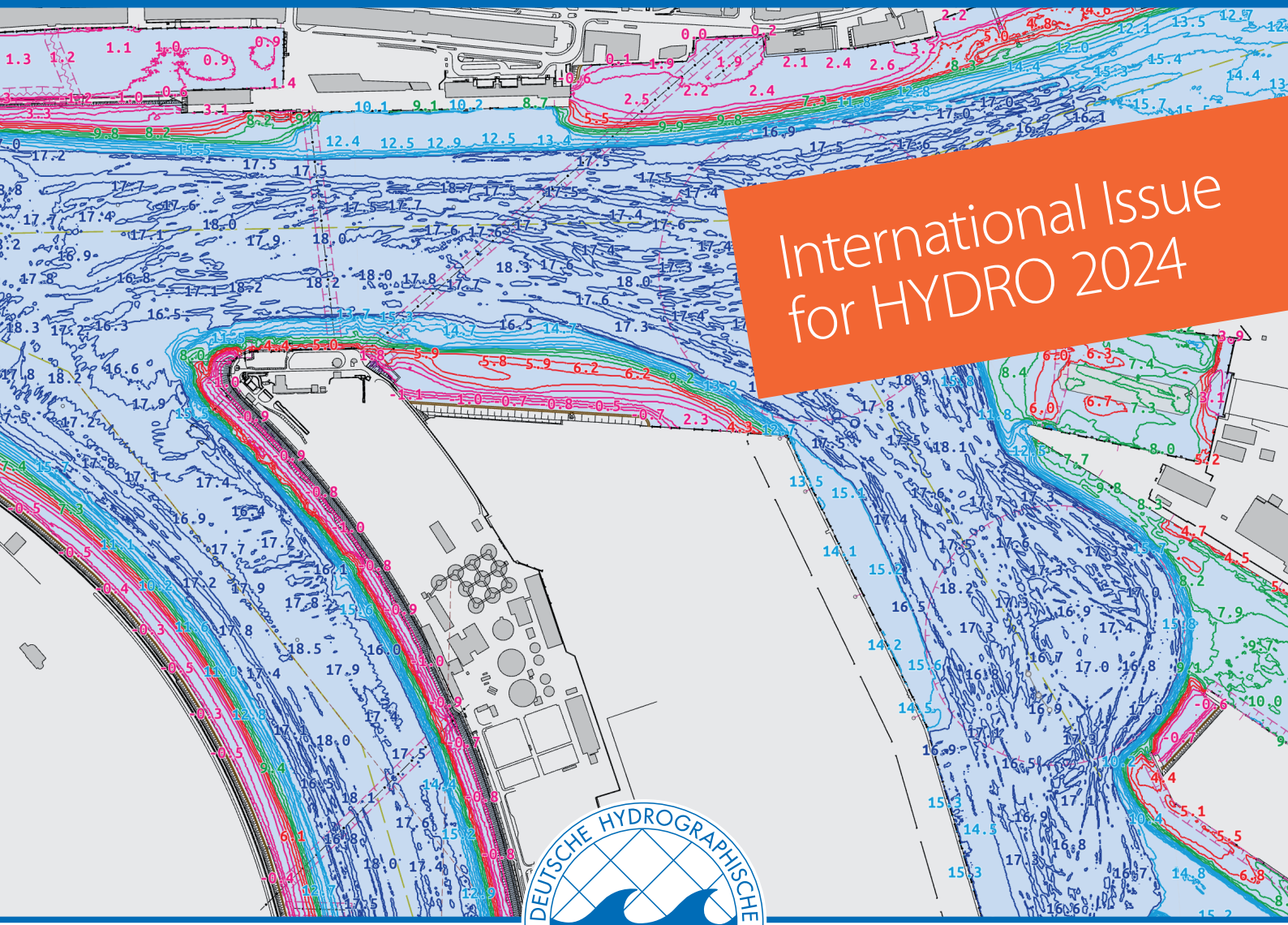
Journal of Applied Hydrography

HYDROGRAPHISCHE NACHRICHTEN 11/2024 HN 129



International Issue for HYDRO 2024

DEUTSCHE HYDROGRAPHISCHE GESELLSCHAFT e.V. DHyG

Innovative quay wall surveys – leveraging unmanned surface vehicles

An article by JANNE SILDEN, EZEKIEL DAVID and JORGE IBACETA

Regular surveys of quay walls ensure they remain structurally sound and operational, but traditional inspection methods can be labour-intensive and limited by access constraints. However, new approaches that leverage autonomous technologies are advancing the field in terms of operational efficiency on the water, data quality and the extent to which 3D models can be created and applied for engineering and maintenance purposes. Subsea Europe Services GmbH has been working on a solution based on the integration of a tilted multibeam echo sounder (MBES) mounted on an unmanned surface vehicle (USV). It was put to the test this summer in the »Alter Hafen Süd« port in Rostock, Germany, during a successful quay wall survey that demonstrated how the combination of cutting-edge acoustic and autonomous systems can significantly enhance surveying and analysis in complex harbour environments.

