

CORE-LOC™ in Modern Coastal Protection: From Design Theory to Site Execution

An engineering deep-dive into CORE-LOC™ armor units — how interlocking geometry dissipates wave energy, how design translates into drawings, and what actually happens on an active breakwater slope.

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1. Introduction

Waves don't ask permission to hit the shoreline. Every coastline absorbs the force exerted by the waves relentlessly, without a homogeneous pattern. A single storm can displace multi-tonne concrete blocks with ease. The primary purpose of the breakwater is to dissipate these undesirable forces and also mitigate the silting action, thereby protecting the shore and facilitating smooth working conditions. At the heart of this defence is a simple idea turned into an engineering solution: to dissipate the wave energy rather than resisting it.

The insights presented draw on direct, on-site observation collected during a month-long internship at an active breakwater project.

1.1 The Role of CORE-LOC™ in Modern Coastal Protection

CORE-LOC™, as a single-layer armor unit, is designed to shield breakwaters, revetments, and other coastal structures from wave-induced erosion. Unlike older armor units such as ordinary rock armor or concrete cubes, which relied primarily on sheer mass to remain stable, CORE-LOC™ achieves stability through its interlocking property. This shift from mass-dependent to interlock-dependent design has made CORE-LOC™ one of the most material-efficient and resilient armor systems developed, and it sets the foundation for the design and site observations this article explores.

When compared to older armor units like Dolos, Accropode, and Tetrapods, CORE-LOC™ provides greater structural efficiency and minimised breakage risk.

2. Dissipating Force: The Engineering Principle Behind CORE-LOC™

At the core of CORE-LOC™'s design lies a single engineering principle: energy that cannot be stopped must instead be managed. Rather than resisting wave forces through sheer mass, CORE-LOC™ works by allowing wave energy to dissipate through the structure itself — passing through gaps in the armor layer, breaking apart, and losing force in the process. This shift, from resistance to dissipation, reflects a broader evolution in coastal engineering: the recognition that structures built to simply block the sea are often more vulnerable than those designed to work with its energy. The following sections examine how this principle translates into CORE-LOC™'s specific geometry and performance.

2.1 Brief History of CORE-LOC™

CORE-LOC™ was developed in the early 1990s by researchers Jeffrey Melby and George Turk at the U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center. Introduced through research published around 1994, the unit was engineered to optimise hydraulic stability, structural strength, and layer porosity, achieving reduced design stresses compared to earlier armor shapes while maintaining superior interlocking. Notably, CORE-LOC™ was also designed to interlock well with Dolos units, allowing it to serve as a repair unit on breakwaters where Dolos armoring had failed. Since its introduction, it has become one of the most widely adopted single-layer concrete armor units in coastal engineering.

2.2 Basic Design Principle of CORE-LOC™

CORE-LOC™'s design principle centres on interlocking geometry rather than mass. Each unit features an irregular, angular shape that, when placed in a single layer, naturally interlocks with neighbouring units to

form a continuous, porous armor layer. This interlocking action distributes wave forces across multiple units instead of concentrating stress on any single block, allowing the structure to dissipate wave energy through the porous layer while resisting displacement. The shape is also optimised to minimise material volume and casting space without compromising structural strength, making it both hydraulically efficient and cost-effective compared to older, bulkier armor units.

3. Where Theory Meets Site Conditions

CORE-LOC™ unit size is primarily determined by the site's design wave height, typically based on an extreme storm event with a 50–100 year return period. More exposed structures facing higher wave energy require larger, heavier units, while sheltered sites can use smaller ones. Structure height and slope further influence sizing, as taller, steeper structures experience greater wave run-up and impact forces. Stability formulas, calibrated through model testing, determine the precise unit mass required.

