DREDGING STIFF TO VERY STIFF CLAY IN THE WIELINGEN USING THE D.R.A.C.U.L.A.®-SYSTEM ON A HOPPERDREDGE

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Abstract

Dredging stiff to very stiff clay with a hopperdredge has always given a number of operational problems resulting in a reduced or limited production. Thus when the dredging of clay was required, operational people always used mechanical and stationary dredges such as a cutterdredge, clamshell or bucketdredge. However, when the dredging area is one of Europe's busiest waterways like the Wielingen and when the dredging area is exposed to rough sea conditions, an alternative has to be studied. When a stationary dredge is used the operational time would be reduced by interruptions clearing the dredge area for passing ships. Due to the exposed nature of the dredge area a seagoing dredge would be necessary and even then the operational time would be limited due to the number of stops because of the bad weather and rough seas.

The patented DRACULA-system (DRedging And Cutting Using Liquid Action) presented a solution. The DRACULA-system integrates high pressure waterjets in the draghead of a conventional hopperdredge. As a result of the waterjets a number of classic problems when dredging clay are overcome. The clogging of the draghead was reduced, almost eliminated. The penetration of the draghead was no problem and there were no propulsion limitations for the hopperdredge, a normal trailing speed could be maintained. The overall pipe-production during dredging was also increased. This paper will describe the use of the DRACULA-system and the experiences during the deepening of the Wielingen where 'Bartoenclay' was dredged.

THE CONTRACT

The contract consisted of deepening and maintaining the access channel to the port of Antwerp with about 1.5 to 2 meters up to an average depth of H – 15.4 meters over a width of 500 meters. This job had to be done as part of the 48-feet programme in the Dutch part of Wielingen. The 48-feet program will allow ships with a draft of 48 feet to reach the port of Antwerp within one tide. This will give the shipping movements to Antwerp more flexibility and make all ship movements less tide-dependent.
The client was the Flemish Government, represented by:

Ministry of the Flemish community,
Department environment and infrastructure
Administration waterways and seas
Section coastal waterways.

This part of the Wielingen channel is known as “GEULVAK 13“ situated between Eastings 526,655 (3° 23’) and 533,600 (3° 29’).

The dredging tolerances were limited to 30 cm in minus or in plus. This means that the maximum dredging depth is H – 15.7 meters. If this depth is exceeded the client can demand a refill of the area to the maximum dredging depth. The minimum dredging depth is H – 15.1 meter.

Over the total distance of approximately 7 km there was one area of about 1.5 km with stiff “Bartoenclay”. In the rest of the channel there were areas with a mixture of sandy material, silt and soft clay.

The estimated volumes to be dredged during the tender phase were as follows:

Soil type	**Total volume in situ (m³)**
Quarternary (holocene) sand	1.100.000
Quarternary (holocene) sand en clay	20.000
Quarternary (holocene) clay	20.000
Tertiary sand	20.000
Tertiary clay (Bartoenclay)	990.000
Total	**2.150.000**

There were several dumping areas available. The dump location is depending on the type of soil.

Soil type	**Dump area**
Sand	Coast of Vlissingen
Sand	Coast of Zeeuws Vlaanderen
Holocene Clay	Belgian dump S3 or R4
Bartoenclay	Schone Waardin (Vlissingen)
Holocene Silty sand	Belgian Dump S3 or R4

For the realization of the capital dredging we opted for the use of hopperdredges. The main problems to be expected were the tolerances to be realized and the dredging of the very stiff Bartoenclay. For the dredging of the Bartoenclay we equipped one hopperdredge with a DRACULA®-draghead.

The choise of hopperdredges was based on two factors:

- ✓ The dredging area is very exposed to rough sea conditions. Working with a stationary dredge would mean a lot of down time, due to weather conditions even when a sea-going cutterdredge would be used. The nearest ports for sheltering are Zeebrugge and Vlissingen which are both at some distance from the dredging area.
- ✓ Due to the shipping traffic a stationary dredge and floating pipelines would be an obstruction to the passing ships. There would be a lot of down time due to the clearing of the dredging area for the passing ships.