quay wall survey | 3D model | USV
Kaimauervermessung | 3D-Modell | USV

Regelmäßige Inspektionen von Kaimauern stellen sicher, dass sie strukturell solide und funktionsfähig bleiben, aber traditionelle Inspektionsmethoden können arbeitsintensiv und durch Zugangsbeschränkungen begrenzt sein. Neue Ansätze, bei denen autonome Technologien zum Einsatz kommen, bringen Fortschritte in Bezug auf die Betriebseffizienz auf dem Wasser, die Datenqualität und das Ausmaß, in dem 3D-Modelle erstellt und für technische und Wartungszwecke verwendet werden können. Die Subsea Europe Services GmbH hat an einer Lösung gearbeitet, die auf der Integration eines geneigten Fächerecholots (MBES) auf einem unbemannten Überwasserfahrzeug (USV) basiert. Sie wurde in diesem Sommer im Alten Hafen Süd in Rostock bei einer erfolgreichen Kaimauervermessung erprobt, die zeigte, wie die Kombination von modernsten akustischen und autonomen Systemen die Vermessung und Analyse in komplexen Hafenumgebungen erheblich verbessern kann.

Tightly integrated quay wall survey

At the heart of the survey was the R2Sonic 2026 V+, an MBES well known for its high-resolution capabilities and versatility. By tilting the sonar horizontally using a mount customised at Subsea Europe Services' R&D centre, it was a straightforward process to optimise beam alignment with vertical structures like quay walls, enabling more accurate and detailed data acquisition. The system operates across a frequency range of 170 kHz to 450 kHz, with up to 1024 soundings per ping, providing exceptional detail of underwater structures. This, combined with its roll- and pitch-stabilised beams, ensure robust performance even in dynamic conditions.

The MBES was mounted on the »Autonomous Surveyor«, a 3.6-metre USV manufactured by Martac Systems and owned by Subsea Europe Services. The USV's compact size and electric twin-screw propulsion system made it ideal for navigating the tight, shallow areas under and around quay walls. With survey speeds ranging from 2 to 12 knots, the USV is agile enough to access confined spaces while still collecting high-quality data. The vehicle's autonomous and semi-autonomous capabilities allow for flexible operations with minimal human intervention, improving both safety and efficiency.

The survey aimed to capture detailed images of the vertical structures along a section of the quay wall in »Alter Hafen Süd«. Traditional horizontal sonar beams can struggle with accuracy when surveying vertical or near-vertical structures. To address this, the R2Sonic 2026 V+ MBES was deployed using a 25-degree tilt angle; a configuration to ensure the beams struck the wall perpendicularly, reducing distortions and improving data fidelity (Fig. 1).

The USV was equipped with the SBG Pulsar 40, an inertial navigation system that provided high-precision positioning and motion compensation. Dual antennas were mounted on the USV to en-

Authors
Janne Silden, Ezekiel David and Jorge Ibaceta work at Subsea Europe Services in Halstenbek, Germany.

j.silden@subsea-europe.com

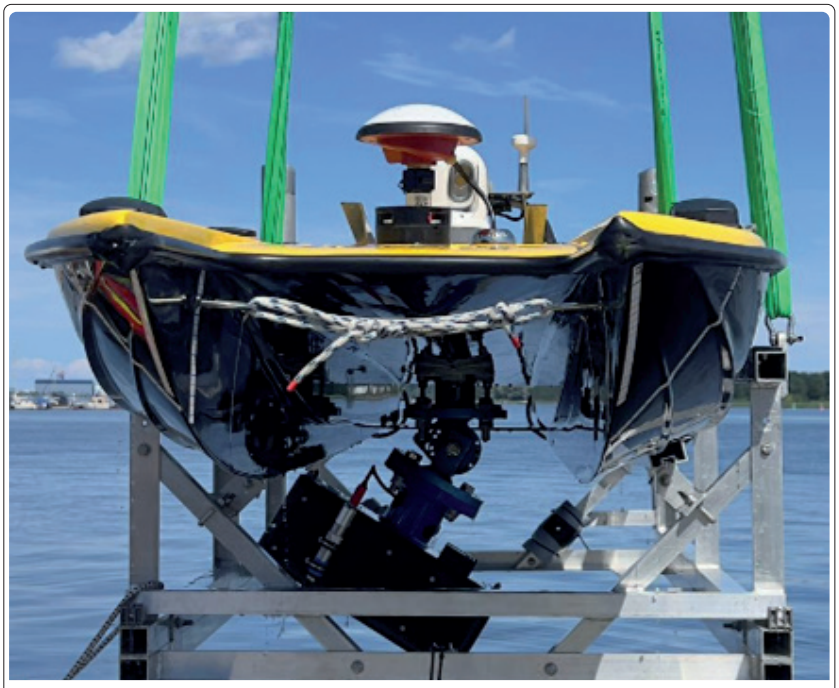


Fig. 1: The multibeam echo sounder was mounted on a tilted flange

hance heading accuracy, which is critical for maintaining alignment with the quay wall. A comprehensive sound velocity profile of the water column was obtained, followed by a patch test to calibrate the MBES system.

