Operational Constraints for Snapback Arresting Structures: Under-Berth Protection at BMA Hay Point

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Abstract

This paper analyses the operational requirements and installation constraints that can determine the feasibility of snapback arresting structures across various maritime applications, with particular focus on a case study involving the temporary under-berth protection implemented during maintenance operations at the BHP Mitsubishi Alliance (BMA) Hay Point Coal Terminal in Queensland (see Figure 1).

The research presented is grounded in observations and data collected from both current and previous projects involving the design, testing, and full-scale implementation of arresting structures. Drawing on real-world project experience, the study demonstrates how end-user operational requirements fundamentally shape both the engineering design process and the practical implementation of these systems. Specifically, the case study examines a flexible snapback arresting structure developed for pile refurbishment in active berth environments, where continuous operations must be maintained with minimal or no shutdowns, even during maintenance activities conducted within potential snapback zones.

Figure 1 Snapback roller deployment system concept - Vollebregt J, (2023); Hay Point Coal Terminal under-berth work zone - BMA (2025)

The case study systematically categorises the critical operational parameters that dictate arresting structure feasibility in this application for BMA: protection coverage across distributed work zones; environmental resilience against maritime conditions; operational visibility requirements; installation footprint limitations; equipment access constraints; structural integration with existing infrastructure; geometric adaptability; rapid deployment using an innovative roller system; demobilisation capabilities during extreme weather events; and efficient transfer between sequential work zones, all whilst prioritising uninterrupted facility operations throughout the maintenance campaign.

Through analysis of the BMA Hay Point Coal Terminal case study, this paper outlined how user-centred design principles were applied in developing a temporary snapback arresting structure to provide equivalent protection to permanent installations, whilst addressing the unique operational challenges of under-berth environments. Throughout the design process, decisions were made to balance installation and operational constraints with performance requirements, and comprehensive full-scale testing validated the unique features of the solution.

This work establishes a framework for evaluating installation and operational feasibility factors of arresting structures across different maritime applications, providing a methodological approach for developing application-specific designs based on end-user requirements.

Keywords: Snapback protection; maritime safety; under-berth maintenance; operational constraints; rapid deployment systems

1. Introduction

Snapback events (ref. Figure 2) from mooring line failures can cause severe injuries, fatalities, and major operational disruptions. Addressing this hazard requires a layered safety approach, with arresting structures as a critical last line of defence. While the technical performance of arresting structures is well established (Keane R, (2024) "Snapback Characterisation for Arresting Structure Design", real-world application demands balancing engineering with practical constraints such as space, environment, and ongoing operations.

Figure 2 Severity of snapback illustrated: vehicle door struck by line at ~770 km/h, causing catastrophic damage - HSLP, (2025).

Every port presents a unique set of operational constraints that guide both the design and successful implementation of arresting structures. Each solution must be tailored to provide protection without disrupting daily port activities. This can be particularly challenging in areas where space is limited and maintaining easy access for mooring activities is critical for continued operations.

This paper demonstrates how operational, installation, and environmental factors can influence the feasibility of snapback arresting structures, focusing on the BMA Hay Point Coal Terminal as a case study to develop a practical framework for effective, site-specific solutions.

2. Project Background

For this project, BMA needed to conduct critical pile remediation and protective coating work beneath the berth, requiring around 60 personnel to work directly under tensioned mooring lines (ref. Figure 3), areas identified as high-risk snapback zones. The work is scheduled to begin between FY25 and FY28.

Figure 3 A typical under berth area at BMA Hay Point where the pile refurbishment work is required – Keane R, (2023)

Due to the risk of snapback, it was determined that, without sufficient controls, the work could not be completed without a major shutdown. The estimated shutdown duration was 12 weeks, equating to a predicted loss of 1.34 million tonnes, nearly $195 million USD. For BMA, these losses were untenable. To avoid such losses, the goal was established to implement adequate risk mitigation controls, including an arresting structure within the work zone, that would enable the work to proceed while keeping production online (ref. Figure 4).