The complete dredging area was split-up into different dredging areas depending on the type of soil in the area. This would allow us to optimize the use of the different hopperdredges in combination with the dump areas and the type of soil.

- ✓ Sand-area I: from E526.655 to E528.085
- ✓ Sand-area III: from E528.085 to E529.500
- ✓ Clay-area: from E529.500 to E531.000
- ✓ Sand-area II: from E531.000 to E533.600

To execute the job we used two types of hopperdredges:

- ✓ Hopperdredge type 8500 m³ (Antigoon) in areas with mixed sandy soil.
- ✓ Hopperdredge type 3500 m³ (Jade River + DRACULA® draghead) in areas with mainly (tertiary) clay

THE SOIL CHARACTERISTICS

The soil data are based on a soil investigation campaign executed by the Dutch Government (Rijkswaterstaat) in 1985. Based on this investigation three subbottom profiles were made along the dredging area.

Holocene:

The Holocene clay varies in thickness from 20 cm on the South-side of the channel to 1 meter the North-side. Towards the eastside the clay layer is covered with approximately 1 meter of sand.

Tertiary:

The tertiary clay is located on the eastside of the dredging area and covers the full depth of the dredging area. Some layers of sand are present between the clay layers. This clay is the most critical soil to dredge in the Wielingen. Some numbers below show the characteristics of the clay.

In situ density γ_{situ}:	2 T/m^3
C_{pt}:	2 Mpa
Liquid Limit LL:	55%
Plasticity Limit PL:	22%
Plasticity Index PI:	33%

These numbers indicate that the Teriary Bartoen Clay is very stiff and will be forming clayballs when pumped.

THE DRAGHEAD

For this purpose DEME has integrated high pressure waterjets on the draghead and patented the system. We named the system DRACULA® which stand for **DR**edging **A**nd **C**utting **U**sing **L**iquid **A**ction. The purpose of these jets is on the one hand to reduce the resistance that the draghead has to penetrate into the hard soil, and on the other hand it prevents the draghead to clog with clay during dredging. We will highlight these two facts more in to detail.

High pressure waterjets are now very commonly used in a large number of industries. The pressures that are used can reach as much as 3000 bar with a standard high pressure pump. Waterjets are used for stripping paint, cutting concrete, cutting steel plates,…, so why not use them to cut the soil during a dredging process.

A study and some tests with scale models learned us that for cutting clay in submerged conditions a pressure of 300 to 350 bar was needed. This only in conditions not deeper than 30 metres. So for the DRACULA® draghead we used pressures of 380 bar. This should be sufficient to cut even the hardest clay at a trailing speed of 2 to 2,5 knots.

- ✓ <u>*Reducing the cutting forces*</u>

When dredging hard soils the only force that makes the points of the draghead penetrate into the soil is the weight of the draghead and the suction pipe. When this is not sufficient the draghead will not penetrate and will drag on top of the surface without cutting any soil. This will result in a very low mixture density and in a low production of the hopper dredge.

To assure a maximum efficiency of the waterjet we had to integrate the nozzle in the points of the draghead. This way the waterjet will cut the soil only moments before the point penetrates the soil. This has as a result that the forces needed to penetrate the soil are reduced and the cutting efficiency is increased.