During the survey, the USV navigated multiple passes along the quay wall to capture overlapping datasets. The tight manoeuvring allowed it to access areas that would be challenging for manned vessels. Data was continuously transmitted to a remote monitoring station set up near the survey site, ensuring real-time observation and control in accordance with maritime safety regulations.

The use of a tilted MBES offers several key advantages over traditional beam-steering methods. One of the most significant is the optimised beam alignment, which allows the sonar to strike the quay wall most effectively. This minimises distortions commonly caused by the incidence angle on vertical surfaces, resulting in more accurate data. The tilted configuration also captures enhanced detail, detecting small cracks, signs of erosion and structural anomalies that could be missed with standard setups.

Additionally, the simplicity of the tilted MBES reduces the need for complex beam-steering algorithms, making it easier to operate in confined harbour spaces without sacrificing data quality. The system offers considerable cost and time efficiency too.

Data processing, analysis and modelling

The MBES data was processed using BeamworX AutoClean software, streamlining the removal of noise and artefacts, and producing a clean dataset ready for analysis. A grid with 15 cm resolution was applied to create a detailed 3D model of the quay wall and surrounding seabed (Fig. 2). The model revealed critical details such as structural deformations and underwater obstructions, aiding in maintenance planning.

The tilted configuration of the MBES proved especially beneficial in the creation of the 3D model. With the sonar beams directed towards the quay wall at an optimal angle, the system captured surface features more accurately than traditional methods. The survey extended 0.9 metres below the water surface, providing a comprehensive view of the wall's condition (Fig. 3). This high-resolution dataset was instrumental in identifying potential weak points that could compromise the wall's structural integrity if left unaddressed.

While the summer survey focused on the application of a tilted MBES and USV to acquire quay wall data, future developments could further enhance the 3D modelling capabilities by incorporating above-water sensors like LiDAR to create a unified model that spans from the seabed to the structures above the waterline. LiDAR, captures precise 3D data of objects and surfaces in real-time, enabling comprehensive surveys of port infrastructure, including vertical walls and surrounding features that rise above the water.

The »Autonomous Surveyor« USV is particularly well-suited for this integration due to its stable, flat design, allowing for the simultaneous mounting of both sonar and LiDAR systems. The fusion of these two data streams – MBES for underwater features and LiDAR for above-water structures – provides a seamless, full-profile model of the quay wall. This can improve both maintenance planning and structural integrity assessments, covering potential areas of concern from the bottom of the quay wall up to overhead components like cranes or fenders.

LiDAR's independence from light conditions ensures reliable operation in low-visibility environments or challenging weather, which is often critical in port surveys. The ability to match LiDAR data with underwater sonar data in real time – using integrated software systems like those in development at Subsea Europe Services – further enhances the accuracy of the survey and provides a holistic view of the area being inspected

Sensor and autonomous platform integration

The combination of the R2Sonic 2026 V+ multibeam echo sounder and the Martac USV presents a unique solution that significantly enhances the efficiency, flexibility and quality of marine surveying. The primary benefit of using a tilted MBES on a USV was the ability to perform high-precision surveys in difficult-to-reach areas without compromising data quality, however, one of its most

notable advantages is the system's ability to be rapidly deployed to any port or harbour across Europe.

Unlike traditional survey vessels that require extensive planning, crew and logistical support, this system can be transported by a van and trailer, allowing for swift setup on-site. This capability is particularly beneficial for time-sensitive operations, such as urgent inspections or when quick data collection is essential. It eliminates the delays associated with larger, more cumbersome survey vessels.

Another standout feature is the Martac USV's durability and performance in rougher weather conditions. Designed for harsh offshore environments, the USV continues to operate efficiently even when weather conditions become challenging, a limitation that often hampers the performance of other USVs or manned survey vessels. This robustness ensures that survey operations can proceed without interruption, regardless of external conditions. Whether it's calm waters or more turbulent offshore environments, the system maintains a consistent level of precision and efficiency.