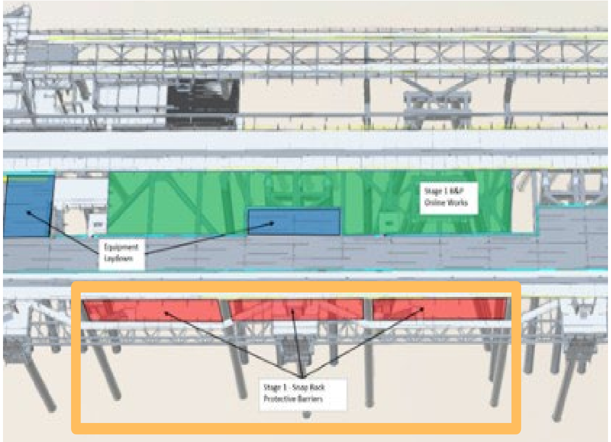

Figure 4 Online work (green zone) can be carried out safely using the proposed snapback arresting structure (red zone) and maintaining a 2–4 m keep-out zone – BMA, (2023)

Previous experience had shown BMA that broader adoption of arresting structures could be limited by challenges in installation, adaptability, and integration of these structures with ongoing operations. Recognising this, the project focused on developing a flexible, temporary snapback arresting solution that could protect personnel without disrupting maintenance or terminal activities. This approach offers a new standard for balancing safety and operational continuity in high-risk maritime environments.

3. Risk Acknowledgment and Understanding

Acknowledgment of risk is the first step in any risk mitigation exercise. For BMA, a previous event in 2021 prompted a project to design and validate an arresting structure (Smith A.S, 2021, “BHP Mitsubishi Alliance Snapback Barrier System Validation Testing”), bringing this risk clearly to the forefront. However, for many ports, risk acknowledgment can be constrained by siloed responsibilities and fragmented communication between stakeholders. For example, separate teams may be responsible for mooring operations, maintenance, engineering, major projects, health and safety, and production, with each function often operating independently. Additionally, shore-side and vessel-side risks are frequently managed separately, even though these risks are equally applicable. These gaps in communication and responsibility can lead to under-reporting of near misses and underestimation of snapback hazards.

A thorough understanding of these risks is equally important. The causes of line failure, such as environmental conditions, poor tension management, mooring configuration, human error, mechanical faults, and especially suboptimal mooring geometry, must be identified and analysed. Industry guidelines such as MEG4 recommend a D/d ratio of 15:1 for optimal line strength and lifespan, but this generally assumes the use of wire ropes and high modulus polyethylene (HMPE) lines. Conventional synthetic fibre lines, which generally have larger diameters, combined with smaller fairleads due to space and hardware constraints (typically 350 to 450 mm), usually result in much lower operating D/d ratios, increasing the risk of line failure. Lower D/d ratios can cause line rupture down to 50% of their Minimum Breaking Load (MBL), as indicated by typical guidance from line manufacturers (ref. Table 1).

Table 1 Practical implications of MBR vs. theoretical breaking load of an 85t mooring line - Poulter B, (2025)

D/d Ratio	MBR (Factor × Rope Diameter)	Rope Manufacturer's General Recommendations	Theoretical Line Efficiency (according MBR)	Theoretical Breaking Load of 85T MBL line (according MBR)	Suitability for Mooring
5:1	2.5 × Diameter	Below lowest MBR of 3 and not recommended for any applications	40-50%	~34-42.5T	Not recommended for any applications
6:1	3 × Diameter	Light-duty, static loads, occasional redirection.	50-60%	~42.5-51T	Not recommended for mooring
10:1	5 × Diameter	Heavy-duty, moderate dynamic loads.	70-85%	~59.5-72.25T	Suitable for mooring with heavy loads with moderate dynamic applications.
15:1	7.5 × Diameter	Heavy-duty, critical dynamic applications.	85-90%	72.25-76.5T	Recommended for mooring with heavy loads with critical dynamic applications

Critically, this value aligns with the Working Load Limit (WLL) recommended in mooring guidelines such as MEG4 (Section 5.2.1), which specifies the WLL as 50% of the ship design MBL for synthetic lines. This means that when lines are subjected to dynamic tensions and sharp angle redirections around fairleads with D/d ratios of 5 or 6, failure can occur as tension approaches the WLL (ref. Figure 5), placing the line at high risk.

