local technical visits and an IHO-led session and stakeholder forum; and a reception in the celebrated Aberdeen Maritime Museum and a conference dinner at the historic Elphinstone Hall.

Main conference topics are: Geophysical & Geotechnical Surveying, Offshore Exploration, Marine Renewables, Subsea Positioning, ROV, AUV and UUVs, Subsea Cables, Pipelines & Structures, Support of the Blue Economy, Airborne Bathymetric LiDAR, Environmental Protection, e-Navigation, Data Processing & Visualisation, Sustainable Maritime Development, and Education, Training & Standards. Abstracts of not more than 300 words on any of the designated topics or related issues are required by the Papers Committee by no later than 25 April and should be submitted in Word format to hydro14@ths.org.uk. Successful authors, who will be entitled to a 25% discount on the relevant standard delegation fee, will be notified in early July.

Further general information on Hydro 14, including abstract conditions, registration details and opportunities for exhibiting and commercial sponsorship, go to: www.hydro14.org.uk.
• Email: hydro14@ths.org.uk.
Through their regional branches or through representatives, members of IADC operate directly at all locations worldwide.

AFRICA
BKI Egypt for Marine Contracting Works S.A.E., Cairo, Egypt
Dredging and Reclamation Jan De Nul Ltd., Lagos, Nigeria
Dredging International Services Nigeria Ltd., Ikoyi Lagos, Nigeria
Nigerian Westminster Dredging and Marine Ltd., Lagos, Nigeria
Van Oord Nigeria Ltd., Victoria Island, Nigeria

ASIA
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Boskalis International (S) Pte. Ltd., Singapore
Dredging Dredging International Asia Pacific (Pte) Ltd., Singapore
Hyundai Engineering & Construction Co. Ltd., Seoul, Korea
International Seaport Dredging Private Ltd., New Delhi, India
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Van Oord Dredging and Marine Contractors bv Philippines Branch, Manila, Philippines
Van Oord Dredging and Marine Contractors bv Singapore Branch, Singapore
Van Oord India Pte Ltd., Mumbai, India
Van Oord Thai Ltd., Bangkok, Thailand
Zinkcon Marine Singapore Pte. Ltd., Singapore

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Jan De Nul Australia Ltd., Australia
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Van Oord Australia Pty Ltd., Brisbane, QLD, Australia
WA Shell Sands Pty Ltd., Perth, Australia

EUROPE
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Baggermaatschappij Boskalis B.V., Papendrecht, Netherlands
Baggerwerken Decloet & Zoon NV, Oostende, Belgium
Ballast Ham Dredging, St. Petersburg, Russia
Baltic Marine Contractors SIA, Riga, Latvia
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Boskalis Westminster Middle East Ltd., Limassol, Cyprus
Boskalis Westminster Shipping BV, Papendrecht, Netherlands
Bravawala Wasserbaugesellschaft Bremen mbH, Bremen, Germany
BW Marine (Cyprus) Ltd., Limassol, Cyprus
DEME Building Materials NV (DBM), Zwijndrecht, Belgium
Dragapor Dragagens de Portugal S.A., Alcochete, Portugal
Dravo SA, Italia, Amelia (TR), Italy
Dravo SA, Lisbon, Portugal
Dravo SA, Madrid, Spain
Dredging and Contracting Rotterdam b.v., Bergen op Zoom, Netherlands

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GENERAL PORT WITH SPECIFIC GOALS

A five-year environmental plan for Lisbon

AVOID DISPUTES, COSTS AND DELAYS

define survey means and methods early

READY FOR RAPID LAND RECLAMATION

combine converter slag and dredged soil

ANNOUNCING:
The New Interactive Terra (see page 4 and www.terra-et-aqua.com)