EARLY CONTRACTOR INVOLVEMENT
Identifying the hallmarks of successful ECI process in maritime projects

INNOVATIVE STRUCTURES
Alternative quay wall structures for inland ports

DREDGE PLUME MODELLING
The importance of including flocculation in numerical modelling
THE IMPORTANCE OF FLOCCULATION IN DREDGE PLUME MODELLING

Numerical models are often used to predict the magnitude and behaviour of dredge plumes to help assess and manage any environmental risks. Previous investigations have shown that in the marine environment, fine-grained sediment suspended by natural processes and dredge-related activities are typically present as aggregated particles known as flocs. Read the full article on page 18 that considers the importance of including the process of flocculation in dredge plume models.
On 9 February 2023, IADC hosted a 1-day conference in Dubai on “Financing Sustainable Marine and Freshwater Infrastructure.” Designed for professionals in the fast changing world of finance, dredging and related sectors, 80 delegates came together to address what is needed to break the deadlock in the funding of sustainable projects. And most importantly, who needs to do what.

While sustainable projects generally make use of nature-based solutions (NbS), one of the main bottlenecks identified in the financing process of such projects is obtaining the certainty of a project’s cash flow. Projects are often relatively small and as a result, the start-up costs are high. A possible solution to interest investors is the bundling of projects. At the same time, a case-by-case approach is necessary since risks, which are a relevant factor for investors, differ per project. NbS projects are generally more risky than traditional projects as the effectivity of the solution is sometimes uncertain.

Can investors be tempted to have a greater risk appetite while accepting a lower ROI as is often the case with NbS projects?

The lack of a proper legal framework with a clear definition of project and governance also remains a challenge.

An ROI can be achieved from, for example, carbon credits. Projects with an NbS design often have a lower ROI and are therefore less preferred by investors. More and more pension funds however are willing to participate in NbS projects, provided to secure for lower returns in favour of sustainability. In addition, insurers can reduce claim costs with NbS coastal protection projects. By investing thereby reducing flood risk, they in turn can reduce their costs.

It is paramount that projects are viewed in an integrated way and that all the costs and benefits, including externalities, are assessed. Another problem identified is the difficulty of translating social benefits into financial benefits. While there are methods for this, they involve many assumptions and discussions about the value of parameters.

Delegates suggested ideas for ways to move forward that included organising regional symposia to showcase examples of successful nature-based solutions. Consultants and contractors to highlight existing NbS projects at infrastructure finance conferences. Developers and authorities to integrate NbS in large commercial infrastructure developments. Authorities to facilitate the implementation framework of sustainability by bringing all stakeholders to the table at the early stages of a project. Along with governments to create laws to include sustainable solutions as part of a project’s evaluation for approval.

Overall, the conference provided a much-needed springboard to move the topic of funding sustainable projects forward. In keeping with the topic, check out the sustainability article on page 30 that shares research on finding more cost effective and sustainable quay wall structures for the future. Also in this issue are articles addressing the importance of flocculation in dredge plume modeling and early contractor involvement in maritime projects.

Frank Verhoeven
President, IADC
A framework for early contractor involvement in infrastructure projects

The PIANC report “A framework for early contractor involvement in infrastructure projects” and is available as a free download for PIANC members (and 215 EUR for non-members) on the PIANC website. At some 183 pages, it provides a detailed introduction into the understanding and the application of early contractor involvement (ECI) in waterborne transport infrastructure projects. It is the only comprehensive guidance document available on the subject of ECI in the construction industry. It offers a practical approach to all industry practitioners to assist in the application of ECI in the waterborne transport infrastructure sector.

The report also identifies the hallmarks of successful ECI process, which have been established over many years, such as dealing with good faith, transparency and equal treatment of all parties, fairness, clarity through clear rules of engagement, confidentiality and protection of intellectual property. The stated aim of the report is to further promote and support the use of ECI in the global construction sector. It provides guidance to industry practitioners so clients, consultants and contractors in how to successfully implement ECI for the betterment of the industry as a whole.

The PIANC report states that the definition of early contractor involvement is a strategy for applying early contractor involvement in marine infrastructure procurement.

Complex construction projects that use traditional procurement practices are often impacted by significant cost overruns and delays. Early contractor involvement (ECI) is a concept that strives to involve the contractor collaboratively at an early stage of a project’s development to mitigate or otherwise eliminate those risks. In August 2022, PIANC published the report “A framework for early contractor involvement in infrastructure projects” to help industry practitioners in choosing and best implementing ECI. This article is intended to develop on key aspects of the PIANC report and look at the factors that can lead to a successful maritime ECI project.
CONTRACTS

should take into account the best practices
principles of early contractor involvement. It is important to note that while the delivery and objectives, through their purpose being to optimise values in project and optionally expanded to consultants, ECI is a strategy initiated by infrastructure owners. The common denominator identified was that countries appear to deal with ECI differently or approach to ECI. Diverse regions and that there was no single dominant concept when drafting the report, the authors noted

The traditional procurement approach invariably leads to cost and time overruns during project execution. The causes of these overruns have been studied extensively (Arcadiani, 2022 Global Construction Disputes Report, Bent Flyvbjerg and Gardner, 2023).

A detailed study by Flyvbjerg and Gardner of some 16,000 major projects from large buildings to bridges, dams, power stations, railways, roads, airports, information technology systems and even the Olympic Games, revealed a massive project management problem. Only 0.5% were completed on time and on budget, and produced the expected benefits. In other words, 99.5% of large projects failed to deliver as promised.

The highlighted events and challenges mentioned in Figure 2 are being felt post-pandemic and construction industry parties are looking to alternatives to this business as usual approach for potential projects in the Netherlands and its principles; contractual framework in and organisational aspects could be used quite easily outside a Dutch context.

Alternative project delivery using methods such as ECI is increasingly being seen as a valid alternative to ensuring a project is delivered within budget and completed on time. The diagram in Figure 2 gives a typical spread of cost overrun events and causes (Kihaly and Judd, 2022).

One of the reasons why projects fail is unforeseen physical conditions as a major cause of cost overruns. Aniso et al. (2021) found that roughly half of the cost overrun increases were caused by unforeseen physical conditions.

The high incidence of unforeseen physical conditions is a major cause of cost overruns. As per Aniso et al., physical conditions are the number one reason for cost overruns. It is found that 50% of cost overruns are caused by unforeseen physical conditions.

One established ECI model is the Bouwteam approach in the Netherlands, which is a non-competitive model in which the client has an active central role. It particularly aims at finding the right solution for the project. This non-competitive model combines the strengths of established contract models such as DBO2020 with effective organisational methodologies outlined in the manual “Handreiking Bouwteams” (Construction Handbook), resulting in a robust framework. It has been successful

innovative alternatives as there is always a threat that the tenderer could cancel and/or tender on the basis of their own alternative, not exposed to the competition.

As Jon Davies, CEO Australian Constructors Association stated in a social media post (LinkedIn, January 2023): “There is significant wastage of skilled resources through inefficient tender processes, but the bigger problem is the myopic focus on selecting the lowest price at the tender box to the detriment of all else. The practice of accepting the lowest bid at the tender box is a completely false economy and is the direct cause of the adversarial contracting environment in which we now find ourselves.”

The traditional procurement approach invariably leads to cost and time overruns during project execution. The causes of these overruns have been studied extensively (Arcadiani, 2022 Global Construction Disputes Report, Bent Flyvbjerg and Gardner, 2023).

A detailed study by Flyvbjerg and Gardner of some 16,000 major projects from large buildings to bridges, dams, power stations, railways, roads, airports, information technology systems and even the Olympic Games, revealed a massive project management problem. Only 0.5% were completed on time and on budget, and produced the expected benefits. In other words, 99.5% of large projects failed to deliver as promised.

The highlighted events and challenges mentioned in Figure 2 are being felt post-pandemic and construction industry parties are looking to alternatives to this business as usual approach for potential projects in the Netherlands and its principles; contractual framework in and organisational aspects could be used quite easily outside a Dutch context.

Alternative project delivery using methods such as ECI is increasingly being seen as a valid alternative to ensuring a project is delivered within budget and completed on time. The diagram in Figure 2 gives a typical spread of cost overrun events and causes (Kihaly and Judd, 2022).

One of the reasons why projects fail is unforeseen physical conditions as a major cause of cost overruns. Aniso et al. (2021) found that roughly half of the cost overrun increases were caused by unforeseen physical conditions.

The high incidence of unforeseen physical conditions is a major cause of cost overruns. As per Aniso et al., physical conditions are the number one reason for cost overruns. It is found that 50% of cost overruns are caused by unforeseen physical conditions.