3.1 Precision in Apparent Disorder

CORE-LOC™ units are placed on a predefined staggered grid rather than truly at random — placement position is fixed, while unit orientation is varied to maximise interlocking contact between neighbouring units. CIRIA's Rock Manual (C683) specifies relative placing tolerances of 13–15% of the horizontal centre-to-centre spacing for CORE-LOC™ and Accropode units, with GPS-guided cranes typically used to maintain this accuracy. Special placement procedures are also used to guarantee contact with adjacent structures, such as crown walls, regardless of standard tolerances — since gaps at these boundaries risk unit rocking and breakage.

Staggered Placement Pattern (Illustrative)

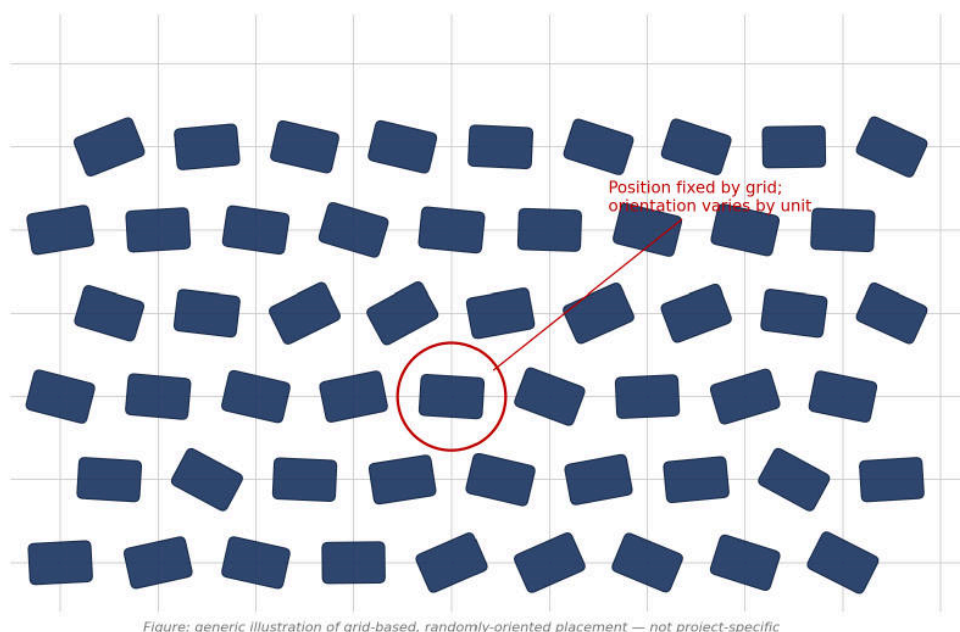


Figure: generic illustration of grid-based, randomly-oriented placement — not project-specific

Figure 1: Staggered placement pattern — illustrative, not project-specific.

3.2 Translating Design into Drawings

Design drawings for a breakwater typically specify CORE-LOC™ unit sizes across different sections of the structure, with larger units used where wave exposure is greatest and smaller units in more sheltered areas

— reflecting the sizing principle discussed earlier, where wave climate and exposure directly shape the specification for each section. Beyond unit sizing, these drawings also define key structural and tidal reference parameters: crest elevation, the top level of the structure, is set high enough above the Design High Water Level (DHWL) to control wave overtopping, while crest width provides adequate access and stability for maintenance and construction. These elevations are referenced against a fixed tidal datum, typically Chart Datum (CD) or Mean Lower Low Water (MLLW), ensuring consistency between design drawings, site surveys, and as-built levels. Alongside layout and elevation, a concrete mix design defines the strength and material composition required for casting, ensuring each unit meets the structural performance assumed in the design. Together, these drawings and specifications form the starting point for everything that follows on site.

