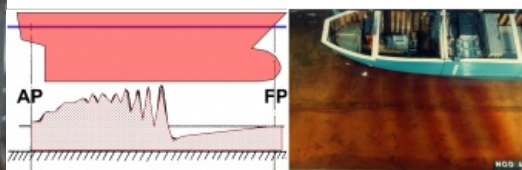
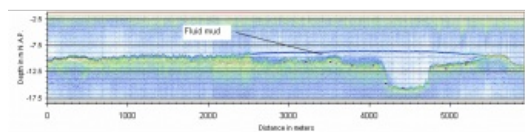
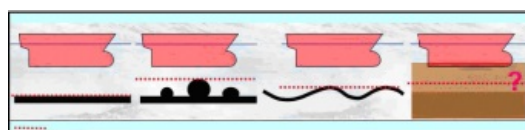


A CASE STUDY

Fluid Mud and Determining Nautical Depth



Ships are getting larger, dredging costs for maintenance are increasing and permits for disposing harbour sludge are increasingly difficult to obtain. An objective evaluation of harbour maintenance practices is therefore justified. Siltation of harbour basins decreases the nautical depth and maintenance is required to ensure safe shipping. The present techniques usually consist of dredging or other methods for removing sediments. Scientific research over the past decades and experience in seaports in the North of the Netherlands, Belgium and Germany have shown that a different approach, based on physical characteristics of mud layers, innovative surveying tools and strategies is feasible. This article presents an approach for determining the nautical depth for a sea harbour with fluid mud and or a muddy bottom layer which can be successfully related to a 'Keep Sediments Navigable' strategy of the PIANC Report 102 'Minimising Harbour Siltation'.

Background

In many parts of the world fluid-mud suspensions occur above the bottom of shipping routes creating difficulties in

defining the navigational depth. When lead lines were used, the depth was recorded to the fairly solid bottom and any overlying mud layer was usually not detected. By introducing echo sounders, the water-mud interface was not always clearly defined. The interface shown on the records may depend on the instrument and the frequency used. The lack of a clearly defined water-mud interface can cause unnecessary depth restriction and possibly excessive dredging.

During the 25th P.I.A.N.C. Congress in Edinburgh, in May 1981, a working group was formed under the auspices of the Permanent Technical Committee II to prepare a short report which was to include: A definition of the term Nautical Depth, Methods of measuring the characteristics of bottom layers and a description of the effect of muddy layers on the manoeuvrability of ships. The results were presented in 1983 (Navigation in muddy areas, *Supplement to Bulletin nr. 43*, PTC2 report of WG 03 - 1983 issue, MarCom Working Group 03).

Safe navigation depends on a combination of ship characteristics, harbour lay-out, flow and wind conditions as well as thickness and the rheological characteristics of the fluid mud layer.

Since 1983, a substantial amount of scientific research has been carried out by institutes in Belgium, Germany and the Netherlands to gain more insight into the behaviour and physical characteristics of fluid mud. Emden Harbour in Germany has 25 years of practical experience in conditioning fluid mud, a process whereby they radically changed the harbour maintenance from dredging and disposing to keeping mud navigable. Of great importance is also the scientific research carried out by Ghent University (Belgium) and Flanders Hydraulics Research (Belgium) on ship manoeuvrability in relation to fluid mud. This resulted in a validated computer model for ship simulations that allows harbour pilots to practice with the effects of different fluid mud conditions in a realistic virtual environment of their harbour.

Case study

The case study was carried out in the Dutch harbour of Delfzijl. The harbour is located in the north of the Netherlands close to the eastern German border, and bordering on an important marine nature reserve and World Heritage area, the Wadden Sea. The harbour board, Groningen Seaports, wants to optimise harbour maintenance. One of the aspects to be covered is to define and prove the optimal nautical depth. In the following paragraphs present the approach chosen and the results. A word of caution based on experience; for acceptance of results of this kind of studies and for swift implementation of changes, open communication and participation of other stakeholders is required.

The Harbour of Delfzijl

The harbour of Delfzijl consists of an outer part subdivided into three sections and an inner part linked by sea locks. The total surface is approximately 1,500 hectares, the depth of the seaports is 9m, the depth of the inner harbour is 5m. The outer harbour is parallel to the shore and has a length of approximately 5.5km. The range between low tide and high tide is approximately 3m.

Nautical Depth

According to PIANC (1997) the nautical depth can be defined as 'the level where physical characteristics of the bottom reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability.' Accordingly, nautical depth can be defined as: the instantaneous and local vertical distance between the nautical bottom and the undisturbed free water surface.