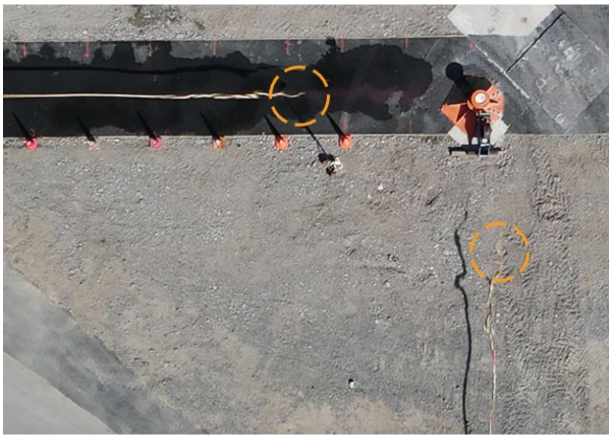

Figure 5 85t, 72mm, mixed PP/PE mooring line failed at 51% LDBF (D/d 5:1); each end travelling at 150 km/h, representing failure towards both vessel and shore sides - HSLP, (2025)

This correlation has been verified both by industry members, particularly for dry bulk and container terminals, where such conditions are common (ref. Figure 6).

Figure 6 Typical fairleads on dry bulk vessel which could be classed as sub optimal when discussing D/d ratio - BMA, (2021)

Without systematically recognising and quantifying risks, the severity of snapback hazards can be dangerously underestimated, leading to insufficient controls and increased risk of injury. Therefore, identifying and fully understanding these complex risks is essential for effective mitigation, as detailed in the following section.

4. Hazard Identification and Risk Assessment

Once the risk has been acknowledged, a comprehensive risk assessment, combining site inspections, incident reviews, and stakeholder engagement is essential to identify hazards and define control measures following industry best practice. Both preventative and consequence reduction strategies should be developed, using the hierarchy of controls (ref. Figure 7).

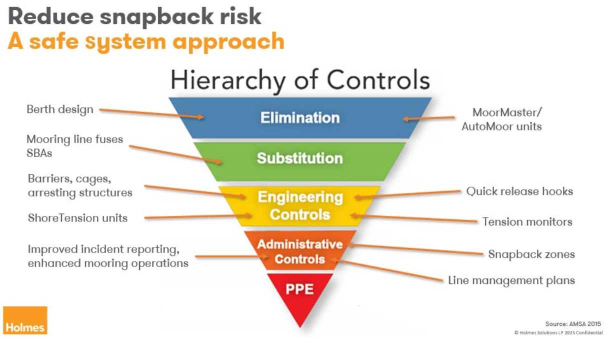

Figure 7 Hierarchy of controls diagram with marine examples - Australian Maritime Safety Authority, (2015)

Validated engineering controls, like snapback arresting structures, provide a crucial final layer of protection. BMA's risk assessment process involved identifying, evaluating, and mitigating risks through multiple controls including a validated arresting structure.

Since each port has unique circumstances, risk controls, especially snapback arresting structures, must be tailored to specific operational needs. The following sections discuss how these solutions might be effectively customised for different port environments.

5. Mapping Operational Constraints

Proven technical performance for any snapback arresting structure is vital for ensuring the protection as intended. However, viability and long-term success relies on the arresting structure addressing each port's specific operational needs. A "one-size-fits-all" approach is rarely effective; solutions must be both practical and robust, integrating smoothly with ongoing activities.

Factors such as maintenance schedules, installation windows, access, and workflow can all affect the practicality and reliability of an arresting structure. These factors often differ based on the operational context, including port activities, vessel types, and facility layout. For example:

- **Cruise Vessel Terminals:** Require temporary passenger disembarkation areas and flexible access for varying vessel sizes.
- **Dry Bulk Terminals:** Require production to be maintained, ship loader movement enabled, and often have complex infrastructure with limited footprints.
- **LNG Terminals:** Require management of high-consequence ship-to-shore transfers, often within constrained zones.
- **Container Terminals:** Require ship-to-shore crane movement, quay line protection, and accommodation of berth traffic.
- **Multiuse Ports:** Require quick and easy adaptability for continuously changing work zones.
- **Commercial Tenants:** Require permanent separation of berth operations from their work zones and secure storage.
- **Public Areas:** Require permanent isolation of mooring equipment, protection against snapback hazards, and enhanced security.

