Multibeam Survey of Quay Walls

Opportunities and limits tested by bremenports

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Abstract

Port authority bremenports GmbH & Co.KG is responsible for the hydrographic survey of the water depths in both Bremen and Bremerhaven, ensuring easy and safe navigation in the port areas. Whereas the determination of the minimum depth is relevant for the harbor master, the pilots and the maintenance dredging team, the maximum depth is important for the ports' maintenance department in order to identify local tidal scours and to ensure the stability of the terminals. Equipped with the multibeam Sonic 2024, bremenports' new survey vessel *Seeadler* is able to survey both the water depth and the quay walls.

1. Introduction

A sheet pile wall or, more generally, a quay wall is the border between water and land. For safe ship loading, unloading and navigation, the stability of the quay must be guaranteed. There can be different reasons why quay wall inspection might be necessary. The nominal depth in front of the quay defines the maximum draught of the vessel for safe berthing, whereas the design depth limits the maximum depth to avoid static failure. Local sours caused for example by natural currents or screw waters require monitoring surveys and possibly refilling of scour holes. *Figure 1* shows a local scour hole in front the container terminal in Bremerhaven which needed to be refilled.

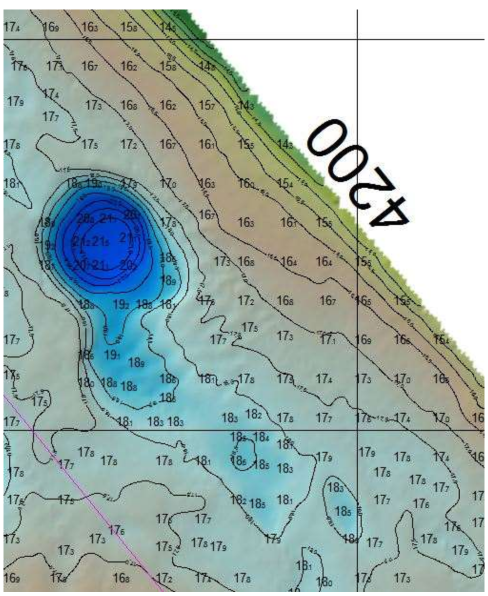

Fig. 1: Scour hole at container terminal section CT4

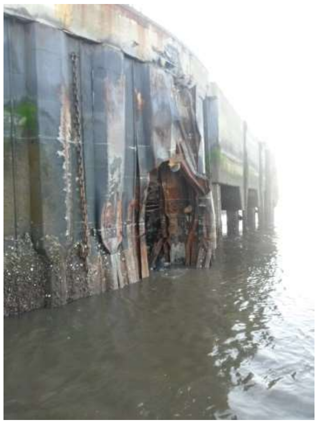

Fig.2: Damage to a quay wall after a ship collision, at the entrance to the North-Lock, Bremerhaven

Figure 2 shows substantial damage to a quay after a ship collision. The harbor basin needed to be surveyed for possible sand emerges creating minor depths as well as for possible broken pieces of the quay wall. These two examples illustrate the traditional tasks of indirect quay wall inspection by hydrographic surveying of the harbor floor. Direct monitoring of the construction deformation requires geodetic survey methods on land and inspection under water by divers. The turbid harbor water in Bremerhaven allows the diver mostly just to feel the condition of the construction rather than to see any damage. This paper shows three examples of quay wall investigations under water by a multibeam survey. In contrast to the survey of water depths, the view is not focused on the bottom but rather on the construction, i.e. from the base point of the wall vertical almost up to the water surface. In the following section, the technical equipment of the survey vessel is described. In section 4, a summary and and outlook of possibilities and limits of quay wall surveying by multibeam systems are provided.

2. Survey vessel *Seeadler*

Bremenports operates the survey vessel *Seeadler*. It was put into service in 2016. An important criterion for the selection of the multibeam was the resolution combined with a high density of measured points. This requirement is very useful for a port in order to detect and possibly identify manmade objects that may act as hindrances on the harbor floor. Using the multibeam for inspection surveys of quay walls was also considered, but there was little prior experience with acoustic inspections of water infrastructure at that time.

Fig.3: Survey vessel Seeadler

The multibeam Sonic 2024 including the optional 700kHz mode UHR (Ultra High Resolution) and the TruePix™ backscatter function was selected by the port. Bremenports has also made use of the UHD mode (Ultra High Density) offered by a firmware update for the full frequency range from 170kHz to 450kHz. The UHD mode increases the number of soundings by about four times; i.e. up to 1024 independent soundings per ping (R2Sonic, 2017). This new feature has significantly improved the results of detailed surveys of objects on the harbor floor as well as the inspection surveys of waterside infrastructure. The 700kHz UHR frequency mode provides a beamwidth of 0,3° x 0,6° for a 70° swath opening angle. Therefore, the UHR mode is primarily useful for the nadir view as the transducer is fixed to the ship's bottom.