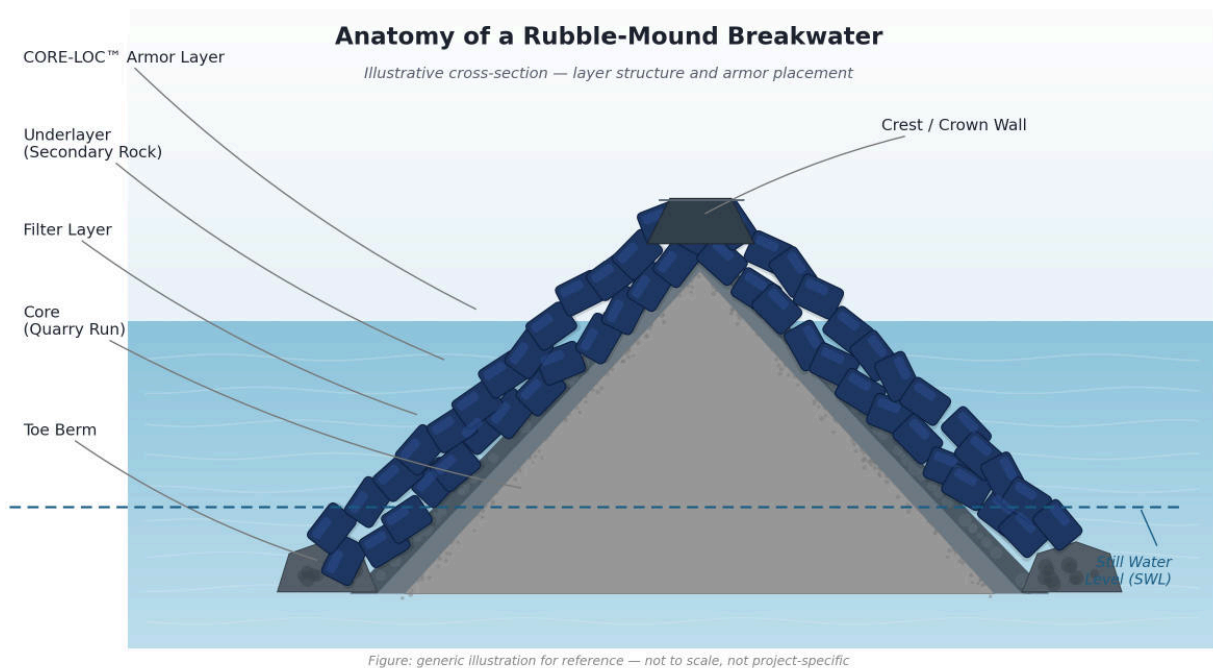


Figure 2: Anatomy of a rubble-mound breakwater — illustrative cross-section, not to scale.

4. Site Observations

A brief description of the site observations during the internship is set out below. It covers the equipment used on site, the mould used to cast CORE-LOC™ units, the casting and curing process, QA/QC compliance during concrete placement, and the curing method adopted — along with the technical specification requirements and adherence observed on site.

4.1 Construction Equipment Used on Site

a. Crane: The crane used on site was a Sany SCC1500A crawler-mounted lattice boom crane — a heavy lifting machine mounted on crawler tracks rather than rubber tyres. It was primarily used for lifting and positioning the CORE-LOC™ mould, lifting cast units from the casting yard to the stockpile, and placing units at their designated locations.

Crawler-mounted cranes are preferred for this kind of work over mobile truck cranes because the tracked undercarriage distributes load over a wider footprint, providing better stability on the uneven, often loose ground found in a casting yard or along an active breakwater slope. This stability is particularly important

when placing CORE-LOC™ units, since even small unintended movement of the crane base during a lift can translate into placement errors at the point of contact — directly affecting the tolerances discussed later in this article.