One established ECI model is the Bouwteam approach in the Netherlands, which is a non-competitive model in which the client has an active central role. It particularly aims at finding the right solution for the project. This non-competitive model combines the strengths of established contract models such as DBO2020 with effective organisational methodologies outlined in the manual “Handreiking Bouwteams” (Construction Handbook), resulting in a robust framework. It has been successful

innovative alternatives as there is always a threat that the tenderer could cancel and/or tender on the basis of their own alternative, not exposed to the competition.

As Jon Davies, CEO Australian Constructors Association stated in a social media post (LinkedIn, January 2023): “There is significant wastage of skilled resources through inefficient tender processes, but the bigger problem is the myopic focus on selecting the lowest price at the tender box to the detriment of all else. The practice of accepting the lowest bid at the tender box is a completely false economy and is the direct cause of the adversarial contracting environment in which we now find ourselves.”

The traditional procurement approach invariably leads to cost and time overruns during project execution. The causes of these overruns have been studied extensively (Arcadiani, 2022 Global Construction Disputes Report, Bent Flyvbjerg and Gardner, 2023).

A detailed study by Flyvbjerg and Gardner of some 16,000 major projects from large buildings to bridges, dams, power stations, railways, roads, airports, information technology systems and even the Olympic Games, revealed a massive project management problem. Only 0.5% were completed on time and on budget, and produced the expected benefits. In other words, 99.5% of large projects failed to deliver as promised.

The highlighted events and challenges mentioned in Figure 2 are being felt post-pandemic and construction industry parties are looking to alternatives to this business as usual approach for potential projects in the Netherlands and its principles; contractual framework in and organisational aspects could be used quite easily outside a Dutch context.

Alternative project delivery using methods such as ECI is increasingly being seen as a valid alternative to ensuring a project is delivered within budget and completed on time. The diagram in Figure 2 gives a typical spread of cost overrun events and causes (Kihaly and Judd, 2022).

One of the reasons why projects fail is unforeseen physical conditions as a major cause of cost overruns. Aniso et al. (2021) found that roughly half of the cost overrun increases were caused by unforeseen physical conditions.

The high incidence of unforeseen physical conditions is a major cause of cost overruns. As per Aniso et al., physical conditions are the number one reason for cost overruns. It is found that 50% of cost overruns are caused by unforeseen physical conditions.

One established ECI model is the Bouwteam approach in the Netherlands, which is a non-competitive model in which the client has an active central role. It particularly aims at finding the right solution for the project. This non-competitive model combines the strengths of established contract models such as DBO2020 with effective organisational methodologies outlined in the manual “Handreiking Bouwteams” (Construction Handbook), resulting in a robust framework. It has been successful

innovative alternatives as there is always a threat that the tenderer could cancel and/or tender on the basis of their own alternative, not exposed to the competition.

As Jon Davies, CEO Australian Constructors Association stated in a social media post (LinkedIn, January 2023): “There is significant wastage of skilled resources through inefficient tender processes, but the bigger problem is the myopic focus on selecting the lowest price at the tender box to the detriment of all else. The practice of accepting the lowest bid at the tender box is a completely false economy and is the direct cause of the adversarial contracting environment in which we now find ourselves.”

The traditional procurement approach invariably leads to cost and time overruns during project execution. The causes of these overruns have been studied extensively (Arcadiani, 2022 Global Construction Disputes Report, Bent Flyvbjerg and Gardner, 2023).

A detailed study by Flyvbjerg and Gardner of some 16,000 major projects from large buildings to bridges, dams, power stations, railways, roads, airports, information technology systems and even the Olympic Games, revealed a massive project management problem. Only 0.5% were completed on time and on budget, and produced the expected benefits. In other words, 99.5% of large projects failed to deliver as promised.

The highlighted events and challenges mentioned in Figure 2 are being felt post-pandemic and construction industry parties are looking to alternatives to this business as usual approach for potential projects in the Netherlands and its principles; contractual framework in and organisational aspects could be used quite easily outside a Dutch context.

Alternative project delivery using methods such as ECI is increasingly being seen as a valid alternative to ensuring a project is delivered within budget and completed on time. The diagram in Figure 2 gives a typical spread of cost overrun events and causes (Kihaly and Judd, 2022).

One of the reasons why projects fail is unforeseen physical conditions as a major cause of cost overruns. Aniso et al. (2021) found that roughly half of the cost overrun increases were caused by unforeseen physical conditions.

The high incidence of unforeseen physical conditions is a major cause of cost overruns. As per Aniso et al., physical conditions are the number one reason for cost overruns. It is found that 50% of cost overruns are caused by unforeseen physical conditions.

One established ECI model is the Bouwteam approach in the Netherlands, which is a non-competitive model in which the client has an active central role. It particularly aims at finding the right solution for the project. This non-competitive model combines the strengths of established contract models such as DBO2020 with effective organisational methodologies outlined in the manual “Handreiking Bouwteams” (Construction Handbook), resulting in a robust framework. It has been successful

innovative alternatives as there is always a threat that the tenderer could cancel and/or tender on the basis of their own alternative, not exposed to the competition.

As Jon Davies, CEO Australian Constructors Association stated in a social media post (LinkedIn, January 2023): “There is significant wastage of skilled resources through inefficient tender processes, but the bigger problem is the myopic focus on selecting the lowest price at the tender box to the detriment of all else. The practice of accepting the lowest bid at the tender box is a completely false economy and is the direct cause of the adversarial contracting environment in which we now find ourselves.”

The traditional procurement approach invariably leads to cost and time overruns during project execution. The causes of these overruns have been studied extensively (Arcadiani, 2022 Global Construction Disputes Report, Bent Flyvbjerg and Gardner, 2023).

A detailed study by Flyvbjerg and Gardner of some 16,000 major projects from large buildings to bridges, dams, power stations, railways, roads, airports, information technology systems and even the Olympic Games, revealed a massive project management problem. Only 0.5% were completed on time and on budget, and produced the expected benefits. In other words, 99.5% of large projects failed to deliver as promised.

The highlighted events and challenges mentioned in Figure 2 are being felt post-pandemic and construction industry parties are looking to alternatives to this business as usual approach for potential projects in the Netherlands and its principles; contractual framework in and organisational aspects could be used quite easily outside a Dutch context.

Alternative project delivery using methods such as ECI is increasingly being seen as a valid alternative to ensuring a project is delivered within budget and completed on time. The diagram in Figure 2 gives a typical spread of cost overrun events and causes (Kihaly and Judd, 2022).

One of the reasons why projects fail is unforeseen physical conditions as a major cause of cost overruns. Aniso et al. (2021) found that roughly half of the cost overrun increases were caused by unforeseen physical conditions.
the PIANC report provides helpful guidance with a single bidding contractor. Having a think that ECI is solely a one-on-one process without the time and expense of going to tender can ensure that the client’s original budget can be “reality checked” by potential contractors. Budgeting and open book pricing of the soil investigation.

An ECI during preliminary soil investigations, i.e. preparation of scope, witnessing and laboratory can be very useful. The contractor can achieve best value whole-of-life solutions; Integrated teams working together to encourage and demonstrate appropriate attention to ensure value for money for the client these being:

- Competitive pricing of supplier and sub-contract components;
- A full understanding and allocation of project risks; and
- Provision for the client to terminate the contract if agreement is not reached on the Phase 2 offer.

The Queensland Department of Main Roads’ “Standard contract provisions roads, Volume 8 Early contractor involvement (ECI) Contract” identified a number of mechanisms used in the ECI process to encourage and demonstrate appropriate attention to ensure value for money for the client these being:

- Open book arrangements in Phase 1;
- Selection of competent contractors and designers who have a proven successful track record;
- The use of an independent estimator to analyse and review target costs to validate the Phase 1 outputs;
- Rates based on benchmark projects provided by the contractor;
- A working environment that encourages innovative thinking;
- Integrated teams working together to achieve best value whole-of-life solutions; and
- Competitive pricing of supplier and sub-contract components.

The testing of the ECI contractors rates and prices, and the basis of the valuation is on the premise of a reasonable price as would be derived under a competitive tender situation. The rationale is that the rates and prices identified by the ECI contractor will form the basis, either directly or indirectly, for the value of the work to be carried out as should be as market competitive as possible.

The intention of a two-phase ECI approach will normally be to maintain the competitive element in the preparation of the rates and prices, and that open book pricing forms the basis of the assessment. In this respect, the use of CIRIA may seem to be subjective as it is not the contractor’s “cost” but rather it is an assessment of the partial allowable and commercial price. It assists greatly however, in a reality check of the ECI contractors’ ‘core’ pricing.