For the positioning of the multibeam data, the Seeadler is equipped with a Trimble SPS 855 GNSS receiver and the iXblue Hydrins inertial navigation system.

3. Multibeam results of quay wall surveys

3.1. Quay wall at the container terminal

At 4930m long and with an annual container handling volume of 5,5 million TEU (bremenports 2018), the container quay has special economic importance in Bremerhaven. Accordingly, the water depths are surveyed monthly to ensure the safe navigation and berthing some of the world's largest container vessels arriving in Bremerhaven. Inspection surveys of the quay walls need to be done separately from a bathymetric survey as these require different sonar settings.
The purpose of the inspection survey is to achieve the highest resolution with maximum point density. A part of the first multibeam test at the transition of CT2 and CT3 around station 1600 is shown in *figure 4*. A point density of 100-120 points per square meter was achieved. Hydrographic data acquisition software provided density values of the bottom during the bathymetric survey in real time to ensure the required quality standards. The point density of the vertical plane here had to be roughly counted. The selected part shows the quay wall over a length of about 80m and depths between 0 and 10m below LAT. The container vessels are about 6m aside from the sheet pile wall due the concrete block construction on top of the quay and the fendering. Along the fender line, a nominal depth of 14,6m is maintained at this terminal section.

Bremenports uses the Eiva NaviModel Producer for cleaning, modelling and post processing of the multibeam data. The screenshot from the NaviModel project in *figure 4* can only give a general impression of the achieved resolution of the structure. For analysis and visualization of the data it is better to look and to zoom to the data in detail on screen. This can be done directly by the maintenance engineers using the freely available Eiva NaviModel Viewer. First analyses of the quay wall survey show that the general design is well presented by the multibeam data. The resolution is sufficient to identify obvious deformations of the structure rather than the recognition of a sheet pile lock failure. Added horizontal construction lines can help to evaluate and measure the deformations. Irregularities of the detailed slope morphology can be an indicator of a structure failure as well.