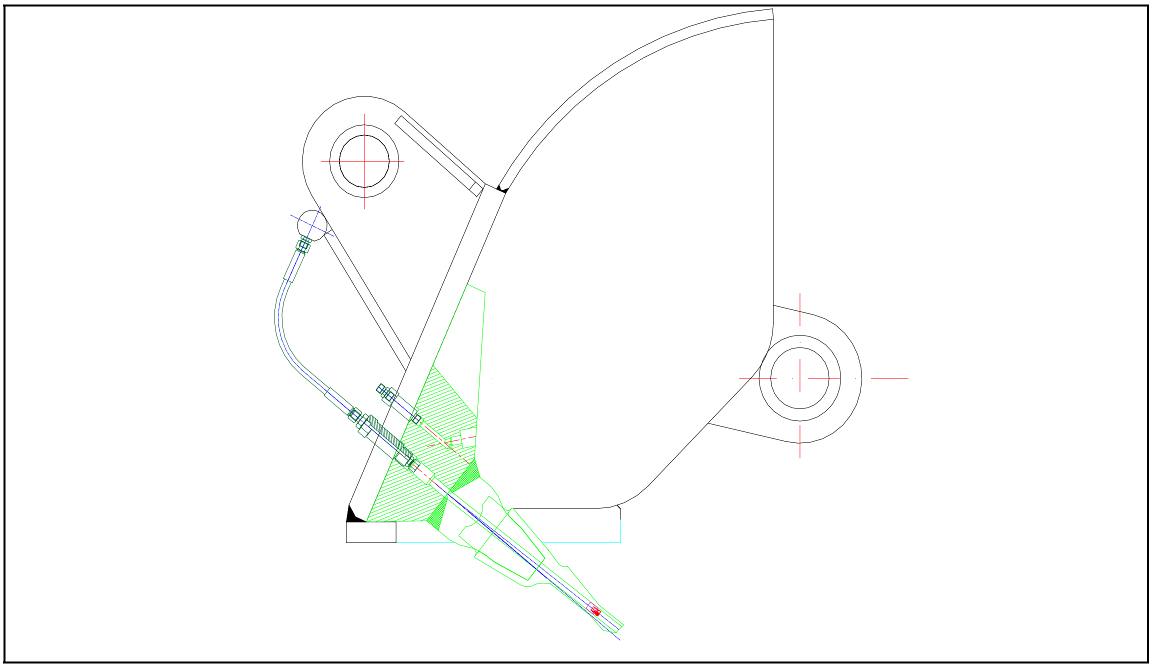

Fig 1: Cross-section of the DRACULA®-Draghead with jets through the point

The drawing above gives a cross-section of the visor of the DRACULA® draghead. It shows that the nozzle is integrated inside of the dredgepoint.

For this purpose a special hollow dredgepoint has been developed. The point has a channel inside through which the high pressure line is mounted.