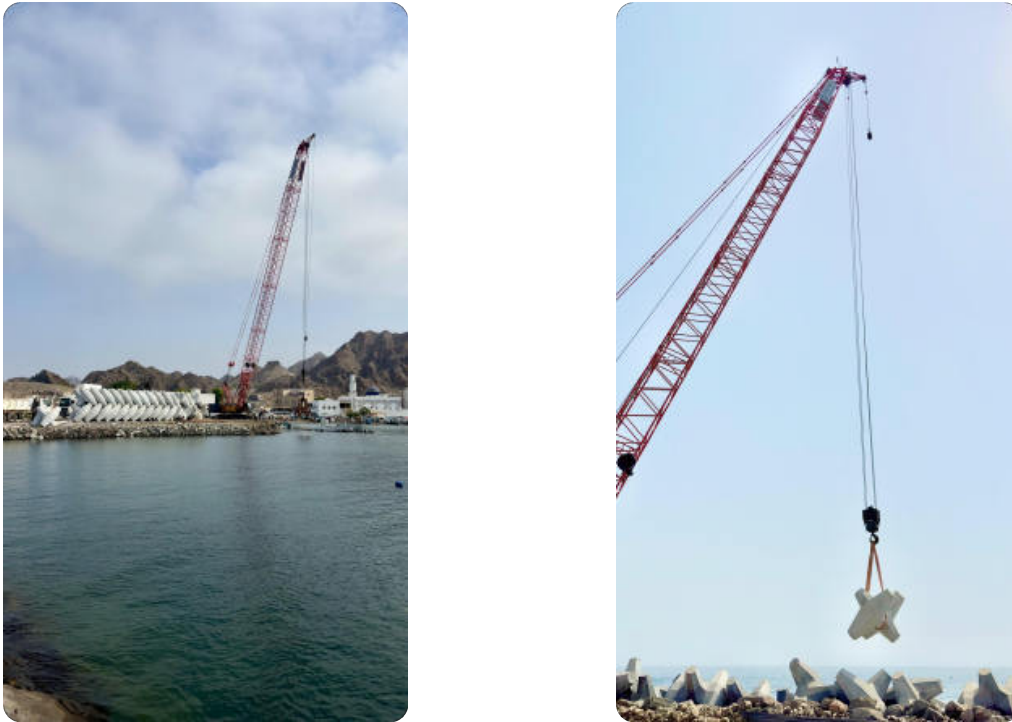


Figure 3: Crawler-mounted lattice boom crane lifting a CORE-LOC™ unit into position.

b. Front End Loaders (FEL): Also known as a wheel loader, a FEL is a wheeled machine with a bucket at the front, commonly rated by bucket capacity and engine power rather than lifting capacity, since its role is centred on movement and handling rather than precision placement. In CORE-LOC™ operations, it's used to transport armor units over short distances.

On this site, the FEL also played a supporting role in handling and moving units within the casting and stockpile yards — repositioning cast units after demoulding, clearing debris from the working area, and assisting with general material handling around the casting operation. It was also used to feed and manage aggregate stockpiles near the batching area, keeping material readily accessible for the casting programme without requiring constant crane involvement for routine yard work. Its manoeuvrability makes it well suited to the tighter, busier spaces of a casting yard, where a larger crane would be less practical for short, repetitive movements — freeing up the crane to focus on the higher-precision task of placing units on the slope itself.