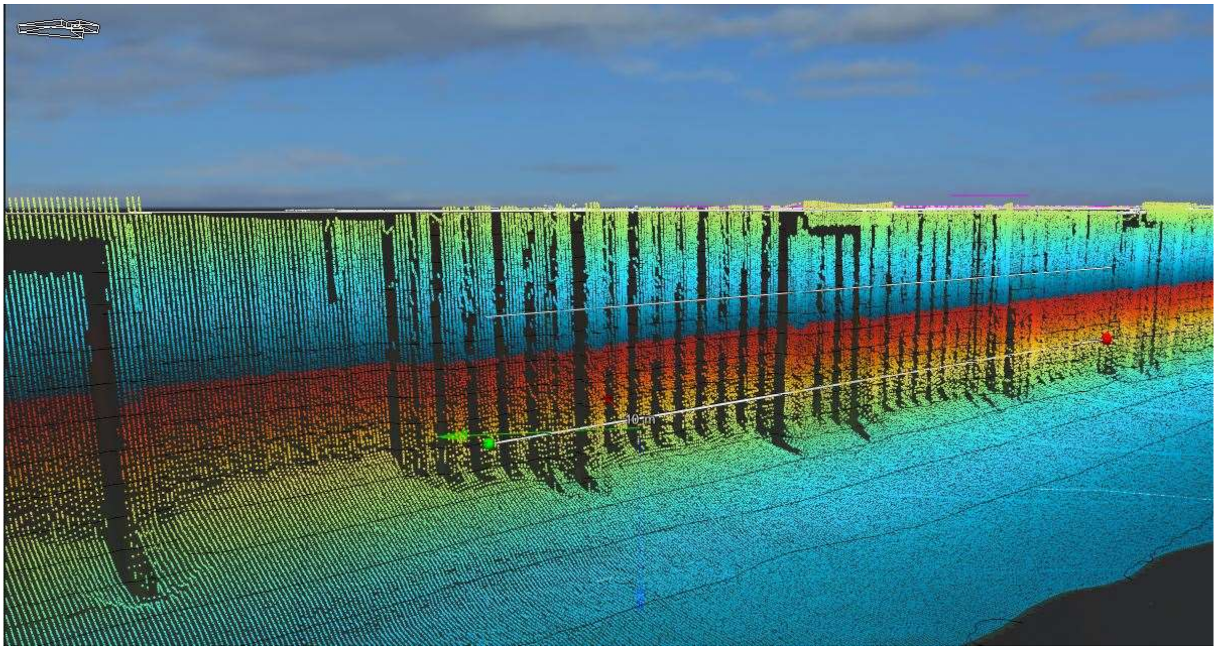

Fig. 4: Transition container terminal CT3/CT2 at station 1600

3.2. Quay wall at the cruise terminal

The second sample shows a section from the Columbuskaje, the cruise terminal of Bremerhaven. For this structure, a combination of multibeam data with image data taken by a survey model copter was tested. The image data was converted to a geo-referenced point cloud by the software Agisoft Photoscan using predefined control points. *Figure 5* shows the combined point cloud which is post processed and visualized by NaviModel.

At this structure, a higher point density of 400-500 points per square meter could be achieved by combining two survey tracks along the quay at water depths of about 13m, i.e. about 5m shallower at high tide in comparison with the depth in front of the container terminal. The resolution of the copter data is 10 times higher, at about 5000 points per square meter. Accordingly, more details can be recognized – especially in the concrete top part of the structure. Despite the high resolution of the airborne image data, it cannot completely substitute a visual inspection of the quay wall by a man basket but will nonetheless complement the inspection report including possible measurements of damage dimensions. Comparable with the container quay, the underwater part offers valuable information about the condition of the structure. The quay wall at the cruise terminal is constructed with a definite inclination. The inclination of the wall can be proofed by comparing the point cloud with vertical lines. Such added vertical and horizontal construction lines can be used to help to check, measure and analyze the point cloud model for irregularities of the structure.

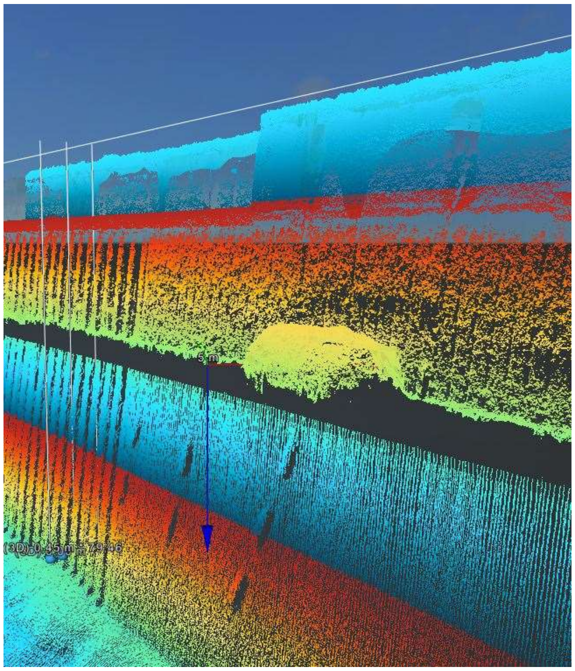

Fig. 5: Cruise terminal around station 600

3.3. Fischereihafen

The third sample shows a quay wall scan in the Fischereihafen at about 6m water depth. Due to the reduced depth, the scan is focused to a point density of 500-600 points per square meter. The analysis together with that of maintenance engineers revealed unknown features which required further investigation by bremenports diving inspections.

A slanted broken pole without function was discovered (*figure 6*, left), a pole lying on harbor bottom, as well as a bigger deformation of the quay wall. Two piles inclined by 0,5-0,6m at the bottom of the sheet pile wall (*figure 6*, center) can be seen.

The position of the objects can be taken by the Nav iModel Viewer to mark the area for the divers in the HafenGIS (*figure 6*, right).