While CIRIA deals with the dredging equipment pricing, pricing needs to be realistic. Marine infrastructure projects have become more complex and multiple disciplinary over the last decade. That complexity has led to other activities becoming just as important that total pricing of a project. Marine infrastructure projects require design and engineering procurement, environmental and sustainable situations. These activities can benefit from the use of a specialised dredging consultant who can realistically price, review estimates, prepare tender–made cost models and can also be involved in the execution stage of the project.

Claims from contractors can arise when there is uncertainty. A dedicated dredging consultant who is involved from the early stages of a project can seek to de-risk a project, avoid claims and mitigate risks through implementing ECI techniques such as open book pricing. In the event of a claim situation arising, full history and involvement in the early stages of a project can prove invaluable for good project management and dispute resolution.

Regulatory and permitting process Clients are continually facing increasing technical complexities, increasing regulatory and environmental restrictions coupled with tremendous internal and external pressures to deliver projects on time, within budget and with uncharged scopes. With marine infrastructure,
Of the international forms of contracts available, only the NEC4 for oil contract implements an Early Warning Register. This includes a description of the matter and the way in which the effects of the matter are to be avoided or reduced.

The NEC4 Early Warning Register is not for division of risk allocation but is a document to help promote risk management, after award of contract. As it only comes into existence at the award of contract it is helpful an ECI contractor can contribute to preparation of a pre-contract Early Warning Register to highlight to the client what potential risk matters the contractor perceives.

An Early Warning Register’s clear procedures also support effective risk management after contract award. Early warning identification of risks is a normal procedure at the ECI stage and the Early Warning Register is simple but effective risk management tools. Both encourage and require the ongoing assessment and management of risk throughout the period of the contract.

New frontiers: offshore wind

The past decade has seen exponential growth in the amount of offshore wind energy projects globally and with it came the creation of a new supply industry and specialised vessels to serve it.

The expansion of the number of projects continues across North Sea basins (excluding the UK) envisages a 20-fold increase in capacity. The EU member states of Denmark, Germany, Belgium and the Netherlands will create offshore energy hubs and islands, and build 300 GW of offshore wind energy by 2050 (The Energy Offshore Wind Declaration, May 2022). A tremendous increase from the present 15 GW of capacity. Offshore wind farms are multi-million euro projects and such investments require extensive and careful planning throughout the entire supply chain. Early in the planning development of this new market, offshore wind energy developers realised that they had to work hand in hand with the installation contractor to get to final investment decision (FID) and the realisation of a commercially viable project.

The sector continues to develop bigger wind turbines, with 15 MW turbines forecast to enter the market in the next decade. These larger and heavier wind turbines require stronger installation vessels and cranes. The existing installation vessels are unable to mount the required 15 MW turbines and either existing or bigger installation vessels are being built and commissioned. Innovative concepts and designs are needed to develop next generation vessels able to lift over 1,500 tonnes.

The offshore environment poses unique technical and logistical challenges that require specialised knowledge and expertise. By involving early contractors, early developers can leverage their expertise to mitigate these challenges and drive the balance of plant costs down.
Early contractor involvement in offshore wind energy construction does not just generate cost savings but it leads to better communication and collaboration, innovation and creativity, and positive relationships between all parties. This is a practice that is becoming increasingly popular and is seen as a key way to improve the supply chain risk as well as the construction process and mitigate the unique challenges that the offshore wind energy industry faces.

All these matters fit well with the application of alternative procurement techniques in the energy supply chain and indeed in the past ECI was instigated in various forms. Now with a predicted “hot” market with wind turbine manufacturers ramping up output exponentially for the years ahead there is limited availability of installation vessels. There is likely to be a worldwide installation vessel shortage, which is a risk to planned project execution and some project developments may have insufficient or in a worst-case scenario no installation asset at their disposal (I-H-Biz 2022). Early contractor involvement and vessel scheduling is therefore seen as vital.

Vessels are being booked many years in advance. Coupled with reducing the BOP as much as possible, this means that offshore wind clients are increasingly turning to work with preferred contractors and using ECI to a far greater extent as well as seeking to develop more long-term relational and collaborative contracts.

Indeed the FIDIC (The International Federation of Consulting Engineers) contracts committee are in the process of drafting a specialised contract drafted specifically to serve the offshore wind energy market. It is unclear at this stage to what extent the FIDIC contract drafters will address the clear need for a collaborative ECI process.

Establishing trust and rapport with your ECI contractor

In 1848, Johan Thorbecke (a Dutch politician) said: “Trust comes on foot, but leaves on horseback.” It is interesting to consider his words and how it succinctly describes the essence of trust and its vulnerability. Trust is a business and is not just important, it is essential.

To build trust takes time and it can be gone quickly and perhaps forever if it is violated. Trust is essential for any kind of business relationship and the need for it in a construction project is no different. Perhaps it applies to a lesser extent for a one-off relationship than for a more collaborative relationship that ECI tends to offer.

In collaborative ECI relationships, you need to be able to rely on whom your chosen partner is saying and your partner must be able to rely on you. Trust in a collaborative relationship always works both ways: it is impossible for you to trust your partner while your partner does not trust you. Without this mutual vulnerability, trust is impossible to build and can thwart a successful collaborative partnership.

Building trust takes time and requires constant positive reinforcement. Earlier in this article, open book pricing was touched upon that reinforces a willingness from the contractor to be open for critical inspection. However, from the client side, it also involves accepting that the contractor should have the ability to make a reasonable margin on the project and having a balanced risk profile. ECI contractors have valid concerns about confidentiality of such critical inspection and can feel vulnerable with complete exposure of sensitive commercial pricing information.

The commercial challenge with a client taking an ECI contractor on board on a one-to-one basis is obvious: how to ensure competitive pricing? Although nothing will completely mitigate that challenge, building openness and freedom of communication between the partners at an early stage is vital. Generally the core means to reduce that risk concern is using competitive dialogue with more contractors in the Phase I stage. This will lead to selecting the contractor with whom the client feels most comfortable.

Unlock ECI success: an ECI advisor matters

Clients who regularly undertake construction projects on a repetitive basis are likely to have built up relationships with consultants, constructors and suppliers and will often turn to them first when embarking on a new project. These relationships maybe lose or be formalised in specific ECI arrangements or framework agreements.

However, the majority of clients who are new to ECI and are considering applying it can benefit from the expertise of a consultant knowledgeable in ECI practices. What is essential is that the ECI selection process is systematic.

The role of the ECI advisor can broadly cover the following:

• Evaluate the potential for enhancing the project’s value through ECI
• Guide in the selection and setup of the most effective ECI framework, such as the contract model, regulatory compliance, selection process, ECI organisation, scope and schedule
• Assist in coaching, training, team building and running workshops with parties, intended to facilitate communication and collaboration
• Record and document the project team relationships, the commitments made by each party and their expectations in a multi-party ECI contract and
• To provide a first port of call in the event of misunderstandings or disagreements between project team members.

The precise selection process chosen by an ECI advisor may vary according to circumstances, such as the level of experience and knowledge of the client, the nature of the project and the specialisation of the ECI contractors being sought. The strongest recommendation and take-away is to have an ECI advisor that has in-depth experience and can build the best project partnering team for the client. It is unfair to skim on costs when building the ECI team. These costs represent a small part of the overall project expenditure and will directly influence how the rest of the money is spent over the whole life of the project.
CONTRACTS

It should be noted that lawyers and law firms may offer ECI consulting services, but a legal background alone may not be the most appropriate for ECI and collaborative contracting as legal training is largely based on an adversarial approach and contract enforcement. A real change in mindset is needed.

The key to making the ECI and collaborative contracting process work lies in the ECI advisor building and maintaining strong teams. A good team produces far more than the sum of the efforts of its individual parts, poor teams produce far less. Right from the outset, it is essential that team building and maintenance are in the minds of the ECI advisor who is charged with bringing the team together. Getting the team right will be at the forefront from the first steps in the ECI process.

Conclusions

Early contractor involvement comes in many shapes and sizes, and when applied properly, with joint commitment, there is a significantly positive outcome for all parties. When the process is properly managed, productive relationships are more likely and trust is a key component for a collaborative and ultimately successful project. If problems start to appear, it is better to identify any issues early and resolve them promptly to ensure the team can move forward. Trust is a key component in ECI, and sustainability and long-term success depend on the trust that can be built on early contractor involvement.

The PIANC report “A framework for early contractor involvement in infrastructure projects” provides a detailed introduction into the understanding and application of early contractor involvement (ECI) in waterborne transport infrastructure projects. It is presented together with the only comprehensive guidance document available on the subject of ECI in the construction industry.