Within their operational context, each port typically faces a unique set of site-specific constraints. Alongside technical performance considerations, addressing these constraints supports the successful implementation of any arresting structure design. When mapping operational constraints, it can be useful to group them into broad categories to ensure more systematic consideration throughout the design process. To support a comprehensive approach, these constraints, together with broad requirements and other considerations for the arresting structure, can be categorised and addressed as part of the design process. Key categories can include:

Operational: When in service the arresting structure must integrate seamlessly with existing operations and minimise disruption during mooring activities, initial installation, and any subsequent mobilisation or demobilisation activities as required, while also addressing specific operational needs such as being relocatable, providing access points if necessary, and maintaining high visibility for effective operational supervision.

Coverage and Placement: The arresting structure must ensure adequate coverage at and across all areas requiring hazard protection, taking into account berth geometry, line angles, and other site-specific vulnerabilities. It should maintain continuous protection throughout hazard zones by eliminating gaps and ensuring effective performance at zone boundaries and end-of-field locations. Arresting structures should be positioned as close as practicable to likely failure points to minimise impact severity.

Installation: The design of the arresting structure should consider installation constraints, including access limitations, the need for specialised installation equipment, site handling capacity, and size limits, as well as available footprint, aesthetics, and mounting requirements, all of which may affect choice of component sizes and weights. The arresting structure must also accommodate varying berth infrastructure geometries to maintain effective coverage across diverse areas.

Structural: The design of the arresting structure must consider the structural capacity of supporting surfaces on existing infrastructure, ensuring that they can safely accommodate the combined loads resulting from the dead weight of the arresting structure, wind loads, and impact loads from a snapback, while maintaining structural integrity and safety.

Environmental: The arresting structure must have metocean resilience by utilising corrosion-resistant, rated components capable of withstanding saltwater, humidity, temperature extremes, and strong winds, thereby supporting long-term reliability.

The BMA Hay Point case study demonstrates how this framework was applied to develop an arresting structure solution that effectively manages snapback risk while addressing site-specific constraints.

6. BMA Case Study: Mapping Operational Constraints

6.1 Operational

The operational needs at BMA Hay Point played a significant role in shaping the design of the arresting structure. Specifically, there were key requirements that needed to be met to ensure the effective in-service operation of the arresting structure for this this particular application. Site specific constraints included:

Scheduling: Installation of the arresting structure was limited to scheduled maintenance outages, requiring the setup of ~50 m x 7 m (3 bays) in under 5 days. This tight window meant using pre-assembled (ref. Figure 8), modular components for rapid, staged deployment and to avoid extended shutdowns.

Figure 8 Snapback arresting structure components ready for installation at the lay down area at Hay Point - Poulter B, (2025)

Rapid Mobilisation and Demobilisation: The arresting structure needed to be quickly removable for sudden operational changes or extreme weather. Easily removable connections, flexible mesh, and an innovative roller system (ref. Figure 9) enabled a small team to roll up the structure, minimising its exposure, using a simple hand tool and rope access.

Figure 9 Snapback protection roller system being retracted to demonstrate rapid operation - Keane R, (2024)

Efficient Transfer Between Work Zones: The arresting structure needed to be easily relocated, progressing onto the next work zones during scheduled outages. Lightweight, modular parts enabled a 5–6-person team (ref. Figure 10) and a Franna (small pick-and-carry crane) to manually handle components. Fully retracted, the roller design compacted a 6.2 m wide x 7 m high, ~500 kg arresting panel into a 600 mm diameter by 6.2 m section, allowing easy movement without the need for a heavy lift crane. This compact design was essential given limited berth access and existing infrastructure.

Figure 10 Rope access team during installation of the snapback arresting structure – BMA, (2024)

Visibility: Maintaining clear operational visibility through the arresting structure was essential, especially for personnel working beneath the berth. The rhomboid mesh structure allows clear visibility and does not block sightlines, helping keep all workers in the area safe by ensuring they can see and react to any potential hazards quickly (ref. Figure 11).