Selecting the R2Sonic 2026 V+ offers the highest resolution in shallow water MBES systems currently available. The level of detail it captures makes it ideal for surveys that demand exceptional accuracy. Whether assessing the condition of port infrastructure or mapping vertical structures, the system excels in detecting even the smallest anomalies, such as cracks, erosion or deformations that might otherwise go unnoticed. This combination of high data density and quality ensures that the survey results are both precise and reliable, enabling better decision-making for maintenance and infrastructure planning.

The integration of the chosen MBES and an advanced USV enables high-precision surveys in hard-to-reach areas without sacrificing data quality, while offering significant cost savings compared to a fully crewed approach on a standard survey vessel achievable. Further, the potential for a seamless integration of additional sensors, such as LIDAR, creates a comprehensive framework for geophysical surveys above and below the water surface. With easy deployment and exceptional data resolution, the system offers a complete solution that outperforms traditional methods.

Ultimately, for ports, harbours and coastal infrastructure projects that require accurate, reliable data in challenging environments, it reduces costs, minimises risk and extends operational weather windows. //

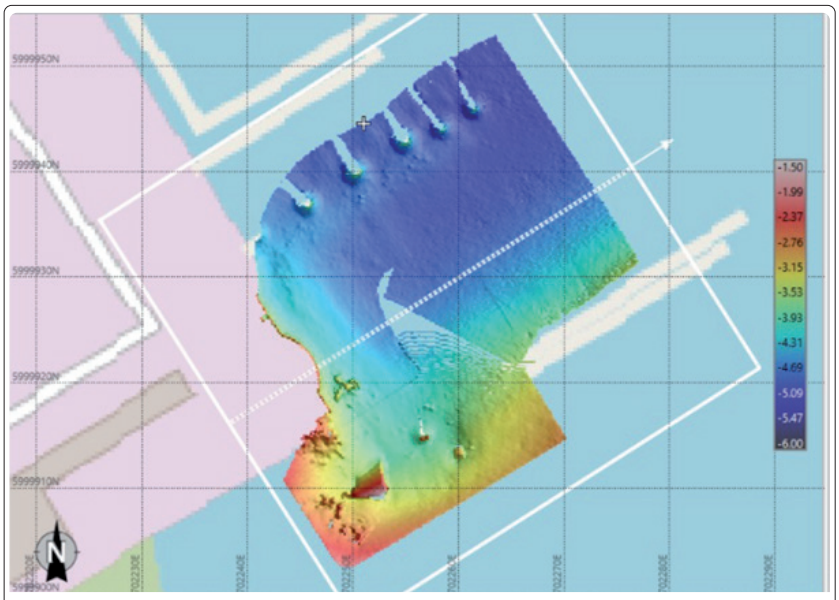


Fig. 2: A 3D model of the whole area showing the wall, pillars and other objects on the seabed was created

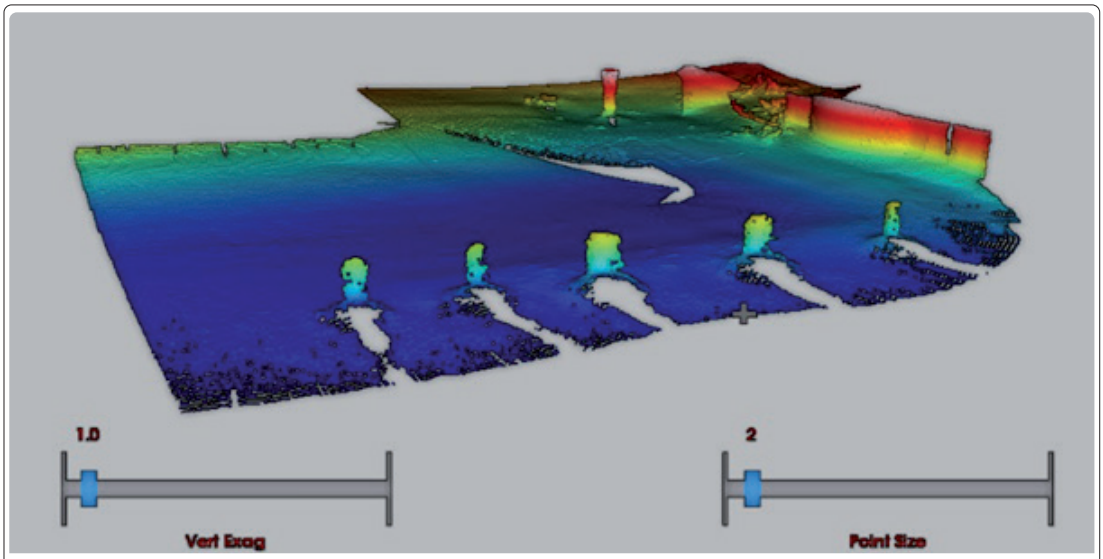


Fig. 3: The multibeam depth was 0.6 m below the water surface, and with the 25° tilt, the quay wall up to 0.9 m below the water surface was reached