Early contractor involvement in construction projects requires that the parties build trust through open communication, collaboration, innovation and creativity. It is seen as a key way to improve the construction process and mitigate the unique challenges of any project. Process and mitigation the unique challenges of any project. Process and mitigation the unique challenges of any project.

Summary

The PIANC report “A framework for early contractor involvement in infrastructure projects” provides a detailed introduction into the understanding and application of early contractor involvement (ECI) in waterborne transport infrastructure projects. It is presented together with the only comprehensive guidance document available on the subject of ECI in the construction industry.

Early contractor involvement in construction projects requires that the parties build trust through open communication, collaboration, innovation and creativity. It is seen as a key way to improve the construction process and mitigate the unique challenges of any project.

Early contractor involvement in construction projects requires that the parties build trust through open communication, collaboration, innovation and creativity. It is seen as a key way to improve the construction process and mitigate the unique challenges of any project.
Numerical models are often used to predict the magnitude and behaviour of dredge plumes to help assess and manage any environmental risks. To provide a realistic prediction of plumes resulting from dredging, numerical models require information on the rate at which sediment is suspended by the dredging, along with the characteristics of the suspended sediment. Previous investigations have shown that in the marine environment, fine-grained sediment suspended by natural processes and dredge-related activities are typically present as aggregated particles known as flocs. This article considers the importance of including the process of flocculation in dredge plume models.

**THE IMPORTANCE OF FLOCCULATION IN DREDGE PLUME MODELLING**

Field measurements have shown that in the marine environment, fine-grained sediment that is naturally in suspension and fine-grained sediment suspended by dredging are typically present as aggregated particles known as flocs (Manning, 2004; Smith and Friedrichs, 2011; Beecroft et al., 2019). The process of flocculation in marine environments is most likely to occur due to particle collisions from turbulent motions, meaning that increased flocculation occurs when suspended sediment concentrations (SSCs) are higher and moderate turbulence is present (Winterwerp and van Kesteren, 2004). Therefore, the localised elevated SSC and increased turbulence that can occur during dredging has the potential to result in flocculation. However, aspects of dredging that result in very high turbulence such as pumping sediment through pipelines have the potential to break up existing flocs or individual particles.

Measured data collected in the Port of Gladstone have shown that flocs were present in a plume generated by a trailing suction hopper dredger (TSHD) dredging silt and clay-sized sediment but that they were smaller than the flocs naturally in suspension (Symonds et al., 2022). This indicates that the turbulence caused by the TSHD did not break up all the flocs present in the dredge sediment, but it did reduce the size of the flocs resulting in the larger flocs >100 microns (μm) being broken up. However, the size of the flocs in the dredge plume were found to increase over time after the plume was generated, demonstrating that ongoing flocculation occurred within the dredge plume. The ongoing flocculation is likely to have been due to flocculation with both sediment suspended by the dredging as well as sediment that is naturally in suspension. These findings indicate that flocculation is an important process that influences how dredge plumes behave.
ENVIRONMENT

interactions between dredged and natural suspended sediment could also influence both the behaviour of dredge plumes and of natural suspended sediment.

Port of Gladstone

The Port of Gladstone (the Port) is located within Port Curtis on the east coast of Queensland in Australia (Figure 1). Port Curtis is a macro-tidal embayment with a mean spring tidal range of 3.2 metres. It is a naturally turbid environment and the sediment transport processes are influenced by strong tidal flows, local wind waves and local river discharges. The Port waters cover Port Curtis and the areas offshore extending to the ports limits as shown in Figure 1.

The Port is made up of approximately 55 kilometres (km) of shipping channels, which utilise the natural deeper channels in Port Curtis and offshore wherever possible. Despite this ongoing natural sediment accumulation within sections of the shipping channels and annual maintenance dredging is required to maintain depth in these sections. The annual maintenance dredging is undertaken by a TSHD, which dredges sediment from the channels and places it in an approved offshore placement site (East Banks Sea Disposal Site (EBSDS)).

The highest sedimentation rates occur at the north-western end of the Port, including Jacobs Channel with the deployed sediment predominantly made up of fine-grained silt and clay (Figure 1). The average natural SSC in the Jacobs Channel region is 14 milligrams per litre (mg/l), with the 99th percentile reaching 64 mg/l.

Approach

A suite of coupled hydrodynamic, spectral wave and sediment transport numerical models were applied to ensure all key processes that influence the transport of natural sediment and sediment suspended by dredging and placement were represented. The modelling was undertaken using MIKE software, which has been develop by the Danish Hydraulics Institute (DHI) and is one of a number of internationally recognised state-of-the-art software packages.

The sediment transport modelling was undertaken using the MudTransport (MT) module, which is able to describe the erosion, transport and deposition of mud, silt and clay-sized particles or sand and mud mixtures due to currents and waves. The model can be adopted for sediment transport studies in estuaries and coastal areas, dredging investigations and sedimentation studies, and can represent the process of flocculation.

The spatial discretisation of MIKE's flexible mesh enabled the model mesh resolution to be varied within the model domain, with higher resolution in areas of interest, such as within the Port waters and channels and lower resolution in offshore areas. This approach assists with optimising the model simulation times whilst compromising on representing important physical processes within areas of interest. The model extent covered an area of approximately 180 km by 80 km and the resolution of the triangular elements varied from around 2 km in the offshore area to less than 100 metres in the Port channels (Figure 2).

Outputs from the hydrodynamic, spectral wave and sediment transport models were compared to in-situ measured data as part of the model calibration and validation process. The calibration and validation demonstrated that the models were able to provide a good representation of the natural hydrodynamic, wave and sediment transport conditions in the region. Example plots comparing the measured and modelled SSC at sites close to Jacobs Channel and the north entrance to Port Curtis are shown in Figure 3.

The different model setups adopted to represent the natural sediment transport, the dredging related sediment transport and the combined natural and dredging sediment transport were as follows:

- Natural sediment transport: the model was set up with a realistically varying thickness of natural sediment on the seabed at the start of the simulation (defined as part of the model calibration process), with no sediment in suspension at the start of the simulation and with no suspended sediment input at the boundaries.

- Dredging sediment transport: the model was set up to represent the sediment transport of the excess sediment suspended by maintenance dredging using TSHD in Jacobs Channel and the subsequent placement of dredged sediment at EBSDS. The source terms for the mass of suspended sediment released by the dredging activity and placement were determined based on comparison with measured data in combination with information from the literature (Becker et al., 2015). The model did not include any natural sediment on the seabed in suspension, with the only sediment present in the model being the excess sediment suspended by the dredging activity and placement was assumed to stop over the model simulation period.

- Natural plus dredging sediment transport: the model was set up to represent the natural sediment transport, the dredging related sediment transport and the combined natural and dredging sediment transport: the model was set up to represent the natural sediment transport, the dredging related sediment transport and the combined natural and dredging sediment transport scenario for potential plume intensities and to help understand the relative importance of interactions between the natural and dredged sediments. The model was set up to include both the natural sediment and the sediment suspended by dredging: in single simulation. Three different particle sizes were used to represent the natural sediment transported in suspension: clay fine to medium silt and medium to coarse silt. Model simulations were set up with and without flocculation of the fine-grained sediment included.

When flocculation was included, a constant setting velocity representative of the individual particle size was adopted for each and when flocculation was included, the setting velocity varied depending on the SSC, with the minimum setting velocity being representative of the individual particles. For all the simulations that included flocculation, the process of flocculation was assumed to occur when the SSC was above 10 mg/l. For the plume simulations, a single particle size of fine silt was adopted as this was representative of the model peak in the particle size distribution (PSD) for sediment suspended by the dredging based on measured data. For the dredge plume simulations, the fine silt setting velocity without flocculation included was representative of the individual fine silt particles and the with flocculation simulations were representative of the minimum size of the measured in-situ flocs (30 μm, with the peak in measured flocs in the plume being between 30 and 200 μm).

FIGURE 1

Location map showing the Port of Gladstone and its location relative to Australia (inset).

FIGURE 2

Modelled and measured SSC at WB50 and MH10 (see Figure 1 for locations).

FIGURE 3

Modelled and measured SSC at WB50 and MH10 (see Figure 1 for locations).
The minimum setting velocity for the dredge plume when modelled with flocculation included was seen to represent a small floc rather than the individual particle size. This is because the spatial resolution of the model mesh results in an instantaneous dilution of the plume from the dredger which will limit flocculation. As the measured data have shown that the majority of the sediment in suspension in the dredge plume close to the dredger is present as flocs, this approach was considered to provide the most accurate conceptualisation of the sediment in the dredge plume.