Figure 11 Mesh installed across several bays has a low impact on visibility for all end users – BMA, (2024)

6.2 Coverage and Placement

Optimal coverage and placement of the arresting structure at BMA was determined by first mapping snapback hazard zones (ref. Figure 12), informed by previous work at BMA (Hodgins K, (2023) "Validating Snapback Risk"). Detailed analysis of vessel and berth geometry, including vessel size and draft, was conducted to determine likely impact angles (ref. Figure 13), whilst probable rupture points informed the expected length of parted lines.

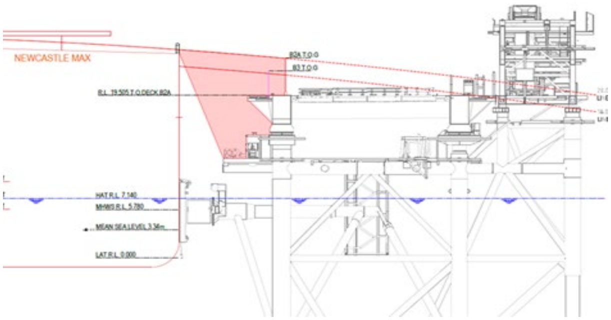

Figure 12 Identified snapback hazard zones at Hay Point – BMA, (2024)

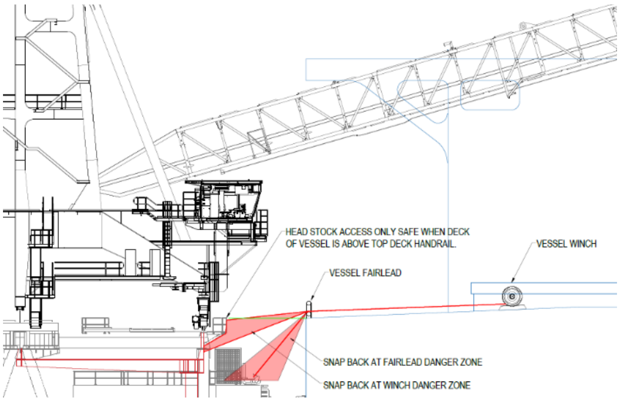

Figure 13 Potential snapback paths intersecting the berth 3 infrastructure at Hay Point – BMA, (2024)

Mooring configurations (breast, spring, head, and stern lines) were evaluated to identify likely snapback paths and define the widest potential hazard zones (ref. Figure 14).

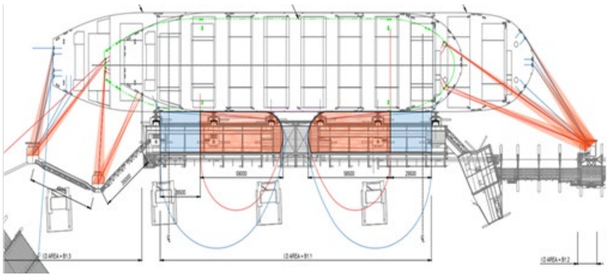

Figure 14 Plan view of an overhead mooring configuration at berth 3, Hay Point – BMA, (2024)

Site specific constraints included:

Working Areas Requiring Protection: Hazard zones were overlaid with maintenance areas, resulting in an arresting structure covering three bays (about 50 m x 7 m). The mesh's high strength-to-weight ratio and low wind resistance minimised demands on surrounding infrastructure. The structure was engineered for consistent protection up to the edges, with minimal gaps, robust end-field strength, and strong edge connections. Flexible panels prevented debris and secondary hazards. Deflection during impact was limited to 1.5 m, maintaining a safe working width for pile access.

Location of Installation: Previous research (Hodgins, K. (2023), "Validating Snapback Risk") demonstrated that installing the arresting structure as close as practicable to likely failure points along the quay line is highly beneficial to its performance. Positioning the system near these points minimises the potential 'whip effect,' thereby reducing impact severity in the event of a line failure. Strategic placement also ensured the structure did not interfere with essential berth operations or maintenance tasks, further optimising both safety and workflow efficiency.