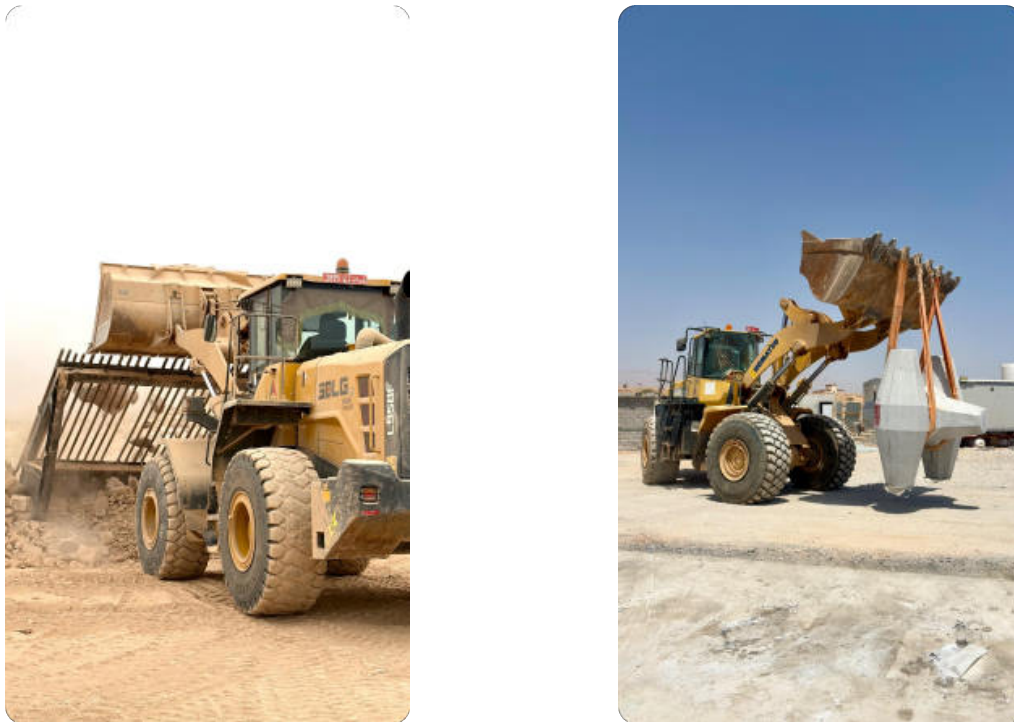


Figure 4: Front End Loaders handling material and CORE-LOC™ units on site.

c. Ready-Mix Transit: Its main purpose is to transport fresh concrete from the batching plant to the CORE-LOC™ casting yard. The fresh concrete is discharged into the concrete pump, which in turn facilitates placement of concrete inside the mould.

Because fresh concrete begins losing workability from the moment it is batched, transit time between the batching plant and the casting yard is a factor that has to be actively managed on site. Concrete arriving outside the specified temperature or slump range — as covered under the QA/QC checks below — is generally rejected rather than used, making the reliability and scheduling of ready-mix deliveries an important part of maintaining a consistent casting programme.



Figure 5: Ready-mix transit truck delivering fresh concrete to the casting yard.

d. Concrete Pump: A CORE-LOC™ mould has an irregular, interlocking shape, so a concrete pump is used to transfer fresh concrete from the transit mixer to the exact location required, through a pipeline connected by a flexible hose.

The pump's flexible hose is particularly important for CORE-LOC™ casting, since the mould's irregular geometry includes internal sections that would be difficult to reach by direct chute discharge alone. Controlled, consistent pumping also helps reduce the risk of segregation — where coarser aggregate separates from the cement paste — which is one of the defects the QA/QC checks that follow are specifically designed to catch.



Figure 6: Concrete pump transferring fresh concrete into the CORE-LOC™ mould.

4.2 QA/QC Checks Performed Prior to Concrete Placement

- **Temperature Check:** Prior to starting the concrete operation, the temperature of the fresh concrete is checked using a thermometer. The ideal temperature range is 20–32°C, preferably not exceeding 32°C.
- **Slump Test:** The fresh concrete is filled into the Abrams Cone in three layers, each tamped 25 times, and the slump is determined and checked against the required specification.
- **Cube Test:** The fresh concrete is poured into a 15×15×15 cm cubical mould in three layers, each tamped 35 times. Compressive strength is checked at various curing ages, with full design strength expected at 28 days.
- **Density Test:** The density of the fresh concrete is determined using a concrete density test container of known volume — the container is filled, compacted, levelled, and weighed.

4.3 Compaction and Curing of the Concrete for CORE-LOC™

The concrete is placed inside the mould in three levels and is continuously compacted from different positions using a needle vibrator, ensuring a homogeneous consistency is maintained before the initial setting time. Over-compaction can potentially lead to segregation of the concrete constituents.