Results

Influence of flocculation

The modelled natural SSC in Port waters was processed to calculate the SSC percentiles over the 5-week model simulation period. The 50th percentile values by which the SSC was below for a given percentile of time over the entire model simulation period. The 50th percentile SSC at some areas where higher SSC occurs. With flocculation included, the 50th percentile SSC within Port Curtis was predominantly less than 40 mg/l, while without flocculation included at Port Curtis had an SSC of more than 40 mg/l. The spatial extent of the SSC with higher concentrations within Port Curtis and lower concentrations offshore highlights how Port Curtis is a semi-enclosed bay, which acts as a natural sink of sediment. The measured SSC data shown in Figure 3 shows that the SSC at WB50 (within Port Curtis) remains below 40 mg/l for the majority of the time, indicating that the model results with flocculation included provide a better representation of the actual conditions.

Spatial plots of the SSC due to the modelled maintenance dredging by a TSHD and without flocculation included in the model are shown in Figure 4. Comparison between the with and without flocculation plots shows that the majority of the sediment is often modelled in separate locations. As shown in Figure 5, the model results with flocculation included show that the SSC of more than 5 mg/l extends from Jacobs Channel to the southern entrance to Port Curtis. It also shows that a higher concentration plume of more than 15 mg/l occurs within Jacobs Channel, but remains confined within the channel. The results predict a localised low concentration plume at and adjacent to EBSDS with a peak in SSC of just over 10 mg/l but concentrations of generally less than 5 mg/l.

Figure 4. Comparison between the with and without flocculation in Figure 5. The modelled natural SSC in Port waters was less than 40 mg/l for the majority of the time, indicating that the model results with flocculation included provide a better representation of the actual conditions.

The results without flocculation included show a significantly larger area with higher concentrations of above 15 mg/l, extending from the north of Jacobs Channel to the southern entrance of Port Curtis. The results also show an SSC of up to 10 mg/l being exported through the north-eastern entrance to Port Curtis. The plume around EBSDS is also larger without flocculation than it was with flocculation, with an SSC of up to 5 mg/l extending from EBSDS to the eastern shoreline of the adjacent Facing Island. The results without flocculation included show a significantly larger area with higher concentrations of above 15 mg/l, extending from Jacobs Channel to the southern entrance of Port Curtis. The results also show an SSC of up to 10 mg/l being exported through the north-eastern entrance to Port Curtis. The plume around EBSDS is also larger without flocculation than it was with flocculation, with an SSC of up to 5 mg/l extending from EBSDS to the eastern shoreline of the adjacent Facing Island.

Time series plots of the water level and natural SSC with and without flocculation included at the water quality monitoring site WB50 (see Figure 1 for location) are shown in Figure 6. The results show that the natural SSC is controlled by the tidal range, with higher SSC during spring tides and lower SSC during neap tides. The modelled natural SSC is predicted to be five to ten times higher at WB50 when flocculation included compared to when it is excluded.

Time series results at WB50 for the excess SSC from maintenance dredging using a TSHD in Jacobs Channel are shown in Figure 6. The results show that the predicted SSC in the plume from the maintenance dredging is up to five times higher without flocculation compared to with flocculation.

To help understand the fate of sediment released by the dredging and how flocculation influences it, the spatial distribution of sediment thickness at the end of the model simulations is shown for both with and without flocculation in Figure 7. Both the with and without flocculation results generally show a similar spatial pattern, but sedimentation depths are generally higher when flocculation was included. Without flocculation, the results show the potential for increased sedimentation in the most quiescent locations, such as the sheltered creeks and intertidal areas upstream of Jacobs Channel. With flocculation included, the sedimentation depths at EBSDS are predicted to be up to 10 mm, while without flocculation they remain below 5 mm. This is more than an order of magnitude difference and suggests that flocculation could be a very important process for the settling of sediment. The results with and without flocculation included are shown in Figure 6. The results show that the predicted SSC in the plume from the maintenance dredging is up to five times higher without flocculation compared to with flocculation.

Influence of natural sediment

Natural SSC is sometimes modelled as well as excess SSC from dredging to allow any potential impacts from the dredging to be related to the natural conditions. However, they are often modelled in separate locations.
The model simulation has the potential to overestimate the ongoing transport and ultimate fate of the sediment. There are two reasons for this:

1. The SSC controls the flocculation that can occur with floe size increasing as the SSC increases. Therefore, when the natural SSC is included in the model, as well as the excess SSC from dredging, it will allow the sediment released by the dredging to mix with the natural sediment as well. This increases the total SSC and allows larger flocs to form that have a higher settling velocity. And
2. When the sediment suspended by dredging is deposited, it is likely that natural sediment will also be deposited and the two sediments will mix in the surface layer on the seabed with the potential for some particles to be buried under other natural or dredged sediment. When the deposited sediment is subsequently re-suspended, some of the re-suspended sediment will be the recently deposited natural sediment and some will be the recently deposited dredged sediment. As a result, the total mass of re-suspended sediment re-suspended will be lower compared to when natural sediment was not included in the model. Similarly, the total mass of natural sediment re-suspended in areas where re-suspended sediment was deposited will be slightly lower compared to when the excess dredged sediment was not included in the model.

To assess the relative influence of the natural sediment on the SSC and fate of sediment suspended by maintenance dredging in Port waters, the numerical model was set up to simulate both natural sediment transport and the transport of sediment suspended by dredging together in the same simulation. The modelled 95th percentile excess SSC from the TSHD under varying maintenance dredging in Jacobs Channel and placement at EBSDS without flocculation, with flocculation and with flocculation and natural sediment transport included are shown in Figure 8.

Comparison between the results with flocculation and the results with flocculation and natural sediment transport show that including natural sediment transport in the model results in a significant reduction in the plume extent and SSC within Port waters but does not result in such a significant change around EBSDS (where Figure 4 shows the natural SSC is much lower than within Port waters). The extent of the higher concentration area of plume above 15 mg/l in Jacobs Channel is reduced by around 30% when natural sediment transport is also included. In addition, the extent where the SSC is between 1 and 15 mg/l for the 95th percentile is significantly reduced when natural sediment transport is also included in the model.

The reduction in SSC from the maintenance dredging by a TSHD in Jacobs Channel at WB50 due to the inclusion of natural sediment transport in the model is shown in Figure 9. The plot shows that the SSC is reduced by between two and five times depending on the tidal range due to the inclusion of natural sediment transport (up to five times during spring tides and around two times during small neap tides).

The relative influence of including the natural sediment released by the maintenance dredging at Jacobs Channel by a TSHD on the natural SSC at WB50 is shown in Figure 11. The plot shows that there is predicted to be a reduction in the natural SSC at WB50 of up to 2 mg/l when the maintenance dredging and the maintenance dredging at Jacobs Channel are included are shown in Figure 10. The plot shows that the natural SSC is similar between the two simulations, except that the extent of the 40 to 50 mg/l contour is reduced within Jacobs Channel and in the adjacent Clinton Channel when maintenance dredging is included.
drifting sediments are included in the model simulation compared to just natural sediment transport. For the simulation with both natural and dredged sediment when the excess SSC due to maintenance dredging is added to the natural SSC, the resultant total SSC at WB50 is almost identical to the natural SSC when the model excludes maintenance dredging.

The rate of erosion is correlated to the seabed properties and bed shear stresses from local currents and waves. In Port waters, erosion generally only occurs over a significantly shorter period, typically the 2-3 hours when peak flood and ebb currents occur. This means that a limited amount of sediment can be resuspended during each flood and ebb stage of the tide. As a result, the mass of sediment that can be resuspended and dredged sediment that can be resuspended, could be added for each of the two sediment types compared to when the bed sediment was just a single type. This could occur when the mass of recently deposited natural and dredged sediment on the seabed exceeds the total mass that can be resuspended during a single flood or ebb stage of the tide. This will be more significant in a natural sediment sink such as the Port waters where widespread natural deposition occurs. In addition, the SSC close to the dredger will be higher when the SSC released by dredging is included compared to just the natural SSC; there will be increased flocculation of both the natural and dredged sediments, which can result in larger flocs forming. These larger flocs will result in a slight increase in sedimentation of both the natural and dredged sediment, and therefore a slight reduction in SSC for both.