Within the muddy bottom layer the physical properties such as density (ρ) and apparent viscosity (η) increase with depth. At a certain depth a transition between the 'liquid' and 'solid' can be established. This transition, associated with specific critical density (ρ_{cr}), could be considered as the nautical bottom. Density is the most practical measurable parameter for indicating the position of the nautical depth, however, not the most relevant. Investigations (Vantorre, 1994) have shown that the nautical depth was found in mud layers with densities varying between 1.15kg/l and 1.24kg/l to 1.3kg/l and that not density is decisive, but viscosity is a measure for the nautical depth. Investigations in the German harbour of Emden (Greiser and Wurpts) also conclude that the critical density is not the best parameter to define the nautical depth. According to the latest investigations, the nautical depth can best be defined by a physical parameter as the yield point (yield stress). At present, fluid mud agitation in the Emden harbour must be carried out when the following criteria are exceeded: maximum yield point 100Pa, maximum fluidisation viscosity 100Pa.s, Newtonian behaviour at shear stresses of maximum 500Pa.s.

Field Survey

Over a period of approximately one year regular measurements were carried out in the outer harbour of Delfzijl. The measurements consisted of surveys (parametric echo sounder+dual frequency single beam (201kc and 33kc) and vertical profiling (Multisampler for turbidity+EC+Ph, DRDP for density and dynamic penetrometer measurements).

The dark blue line clearly shows the top of the fluid mud layer in the harbour entrance. Near the entrance is a mud trap. In the harbour entrance a sand bar is present before the bottom layer descends into the deeper entrance channel.

During each survey at predefined locations undisturbed samples were taken for laboratory analyses. For this purpose a dedicated piston sampler was developed with an air operated tube valve at the bottom. The maximum sample length was 2m. Based on the coupled density measurements and depth, sensor samples can be taken at various depth intervals. During the field investigations 10 surveys were carried out and approximately 1000 samples were collected for further laboratory analyses.

Laboratory Tests

A large number of tests were carried out on the collected samples. These consisted both of regular tests such as grain size distribution, water content, organic content, density, and specific weight but also rheological tests to determine the characteristics of the fluid mud.

The mud layer in the harbour of Delfzijl can be considered as fluid mud. The characteristics of the material are suitable for a 'Keep Sludge Navigable' maintenance dredging approach. The present characteristics of the fluid mud layer have not changed significantly during the investigation although no significant maintenance work was carried out further inland from the sand trap near the harbours entrance.

Simulation Study

The presence of a mud layer in the port of Delfzijl in the Netherlands implicates a major restriction to the nautical accessibility of the port. At present, the maximum drafts for shipping traffic to Delfzijl are limited by a minimum under keel clearance with respect to the top of the mud layer. Laboratory tests indicated that a KSN approach should be possible. Simulator studies with local pilots were carried out to confirm these findings.

In 2008, a new consolidated mathematical model was implemented in the simulators of Flanders Hydraulics Research institute enabling the simulation of a vessel's behaviour above and in contact with any realistic mud layer. As a result of the availability of this model, Flanders Hydraulics Research was asked to investigate the influence of sailing at very low and even negative under keel clearances with respect to the mud layer on the inbound and outbound route to and from the port of Delfzijl. In addition, the mud layer characteristics (thickness, density and viscosity) were varied systematically. In order to perform the simulations as realistically as possible, local pilots experienced with the port of Delfzijl, participated in the study.

Simulations were carried out with a 1,700 TEU vessel for which the mathematical manoeuvring models have been derived from comprehensive captive model tests performed in the towing tank for manoeuvring in shallow and confined waters (co-operation Ghent University and Flanders Hydraulics Research). During this experimental programme (2001-2004) the ship behaviour above and in contact with several mud layers was measured. The mud layers were simulated using paraffin's characterised by layer thickness, density and viscosity.

The simulator study revealed the possibility of working with a nautical bottom that is at a lower level than the top of the mud layer. This opens up the possibility for the port of Delfzijl to receive vessels with a larger draft in the future without the requirement of extra dredging efforts. In order to validate the conclusions from the simulator study, full scale testing will be organised on site in the second half of 2012. Flanders Hydraulics Research will also be involved in this study.

Conclusions

Based on the results so far, definition of a lower nautical bottom and optimising harbour maintenance is possible in the harbour of Delfzijl as well as for other muddy ports. Due to the different aspects involved this requires a multi-disciplinary team as well as the early involvement of stakeholders. As safety is a primary concern for the harbour board, Groningen Seaports, full scale field tests will be carried out for validation, and after being successful, an optimised harbour maintenance schedule will be implemented.

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More Information

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