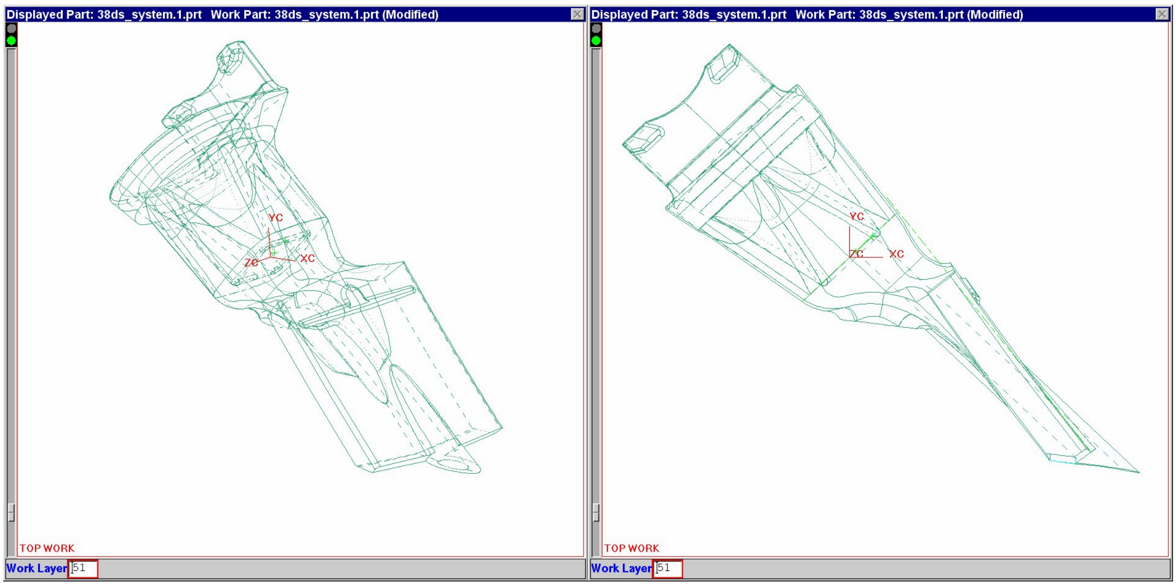

Fig 2: transparent view of the hollow dredgepoint used on the draghead

✓ *Preventing clogging*

When dredging clay the draghead will easily be clogged with clayballs that get stuck inside of the draghead construction. This is especially the case with softer and more sticky clay. To prevent this, the clay should be prevented of forming clayballs and should be cut in to as small as possible pieces. Therefore we also placed high pressure jets just above the points inside of the draghead. The large lump of clay that is formed by the point is immediately cut in to small pieces by the waterjet just above. The direction of the jet is towards the suction mouth so that the clay particles are directed towards the suction mouth, and so preventing the draghead to clog.

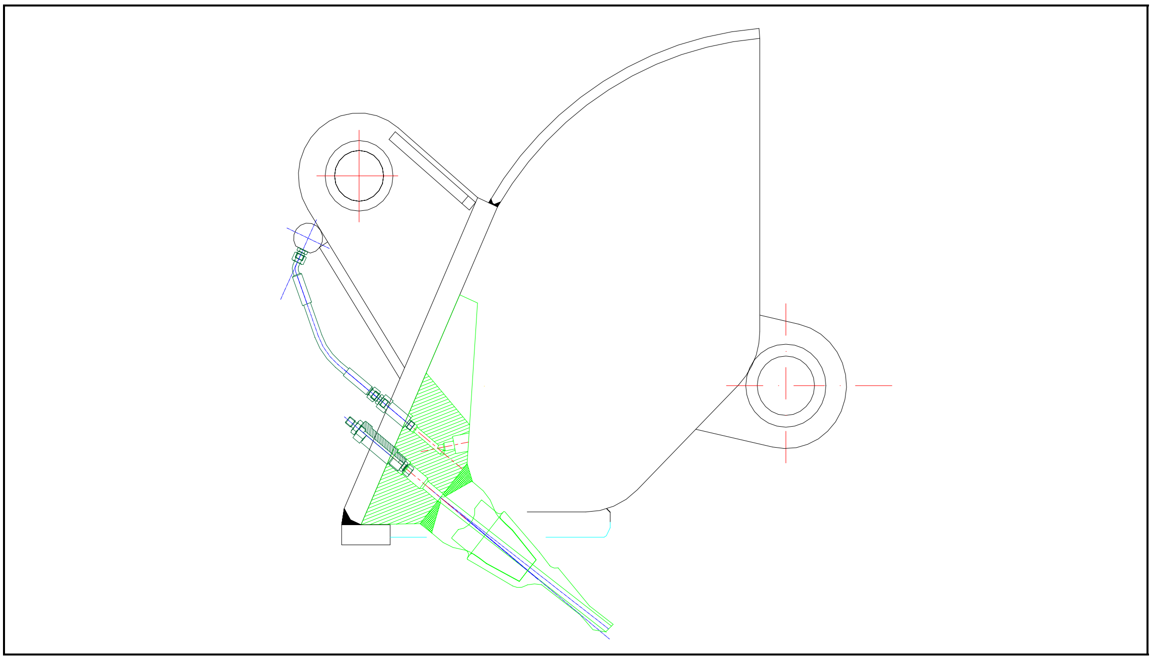

Fig 3: Cross-section of the DRACULA®-draghead with jets inside of the visor

✓ *Precutting (ripping)*

A third application of the waterjets on the draghead is to use the waterjets as a kind of hydraulic ripper. The waterjets are placed next to the existing low pressure waterjets on the heel of the draghead. They are directed vertically in to the soil. This gives a similar effect as a ripper, the soil is cut by the waterjet and will create cuts into the clay surface.

This results in the fact that both the cutting forces of the points are reduced because the soil is already cut and because the clay is cut in to smaller pieces, reducing the risk of clogging, by the waterjets.