The potential long-term fate of both naturally suspended fine-grained sediment and sediment suspended by dredging is important to understand. The results from the numerical modelling have been compared to just the natural sediment transport and the combined mass of natural and dredged sediment under different conditions (flocculation included and dredged natural sediment modelled together), the modelling predicted that the total combined mass of natural and dredged sediment exported from Port Curtis was approximately 3 times larger if no flocculation occurred. When flocculation was included in the model, approximately 3% of the sediment suspended by dredging was predicted to be exported from Port Curtis, but if flocculation was not included this value increased to 11%.

When both flocculation and natural sediment transport were included in the model, the mass of sediment suspended by the TSHD predicted to be exported from Port Curtis was almost an order of magnitude lower than with just resuspension (see Figure 13), with 0.3% of the sediment released within Port Curtis by the maintenance dredging predicted to be exported from Port Curtis. These results therefore indicate that the fate of the majority of the sediment suspended by the maintenance dredging activity (>95%) is to be deposited within Port Curtis, with very little sediment predicted to be exported from the embayment.

As previously noted, the inclusion of dredged sediment along with natural sediment also has the potential to result in increased flocculation (and therefore deposition) as well as a small reduction in the resuspension of natural sediment. Flocculation occurred. When flocculation was included in the model, approximately 3% of the sediment suspended by dredging was predicted to be exported from Port Curtis, but if flocculation was not included this value increased to 11%.

When both flocculation and natural sediment transport were included in the model, the mass of sediment suspended by the TSHD predicted to be exported from Port Curtis was almost an order of magnitude lower than with just flocculation (see Figure 13), with 0.3% of the sediment released within Port Curtis by the maintenance dredging predicted to be exported from Port Curtis. These results therefore indicate that the fate of the majority of the sediment suspended by the maintenance dredging activity (>95%) is to be deposited within Port Curtis, with very little sediment predicted to be exported from the embayment.

As previously noted, the inclusion of dredged sediment along with natural sediment also has the potential to result in increased flocculation (and therefore deposition) as well as a small reduction in the resuspension of natural sediment. Flocculation occurred. When flocculation was included in the model, approximately 3% of the sediment suspended by dredging was predicted to be exported from Port Curtis, but if flocculation was not included this value increased to 11%.

When both flocculation and natural sediment transport were included in the model, the mass of sediment suspended by the TSHD predicted to be exported from Port Curtis was almost an order of magnitude lower than with just flocculation (see Figure 13), with 0.3% of the sediment released within Port Curtis by the maintenance dredging predicted to be exported from Port Curtis. These results therefore indicate that the fate of the majority of the sediment suspended by the maintenance dredging activity (>95%) is to be deposited within Port Curtis, with very little sediment predicted to be exported from the embayment.

Conclusions

Numerical modelling has been undertaken to determine how important the process of flocculation is in Port waters for both natural and dredging-related sediment transport. The modelling predicted that the natural SSC of sediment released by the maintenance dredging predicted to be exported. Therefore, for the scenario considered to be most representative of actual conditions (flocculation included and dredged and natural sediment modelled together), the modelling predicted that the total combined mass of natural and dredged sediment predicted to be exported when just natural sediment transport was modelled on its own.

The mass of both naturally and dredged suspended sediment exported from Port Curtis would be approximately three times larger if no flocculation occurred.
would be five to ten times higher if flocculation did not occur, and if the SSC of plumes resulting from annual maintenance dredging could also be increased by up to five times if flocculation did not occur. In addition, the modelling results predicted that the process of flocculation reduces the mass of fine-grained sediment suspended by maintenance dredging that is exported from Port Curtis by a factor of four.

The modelling showed that when natural sediment transport is included in the same simulation as excess SSC from dredging, there is another reduction in both the predicted SSC due to dredging and the mass of dredged sediment exported from Port Curtis. This is because an increase in flocculation due to the higher combined SSC results in a reduction of natural SSC from Port Curtis being suspended and therefore the sediment deposited on the seabed is a combination of natural and dredged sediment. Therefore, when natural sediment transport is included as well as dredged sediment, the eroded sediment will be a combination of natural and dredged sediment, while when natural sediment transport is excluded the sediment will be entirely composed of dredged sediment. As a result, areas where both natural and dredged sediment are deposited are the amount of dredged sediment resuspended will be lower when natural sediment transport is also included.

The modelling results also predicted that due to increased flocculation of natural sediment close to the dredger and some dredged sediment being resuspended rather than natural sediment, there was a small reduction in the natural SSC in some areas when dredging was also included in the model at the same time. This reduction in SSC was also similar to the reduction in SSC from where natural sediment from Port Curtis was also included in the model at the same time. This reduction in SSC was also similar to the reduction in SSC from natural and dredged sediment exported from Port Curtis. The total combined mass of natural and dredged sediment predicted to be exported when natural sediment transport is also included.

Summary
Sediment can be suspended into the water column during dredging and placement activities. This suspended sediment has the potential to be transported away from the dredge and placement locations by currents and therefore could result in environmental impacts. Previous investigations have shown that in the marine environment, fine-grained sediment suspended naturally and by dredging are typically present as aggregated particles known as flocs. To reliably represent the behaviour of dredged sediment in a numerical model and predict potential environmental impacts it may be necessary to include the process of flocculation in the model.

This article presents results from numerical modelling of maintenance dredging in the Port of Gladstone, on the east coast of Queensland in Australia, to assess the importance of flocculation. The model was set up to simulate sediment transport with and without flocculation for natural sediment and sediment suspended by maintenance dredging. The importance of interactions between the dredged suspended sediment and natural suspended sediment on flocculation was also investigated.

The results from the study highlight the importance of including flocculation in numerical modelling related to dredging fine-grained sediment in marine environments. Without the inclusion of flocculation, the modelling has shown that the SSC in the dredge plume can be overestimated up to five-fold compared to observations. The results also showed that modelling the sediment suspended by dredging without including natural/suspended sediment can result in a significant overestimation of ongoing resuspension of the dredged sediment and therefore an overestimate of the transport rates, as well as the distance the dredged sediment is transported.
Steel and concrete are the most common materials used in quay wall structures. The application of these materials contributes to a high emission of greenhouse gases such as CO2 and the materials make up a large part of the construction costs. This graduate research examines whether alternative quay wall structures have the potential to be more cost effective and more sustainable compared to conventional structures for inland ports. An innovative quay wall of reinforced soil was designed and quay elements implemented to make a quay wall structure. A comparison was then made based on the criteria costs and sustainability between the innovative quay design and two conventional quays.

REINFORCED SOIL - THE QUAY WALL STRUCTURE FOR THE FUTURE?

For their thesis, the authors conducted research on more sustainable and cost-effective quay wall structures for inland ports in the Netherlands. There is still a demand for new inland ports that can fulfill a function as a connecting link in the Dutch inland waterway network. Moreover, most of the current quay walls were constructed shortly after the Second World War. These outdated quays may have reached their technical life span and safety limits due to increased loads over the years, and a large replacement programme must be executed in the next decades.

Expectations for the future must be considered prior to the design. By anticipating increasing loads, rising water levels and long-term trends will create a future-proof quay that is able to retain its functionality over a longer period. Due to the growing demand of today’s consumer society, a trend is happening in the transshipment of containers. The rising number of transported containers results in a need for extra transshipment ports that require heavier port equipment and bigger storage loads.

As previously mentioned, the most common materials applied in current quay walls are steel and concrete. The use of these materials results in both high emissions and high investment costs. However, the ongoing climate changes and rising material prices create a growing necessity for sustainable and more cost-effective quay wall structures. After promising results and having been successfully applied in different civil engineering disciplines, it is interesting to investigate the possibilities of reinforced soil structures within hydraulic engineering.

Quay elements
A reinforced soil structure is a well-known construction method with which height
Conventional quay wall structures allow equipment, ships and water level fluctuations. Unfavourable loads caused by heavy port adjustments and implementations to reinforced soil structure as a quay requires differences can be reached. Using a reinforced soil structure, the least amount of concrete and the most favourable load transfer. A vessel classified in the Flevokust haven, located near Lelystad, in the Netherlands. The main reason for choosing the Flevokust haven as case location is due to its representative characteristics for inland ports with detention costs. The soil consists of non-loadbearing soil types, there are limited water level fluctuations and this inland port is accessible to a representative number of vessels. In addition, this port is used as a container terminal that causes large surface loads, which is also representative for other inland ports due to a trend in the transshipment of containers. The three different quay wall structures are designed with a total retaining height of 9.25 metres. In case of any settlement, an extra height can be added to maintain the total retaining height. The topside of the constructions must be at a level of 2.45 metres + N.A.P. With the current water level of 0.5 metres - N.A.P, there is 2.95 metres above the water surface. The remaining 6.3 metres of the retaining height is below the water surface. This water depth provides the accessibility to vessels classified to CEMT-VA/Vb. The design of containers requires heavy port equipment and storage of the containers resulting in high surface loads that effect the quay. In this study, the Flevokust haven was used as a case study to compare the performance of three designs that effect the quay wall. Figure 2 includes all the quay wall structures that was used for the comparison with the innovative quay wall. The design is the basis for the bill of quantities with which the material costs can be estimated. General rules are used for the dimensions and proportions of the wall. The dimensions of the design are as shown in Figure 3.