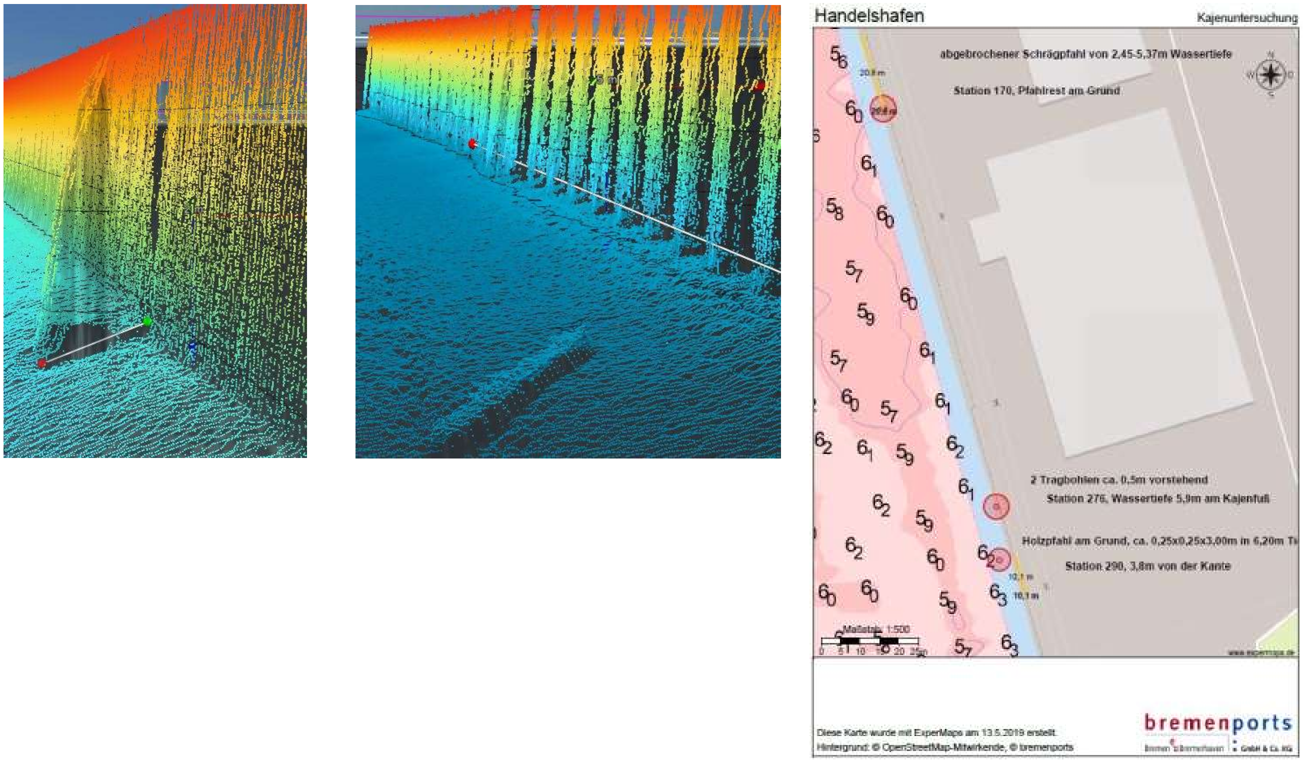

Fig.6: Handelshafen at Fischereihafen

3.4. Summary and outlook

Bremenports is just at the beginning of using multibeam data for quay wall inspections. However, the first investigations already demonstrate that the survey equipment of the *Seeadler* can help to analyze and assess the condition of waterside infrastructure in Bremerhaven. The UHD mode of R2Sonic has significantly improved the multibeam results of the quay wall surveys. Critical for the quality of a quay wall scan are the resolution and point density of the multibeam survey. Further test surveys will be necessary to find the best parameter configuration of the sonar as well as the optimal hydrographic survey runline planning. NaviModel is an appropriate tool to visualize and analyze the data. The NaviModel Viewer allows all engineers working on the quay wall inspection direct access to the information. In this way hydrographers, civil engineers, surveyors and divers have a common database to exchange and deepen their knowledge of the structure for a better assessment. Bremenports will include these possibilities in their working processes to realize more value from the inspection of waterside infrastructure.

At present, visualization is done exclusively by viewing point clouds. The analysis requires the user to view the point cloud from different perspectives at different zoom steps in order to recognize details of the structure and achieve the correct interpretation and judgment. For the deformation analysis it is helpful to have construction lines and planes. It would be worthwhile to have a 3D CAD as a reference drawing of a new construction, which could then be compared with the point clouds in the future. There is ongoing research and development of EIVA a/s to derive 3D models (mesh) out of the point clouds. A first test was generated from the high-resolution point cloud of the copter survey (*figure 7*). This first attempt shows the trend from the 2D map or drawing to a 3D visualized world, which promises a lot of interesting new opportunities for the future of the inspection of structures.

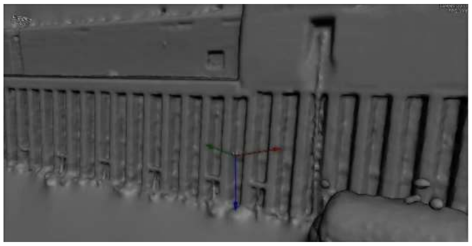
Fig. 7: Part of the cruise terminal in a 3D model

References:
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