6.3 Installation

Installation of the arresting structure in the under-berth environment at BMA presented significant challenges. There was limited space for mounting the structure, restricted access for heavy install equipment, and the necessity to avoid interference with existing infrastructure and services. Site specific constraints included:

Access Limitations: Restrictions existed on bringing in heavy components or large specialised equipment for installation, requiring solutions (ref. Figure 15) that could be handled manually or with minimal equipment. This required smaller modular, lightweight components that could be transported and assembled by a small team.

Figure 15 Compact snapback solution installed below existing upper deck grating – BMA, (2024)

Footprint: The limited installation space required a compact system that still provided full coverage across large work zones. The design ensured no gaps or vulnerabilities at the ends, maintaining comprehensive protection (ref. Figure 16).

Figure 16 Continuous snapback system neatly installed between rail girder beams – BMA, (2024)

Adaptability: The installation had to be flexible to accommodate varying under-berth geometries and shifting work zones. The design allowed the structure to be effectively deployed around different infrastructure configurations. (ref. Figure 17)

Figure 17 Traversing support beams were accommodated using saddle bracketry and infill panels – BMA, (2024)

6.4 Structural

Structural factors were central to the design. The under-berth environment required thorough evaluation of girders, piles, and headstocks to ensure they could safely support both the weight and dynamic loads from a potential snapback event. Structural assessments included analysis of environmental, operational, and impact loads gathered during testing (ref. Figure 18) to confirm the combined effects would not jeopardise the supporting structure.

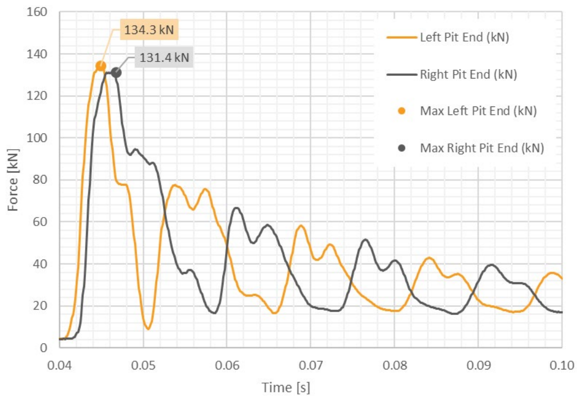

Figure 18 Peak loads for bottom wire rope connection recorded during testing - Keane R, (2024)

Load demands and factors of safety were rigorously applied using established engineering principles and safety factors as shown below for different load cases:

- **Operational Limit State (including impact):** 1.2G (dead load) + Wop (operational wind load) + 2FIMP (double the maximum impact force)
- **Serviceability Limit State:** G (dead load) + WSLS (serviceability wind load)
- **Ultimate Limit State:** 1.2G (dead load) + WULS (ultimate wind load)

Assessment steps included reviewing structural drawings and consulting manufacturer data for hardware strength. Mounting methods that avoided permanent alteration, along with effective load distribution, minimised impact on the berth and protected key infrastructure such as the shiploader rail. This approach ensured both personnel safety and long-term port infrastructure integrity.

6.5 Environment

Environmental durability was essential for the BMA arresting structure (ref. Figure 19). The design addressed saltwater, humidity, temperature cycles, wave impacts, marine debris, and high wind speeds, using corrosion-resistant and UV-stabilised materials with protective coatings for a minimum three-year service life and low maintenance. Porosity of the mesh and streamlined design reduced wind load, ensuring robust protection for both personnel and infrastructure under serviceability and ultimate limit states.

Figure 19 Hay Point metocean conditions - Poulter B, (2025)

7. Technical Performance

The technical performance of an arresting structure is defined by its ability to reliably protect personnel and infrastructure under extreme conditions. The structure must be capable of capturing and containing parted mooring lines during worst-case snapback events, isolating workers from this hazard while avoiding the creation of secondary risks such as debris and maintaining structural integrity under dynamic impact loads.