After designing the construction, all forces on the wall are determined. This is necessary in order to calculate the moments of force including safety factors. Checking the design on geotechnical failure mechanisms according to the Dutch guideline for geotechnical designs, the KIVI-reader provides the following calculations: tilt stability, vertical loadbearing capacity (drained and undrained situation) and horizontal sliding of the structure.
Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.

Uniaxial geogrids such as HDPE reinforcement can carry high tensile loads applied in one direction.
The global circular failure mechanism as a final check showed to be normative in determining the geogrid lengths, resulting in a 15-metre-long reinforcement.

The construction consists of 17 layers of soil, each 0.6 metres high; two layers for the embankment deck and 15 for the required retaining height, including settlement compensation. Settlement calculations showed that a settlement of 0.72 metres occurs, resulting in an extra layer of reinforced soil of 0.8 metres to meet the settlement requirement.

The construction of a reinforced soil structure in this case is as follows: A construction pit of temporary sheet piles with a strut frame makes it possible to excavate approximately 3 metres of the soil and lower the water level. Then the reinforced soil structure can be built layer-by-layer. A steel mesh formwork is repeatedly applied followed by rolling out and extracting geogrids and geotextile, and applying and compacting the backfill material. Finally, the geogrids and geotextile are folded back to close the backfill material.

The costs for all three designs is the concrete, steel, and reinforced soil structure can be divided into two categories: construction costs and material costs. Focusing on the material costs, the limited use of steel with the reinforced soil structure results in a solution with the lowest material costs (total material costs 1953,000 EUR) in the case of both the conventional structures, only the costs of steel are more expensive (cantilever wall 1,971,000 EUR and sheet pile wall 2,010,000 EUR) than the total material costs of the reinforced soil structure. For each construction, the backfill material costs are approximately 1 million EUR.

Compared to the material costs, the construction costs are somewhat different. The respective high-construction costs of the cantilever (1,720,000 EUR) and reinforced soil structures (1,006,000 EUR) are caused by using temporary sheet piles to create a construction pit. Therefore, the sheet pile wall is a less labour-intensive construction method resulting in lower construction costs.

Nevertheless, the total investment cost of the geogrid reinforced soil structure is still significantly lower than the total investment costs of either conventional structures. The material and construction costs show that the total investment cost for the soil structure is approximately 3.1 million EUR compared to 5.9 million EUR and 4.1 million EUR for the cantilever wall and sheet pile wall respectively.

Environmental effects

During the total life cycle of a project, for each material or construction process it is possible to determine the societal cost to compensate the environmental effects. Using the Environmental Cost Indicator (ECI), the impacts can be determined by multiplying the quantified emissions of a material or process per functional unit with the total amount. The outcome of this calculation is for each material or process an environmental impact expressed in euros. It is important to note that all materials are calculated with a life span of 100 years.

The ECI can be divided into different system phases or impact categories. The dying out by lifecycle phase is shown in Figure 8. The production phase of the materials has the highest contribution to the total ECI. Sand mining and transportation is for all three constructions the main cause of this high ECI. This is due to the relatively high density and the large volumes of sand used and the large number of transport movements required. Both conventional structures further increase these ECIs within this phase due to the large amount of steel. During the production of steel, a vast amount of heat is necessary to deform the material which in turn effects the Global Warming Potential (GWP).

The environmental impact during construction is almost equal to each other. The three structures include almost the same amount of sand. Processing the sand has in all cases the highest impact and effects the Global Warming Potential (GWP), Acidification (AP) and Human Toxicity (HT) the most.

The last phase assesses to what extent the materials can be reused or recycled for the next production system. Sand and concrete can easily be reused or recycled. Sands are an extremely circular product and mining of new sand can be avoided by reusing the product. Meanwhile, according to the Dutch National Environmental Database, 45% of steel in the sheet pile wall is lost during its lifetime due to corrosion. This negative fund is taken into account by reproducing the lost steel. The environmental costs of reproducing the corroded steel do not outweigh the positive funds of reusing sand.

The construction processes other than the application of the materials, such as excavating the soil, water extraction and the temporary sheet piles cover around 60,000 EUR for the cantilever wall and the reinforced soil structure in case of the sheet pile wall these costs are only 26,000 EUR for not applying temporary sheet piles.

Instead of using concrete and steel as main materials, the retaining function of the reinforced soil structure is derived from the use of polymers. However, low steel and concrete, polymers also have major environmental impact. High density polyethylene (HDPE) and polyethylene (PE) – the polymers that are used – are mainly obtained from petroleum, yet the reinforced soil structure has significantly lower environmental costs. The low ECI of these polymers originates in the very limited volume that is used in thin layers of stretched HDPE collectively having a low volume.

The environmental effects can also be expressed in 13 impact categories as shown in Figure 9. Global Warming Potential (GWP), Human Toxicity (HT) and Acidification (AP) are the most notable categories indicated in shades of blue. GWP is caused by greenhouse gasses, such as CO2, methane and nitrous oxide. This category is expressed in an equivalent with CO2 as reference. Greenhouse gases hold warmth that results in a (faster) rising temperature on earth. Human toxicity includes the emissions of toxic substances that are exposed to human beings. This exposure finds its way in products like meat and fish. Acidification arises after releasing sulphur oxides. The acidification of soil and water has a negative influence on ecosystems.

The study showed it is technically feasible to design a reinforced soil structure quay.

The material costs of the reinforced soil structure are considerably lower compared to both the cantilever wall and the sheet pile wall quays. The combined material and construction costs are 25% lower than the most favourable quay wall structure. The same is true for the environmental costs; which are 35% cheaper with the reinforced soil structure.
Summary

Nowadays, most inland quay walls mainly consist of concrete or steel materials. As a result of ongoing climate change and rising costs of materials, an investigation into more sustainable and more cost-effective structures for inland quay walls has been carried out. Various innovative quay wall structures have been designed after which a Multi Criteria Analysis (MCA) concluded that a reinforced soil structure has the highest overall value for implementation as an inland quay wall. Various solutions to implement quay elements such as bollards were necessary to use a reinforced soil structure as a quay. Designing three quay wall structures under equal circumstances, including the innovative quay and two reference quays of steel and concrete, made it possible to compare the criteria costs and sustainability. By calculating the material and construction costs, a cost estimation could be made. Determining the environmental effects on so-called impact categories was completed using a Life Cycle Analysis (LCA). The result is that a reduction of 25% on investment costs and reduction of 35% on the environmental cost indicator is achievable with a reinforced soil structure.

References

CUR Centre for Civil Engineering (2013) Handboek van Quay Walls. Taylor & Francis Ltd.
Dutch Environmental Database (2022) https://milieudatabase.nl/database/nationalemilieudatabase/

Berend Schmidt

Berend graduated in 2022 with a degree in Civil Engineering from Windesheim University in the Netherlands. Throughout his studies, his interest in hydraulic engineering and future-proof solutions has grown. Berend’s internship at Arcadis gave him insight into the world of port and waterfront designs. These experiences provided him with a better knowledge about these topics during his thesis on innovative quay wall structures. Berend’s joint research was awarded the Waterbouwprijs for best hydraulic engineering graduation research of 2022 in the Netherlands.

Lars van Rouwendaal

In 2018, at the age of 16, Lars started the civil engineering programme at Windesheim University, in the Netherlands. The lessons in hydraulic engineering and internships working on both the Afsluitdijk and IJburg projects further inspired his interest in hydraulic engineering and specifically in the offshore wind industry and land reclamation and port development. In November 2022, together with Berend, Lars’ graduation thesis on innovative quay wall structures was awarded the Waterbouwprijs.
Dredging for Sustainable Infrastructure Course
20-22 June 2023
Beveren, Belgium

How to achieve dredging projects that fulfill primary functional requirements, while adding value to the natural and socio-economic systems. This is just one of the questions addressed during the 3-day course that is based on the philosophy of the book, ‘Dredging for Sustainable Infrastructure’.

Experienced lecturers will describe the latest thinking and approaches, explain methodologies and techniques, and demonstrate through engaging workshops and case studies, how to implement the information in practice.