Fig 4: Picture of the DRACULA®-draghead on the TSHD JADE RIVER

HIGH PRESSURE PUMPS

For this purpose we had to install high pressure pumps on board of the hopperdredge. We opted for a flexible system which could be used on different hopper dredges. The pumps are mounted in a 20' container and can operate as a stand-alone unit. Each pump is driven by a CAT 3412 DITA diesel engine of 558 kW. The pumps have the following capacity: 759 l/min @ 380 bar.

The pumps we use are piston pumps so the water has to pumped to the high pressure pump using an inboard centrifugal pump which feeds the water at a pressure of ca. 8 bar. The water is then filtered to 75µ before it enters the high pressure pump.

The nozzles we use are between 1.7 mm and 3.3 mm. As the total flow is limited the nozzle diameter depends from the number of nozzles and from the number of pumps. As a rule we can say that one pump can feed ca. 20 nozzles of 2.0 mm. For the Wielingen, on the JADE RIVER, we used two pumps in parallel operation.

At these operation conditions the water under 380 bar is leaving the nozzle at a speed which can reach 250 to 300 m/s. This creates a hydraulic cutting power which is sufficient to cut the stiff clay layers in the soil.

The pumps are placed on deck and the high pressure water is fed to the draghead by flexible lines on the suction pipe. As the flow is limited the flexible lines have a small diameter and are easy to manipulate.

Fig 5: TSHD JADE RIVER with the high pressure pumps

RESULTS

During the dredging of the Wielingen an intensive monitoring program was set up to determine the effectiveness of the DRACULA® draghead. The following parameters were monitored:

- ✓ The influence of the jets on the pipe-production
- ✓ The influence of the jets on the cycle-production
- ✓ The influence of the jets on the propulsion power
- ✓ The influence of the jetting location

The pipe production

Depending on the jetting location, the pipe production of the JADE RIVER increased between 15% and 27%.

The cycle production

An exact figure is hard to determine but it was clear that when the system was not operational, the draghead tended to clog quite quickly. This meant that the dredging operation had to be stopped to clear the draghead. When the jets were on, no clogging of the draghead was observed. The DRACULA system reduced the down time considerable.

Propulsion power

The TSHD JADE RIVER has a lot of propulsion power (2 x 1730 kW), independent from the dredge pumps. During the project there was never a problem with the propulsion, a trailing speed of 2 to 3 knots was always possible. However we logged the fuel rack on the propulsion engines and from these data we could conclude that when the system was active, the average fuel rack was 5% less compared to dredging without DRACULA®.

The jetting location

As propulsion was no problem for the JADE RIVER, the jets through the points were not really effective. We saw that the most important increase in pipe production (27%) occurred when the jets in the visor together with the jets on the heel were active.

Accuracy

As the dredging tolerances were only +/- 30cm, which is very little for a job with a hopperdredge, there was a risk that in the hard clay areas some tracks would be formed by the draghead. This would result in local overdepths. Due to the Dracula system and an adapted working method this was not the case. Below you see the final survey of the dredge area.