When designing an arresting structure capable of containing parted mooring lines during worst-case snapback events, several technical considerations must be addressed to ensure both safety and functionality under real-world conditions. The most critical aspects influencing the technical performance of the arresting structure include:

Impact Severity: When designing an arresting structure, the impact force or impact severity generated by a failed mooring line under worst-case scenarios is considered, with limit states philosophy used to set upper limits (typically at or above the 95th percentile). For BMA, key assumptions and input parameters were selected in order to represent the worst-case snapback event, along with the associated outputs. The following summarises the main parameters and resulting outputs considered in the analysis:

Inputs

- **Tension at failure:** Set at 50% of the Line Design Break Force (LDBF) for synthetic lines, aligning with the typical Working Load Limit (WLL) and representing the most probable worst-case load.
- **Mooring configuration:** The spring line was selected, as it was most likely to result in the highest snapback risk in terms of path and velocity.
- **Line type:** A conventional synthetic fibre (polypropylene) line with a LDBF of 85 tonne was selected due to its high elasticity and energy release upon failure.
- **Distance of arresting structure from rupture:** Set at approximately 19 metres, as this was the closest practicable position for the arresting structure to the probable rupture point. This, combined with the tension at rupture and the mooring configuration, directly influenced the resulting tail length and impact severity.
- **Critical impact point (CIP):** Targeted to ensure that impact from the failed mooring line occurred in the most vulnerable locations of the structure.

Outputs

- **Tail length upon impact:** Targeted at 2–3 metres, as this typically resulted in the highest impact velocity and event timing. Tail length was determined by the selected mooring configuration, line type, rupture location, and the distance from rupture to the arresting structure.
- **Design velocity of elbow at impact:** Targeted at 700 km/h ± 50 km/h, as determined by the combined effects of tension at failure, tail length, rupture location, distance from rupture, line type, and mooring configuration.

These outputs represented a selection of key characteristics that could arise as a direct result of the input parameters. Collectively, these factors set the upper limit for a worst-case event for BMA and design velocity for the arresting structure. It should be noted that there are additional characteristics that occur during a snapback event which directly affect severity and, consequently, the performance of the arresting structure (Keane, 2024). The identification and consideration of these ensure that the design of the arresting structure meets technical performance requirements whilst also addressing site-specific risks and operational needs.

Performance Zones: Previous testing and simulation have shown that, particularly for flexible or semi-flexible arresting structures, different areas of the structure (see Figure 20) respond differently to impact. Specifically, the central zone (Zone 1), which is furthest from edge constraints, is typically more flexible and can arrest snapbacks with higher velocities. In contrast, the boundary zone (Zone 2), located near the edges and closer to fixed constraints, becomes stiffer and arrests snapbacks at slightly lower speeds. As a result, the expected performance of Zone 2 typically determines the limiting design velocity for the structure.

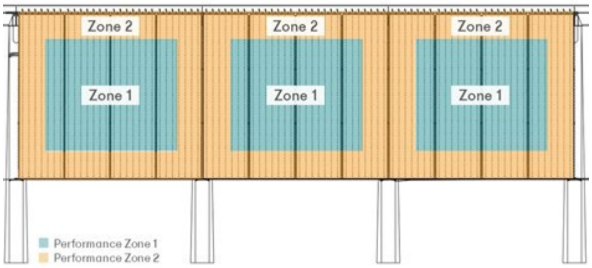

Figure 20 Identified performance zones (high deflection vs. more rigid) of a snapback arresting system – Keane R, (2025)

Boundary Connections: Continuous coverage with robust end-field and panel-to-panel connections is essential to prevent snapback risks at boundaries (ref. Figure 21), which are prone to stress concentrations and potential failure. The system must maintain consistent protection across all impact zones.

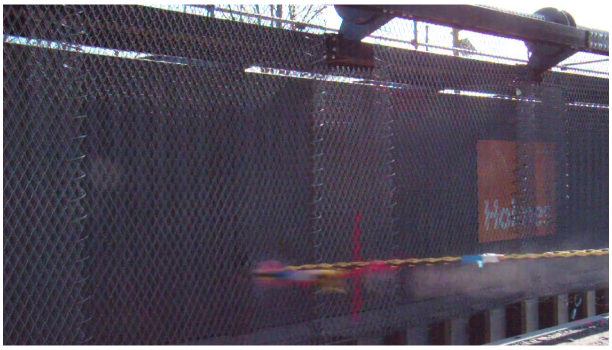

Figure 21 Zone 2 Boundary condition impact during testing – Keane R, (2024)

Safe Working Widths and Debris Management: The structure must allow safe operations behind it, controlling deflection under impact and preventing debris generation. Effective containment ensures personnel and equipment remain protected from hazardous projectiles. For BMA, the safe working width was selected as 1.5 m. Subsequently this was validated through testing (ref. Figure 22).