During the course, participants will learn how to implement the sustainability principles into dredging project practice, through answers to the following questions:
• What is the role of dredging in the global drive towards more sustainable development?
• How can water infrastructure be designed and implemented in a more sustainable and resilient way?
• How can the potential positive effects of infrastructure development be assessed and stimulated as well as compared with potential negative effects?
• What equipment and which sediment management options are available today?

A brief introduction to the question, ‘What knowledge and tools are available to make sound choices and control a project?’


Dredging and Reclamation Seminar
3-7 July 2023
IHE Delft Institute for Water Education
Delft, The Netherlands

About the seminar
Since 1993, the IADC has regularly held a week-long seminar developed especially for professionals in dredging-related industries. These intensive courses have been successfully presented in the Netherlands, Singapore, Dubai, Argentina, Abu Dhabi, Bahrain and Brazil. With these seminars, IADC reflects its commitment to education and urging young people to enter the field of dredging and improving knowledge about dredging throughout the world.

For whom
The seminar has been developed for both technical and non-technical professionals in dredging-related industries. From students and newcomers in the field to those in involved in higher lever consultancy, advisors as port and harbour authorities, offshore companies and other organisations that carry out dredging projects. Attendees will gain a wealth of knowledge and professional expertise are available to make sound choices and control a project.

For more information and how to register please visit https://bit.ly/IADC-events.

IADC Safety Awards 2023
Two safety awards will be presented in 2023. One to a dredging organisation and one to a supplier of goods and services.

Practical experience is priceless and it sets aside this seminar from all others. There will be a site visit to a dredging yard or a dredging project of an IADC member to allow participants to view and experience dredging equipment first-hand to gain better insights into the multi-faceted field of dredging operations.

Networking
Networking is invaluable. A dinner, where participants, lecturers and other dredging employees can interact, network, and discuss the real hands-on world of dredging provides another dimension to this stimulating week.

ENERGY EFFICIENCY CONSIDERATIONS FOR DREDGING PROJECTS AND EQUIPMENT

The information paper by CEDA’s Working Group on Energy Efficiency (WGEE) aims at raising awareness and supporting informed decision-making by members. The paper promotes sustainable and cost-effective measures in support of energy efficiency.

The quest to improve the energy efficiency of dredging projects and equipment has been a constant goal within the industry, particularly as fuel prices rise and the IMO’s greenhouse gas emissions strategy comes under revision this year.

Through the exploration of concepts, such as the life cycle of infrastructure projects, alternative fuels and technical improvements, the paper determines that for energy efficiency to be sustainable, it needs to factor in both environmental practices and the economy. This creates a business case for owner of dredging equipment to be early adopters of new technologies for their fleet to keep pace with market trends.

The paper is divided into five sections. Section 1 defines the drivers behind the quest for energy efficiency and benchmarks the CO2 emissions of the dredging industry. Section 2 summarises actual global, interregional and national policies, and Section 3 considers legislation with a focus on Greenhouse Gas (GHG) emissions. Section 4 with a focus on the topic from the perspective of a dredging business and the economy. This creates a business case for owner of dredging equipment to be early adopters of new technologies for their fleet to keep pace with market trends.

The paper is divided into five sections. Section 1 defines the drivers behind the quest for energy efficiency and benchmarks the CO2 emissions of the dredging industry. Section 2 summarises actual global, interregional and national policies, and Section 3 considers legislation with a focus on Greenhouse Gas (GHG) emissions. Section 4 with a focus on the topic from the perspective of a dredging business and the economy. This creates a business case for owner of dredging equipment to be early adopters of new technologies for their fleet to keep pace with market trends.

The authors argue that investing in new technology to improve energy efficiency can help reduce efficiencies with operational procedures, ensure regulatory compliance and reduce operational costs by using less fuel. Thus, dredging companies managing these investments will see benefits to their business.

The paper also highlights the importance of reducing a dredging project’s impact on air and water quality (local impact) and climate (global impact). To implement this project managers must take into account the phases of the life cycle infrastructure projects to address the energy efficiency of dredging campaigns.

As legislation becomes stricter, it is imperative that decisions are made early on in the project initiation phase to ensure that energy consumption is managed in a sustainable manner throughout all subsequent lifetime phases of the project.

Author: Members of the CEDA Working Group on Energy Efficiency Considerations (WGEE) for dredging projects and equipment.

Editorial Advisory Committee

Mr Robert de Bruin, Chair
Mr René Hoffman, Secretary General
Mr Vince Cosmane
Mr Jelle Schoben
Mr Arno Schikker

Board of Directors

Mr Frank Verhaert, President
Mr Jan-Harmouw, Vice President
Mrs Els Verbraken, Treasurer
Mr Theo Baetens
Mr Niek de Bruijn
Ms Melodie Forden
Mr Nel Wexhout
Mr Philip Hermans

Available from https://dredging.org/resources/ceda-publications-digital-position-and-information-papers

Main members

DEME Group
Head office Belgium
+32 3 250 5211
info@deme-group.com
www.deme-group.com

Dutch Dredging
Head office The Netherlands
+31 (0)71 274 2424
dutchdredging@kbn.com
www.dutchdredging.nl

Group De Cloedt – DC Industrial N.V.
Head office Belgium
+32 2 647 12 54
office@groupdecloedt.be
www.groupdecloedt.be

Hyundai Engineering & Construction Co., Ltd.
Head office South Korea
+82 2 746 1114
webmaster@hec.co.kr
www.hec.co.kr

Jan De Nul Group
Head office Luxembourg
+352 59 8911
info@jan.denulgroup.eu
www.yandenui.eu

National Marine Dredging Company
Head office United Arab Emirates
+971 2 651 3000
nmco@nmco.ae
www.nmco.com

Penta-Ocean
Head office Japan
+81 3 5871 7181
poc_international_weldmail@pentaocean.co.jp
www.penta-ocean.co.jp

Rohde Nielsen A/S
Head office Denmark
+45 33 91 25 07
mail@rohde-nielsen.dk
www.rohde-nielsen.dk

Gulf Cobia (L.L.C.)
Head office United Arab Emirates
+971 4 80 7777
go-info@gulfcobia.com

Royal Boskalis Westminster N.V.
Head office The Netherlands
+31 (0)70 269 66 00
royal@boskalis.nl
www.boskalis.com

TOA Corporation
Head office Japan
+81 3 6757 3600
webmaster@toa-const.co.jp
www.tosa-const.co.jp

Van Oord
Head office The Netherlands
+31 (0)88 280 00 00
info@vanoord.com
www.vanoord.com

Colophon

Editorial
For editorial inquiries, please email editorial@iadc-dredging.com or call +31 (0)70 352 5544. Articles featured in Terra et Aqua do not necessarily reflect the opinion of the IADC Board of Directors or of individual members.

Editor
Mr Sarah Nunn

Editorial Advisory Committee

Mr Robert de Bruin, Chair
Mr Rene Hoffman, Secretary General
Mr Vince Cosmane
Mr Jelle Schoben
Mr Arno Schikker

Board of Directors

Mr Frank Verhaert, President
Mr Jan-Harmouw, Vice President
Mrs Els Verbraken, Treasurer
Mr Theo Baetens
Mr Niek de Bruijn
Ms Melodie Forden
Mr Nel Wexhout
Mr Philip Hermans

Front cover (Boisale)

Back cover (Boisale)

Design
Shortwater, The Hague, The Netherlands

Printing
Tulvez B.V., Harderwijk, The Netherlands

Copyright © 2023 International Association of Dredging Companies

Terra et Aqua is published four times a year by International Association of Dredging Companies, Stationplein 4, 2275 AZ Voorburg, The Netherlands. www.iadc-dredging.com

How to subscribe?
To receive a free print or digital subscription, register at www.iadc-dredging.com/terra-et-aqua/subscribe.

Call for submissions
Published quarterly, Terra et Aqua is an educational and professional resource that features cutting-edge innovations to disseminate knowledge throughout the dredging industry. Are you an author, researcher or expert in dredging or a related field? Do you want to share your innovative research, paper or publications with the dredging industry? Then submit your proposals to the editor at editorial@iadc-dredging.com for consideration.

Terra et Aqua publishes four times a year by International Association of Dredging Companies, Stationplein 4, 2275 AZ Voorburg, The Netherlands. www.iadc-dredging.com

#165 - SPRING 2023
IADC stands for International Association of Dredging Companies and is the global umbrella organisation for contractors in the private dredging industry. IADC is dedicated to promoting the skills, integrity and reliability of its members as well as the dredging industry in general. IADC has over one hundred main and associated members. Together they represent the forefront of the dredging industry.

www.iadc-dredging.com