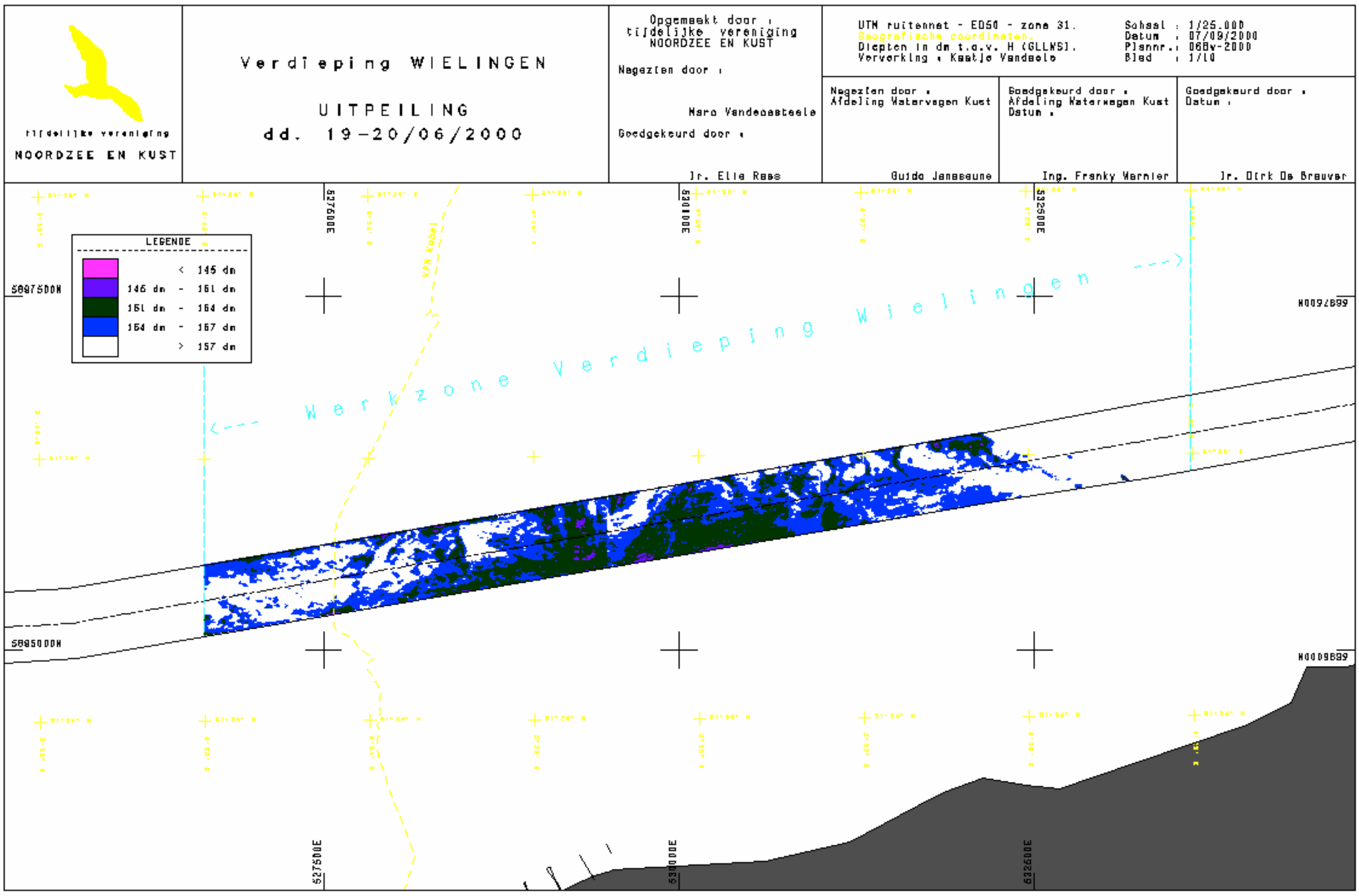

Fig 6: General view of the dredging area with the final survey data

CONCLUSIONS

During the project of deepening the Wielingen, based on previous experiences in Liepaja (Latvia), DEME used for the first time on such a big scale the new patented DRACULA®-system on a hopperdredge. The results when dredging the very stiff clay were very successful and after solving some technical problems the system proved to be operational on a hopperdredge.

Further tests will be executed for dredging harder soils such as cemented sand using a hopperdredge as an alternative for a stationary dredge like a cutterdredge or bucket dredge.

The results from the Wielingen project proved that a hopperdredge is now a possible alternative for a stationary dredge for dredging stiff to very stiff clay. The typical problems that occur when dredging clay with a hopperdredge are largely solved by the DRACULA®-system.

The deepening of the Wielingen was executed in 9 weeks in total using the hopperdredges ANTIGOON and JADE RIVER. During the tender phase we estimated the total duration of the job on 19 weeks using the same hopperdredges. The success of the project was largely obtained by using the DRACULA®-system on the JADE RIVER to dredge the stiff-clay.

KEYWORDS

hopperdredge, stiff clay, high pressure jets, draghead, cutting forces, clogging, ripping, production