Figure 22 Deflection of arresting structure observed during testing – Keane R, (2024)

Berth Interface, Foundations and Fixings: Anchors and connections must safely transfer dynamic loads to the supporting structure, meeting

Ultimate and Serviceability Limit State (ULS/SLS) criteria (ISO 2394). Edge connections are especially critical under dynamic loads.

8. Compliance and Validation Pathway

Snapback arresting structures are designed to protect employees and ensure a safe work environment. Although no dedicated standards or specifications currently exist, frameworks from analogous structures, such as roadside safety barriers, carpark barriers, occupant protection systems, and rockfall protection barriers, can be referenced to ensure robust and safe design. Construction and installation activities are conducted in accordance with relevant standards.

8.1 Testing

Integral to these frameworks is the validation of system performance, which is principally achieved through physical testing with defined evaluation criteria to demonstrate safety and reliability. Calibrated computer simulations may also be used to assess design variations, enabling interpolation of performance outcomes but, generally, not extrapolation. Table 3 summarises comparable validation approaches.

Table 2 Analogous performance validation and approval frameworks - Poulter B, (2025)

Product Framework	Performance Requirements	Energy Level (kJ)	Basis for Approval	Evaluation Criteria	Relevant Standard/Guideline
Roadside Hardware	High velocity vehicle impact	97 – 806	Full-scale testing	Structural adequacy, occupant risk, residual energy	AS/NZS 3845 series, MASH (2016), EN 1317:2010 series
Roadside Hardware	Computer simulation	—	Simulation validation	Model correlation to test results	NCHRP Report 179, CEN/TS 17342:2019
Carpark Barrier	Low velocity vehicle impact	4 – 36	Calculation or testing	Structural adequacy	AS/NZS 1170 series
Roll-over Protective Structure	Low velocity vehicle roll-over	~30*	Full-scale testing	Structural adequacy, occupant protection	AS 2294
Rockfall Protection Barriers	High velocity concrete block impact	85 – >4,500	Full-scale testing	Structural adequacy, personal/asset protection	ETAG 027
FIA Debris Fences	Debris/flying object containment	40 – 1,000	Testing/Calculation	Structural adequacy, debris containment	FIA 3502-2018

For BMA technical performance was confirmed through full-scale testing and simulation, ensuring the system performed as intended (ref. Figure 23).

Figure 23 Full-scale testing, snapback system successfully redirecting parted mooring line - Keane, R (2024)

9. Conclusion

Snapback events pose a serious safety risk in maritime environments, requiring robust and tailored solutions. The BMA Hay Point case study demonstrated that effective risk management needs an integrated approach, combining engineering performance with real-world operational requirements. The framework utilised in this project included:

- Risk Acknowledgment and Understanding
- Hazard Identification and Risk Assessment
- Mapping Operational Constraints
- Technical Performance
- Compliance and Validation Pathway

The resulting temporary arresting structure addressed key needs such as easy installation, adaptability, durability, and safe access, all whilst meeting strict safety standards.

The approach utilised in this project can be replicated at other ports to provide effective snapback protection with proven technical performance, whilst accommodating varying operational needs and site-specific constraints. This practical methodology supports wider adoption of snapback arresting structures as a standard engineering control, ensuring safer working environments across the maritime sector.

10. Acknowledgements

Holmes Solutions would like to acknowledge the teams at BMA and Geobrugg for their input and collaboration.

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13. UN SDGs

Installation of snapback arresting structures promotes SDG 8 by safeguarding workers during hazardous maintenance activities and advances SDG 9 by enabling innovative methods that extend the service life of critical infrastructure. This approach also supports SDG 12 by minimising resource consumption and environmental impact compared to full-scale replacement.