To achieve the desired workability of the fresh concrete without increasing the w/c ratio, superplasticiser is used in the prescribed amount as per the mix design. For curing, the concrete surface is covered with wet hessian; the surface is later treated with a curing compound, as per the specifications.



Figure 7: Concrete casting into the CORE-LOC™ mould, and curing compound application after demoulding.

5. The Realities of Site Execution

No design, however precise, survives contact with a live construction site unchanged. Wave conditions shift with the season and tide, ground conditions vary along the length of a structure, and even the most carefully engineered placement tolerances must be verified and defended in real time. This section moves beyond the drawing board to examine the practical challenges of building a breakwater — from environmental constraints to placement accuracy — and the quality control measures that ensure design intent is preserved once construction begins.

5.1 Placement Tolerance and Alignment Challenges

Even with a predefined placement grid, maintaining accurate unit position and orientation on a live slope is harder than it appears on paper. Wave action, uneven underlayer surfaces, and multi-tonne unit weights mean small errors compound quickly, risking gaps or poor interlocking contact. CIRIA's Rock Manual limits relative placing tolerances for CORE-LOC™ units to 13–15% of centre-to-centre spacing — a tight margin once a unit is airborne.

These conditions also carry real risk for the workforce. Steep, uneven, and often wet slopes increase the risk of slips and falls, while working near suspended multi-tonne loads demands strict adherence to lifting plans, crane exclusion zones, and PPE. Tidal changes can further expose lower-slope areas to sudden inundation risk. Contact with adjacent structures, such as crown walls, adds a further technical challenge, since gaps at these boundaries risk unit rocking and breakage.

Breakage of this kind is one of the more visible consequences of placement or handling stress on CORE-LOC™ units. Because the unit derives its strength from a single, continuous concrete section rather than a bulkier mass, a chipped or fractured limb reduces both the structural integrity of that unit and its ability to interlock cleanly with its neighbours. Damaged units identified during placement or routine inspection are typically flagged for review, and depending on severity, may be repositioned, supplemented

with an adjacent unit, or replaced entirely to preserve the intended armor layer performance.

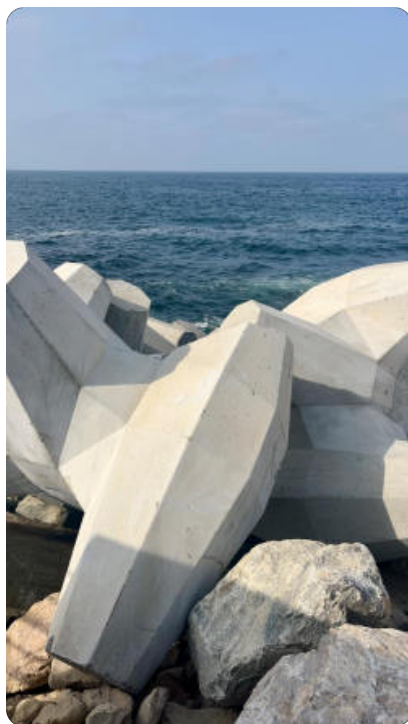


Figure 8: A CORE-LOC™ unit showing visible breakage at one limb — a practical illustration of the handling and placement stresses discussed above.

5.2 Environmental and Tidal Constraints

Oman's coastline, facing the Arabian Sea and Sea of Oman, experiences a semi-diurnal tidal regime with a typical tidal range of around 2 metres, alongside two distinct monsoon seasons that shape wave conditions throughout the year. The summer southwest monsoon (roughly June to September) brings strong, persistent winds and energetic sea states, with wave heights in the Arabian Sea reaching 6–7 metres during peak conditions, while winter brings comparatively calmer northeasterly wind patterns. These seasonal shifts directly influence construction windows — placement activities are typically scheduled around calmer periods and favourable tidal states, while monsoon season often restricts or halts marine construction altogether due to elevated wave energy and reduced site access. Tidal state also governs day-to-day access to lower sections of the slope, requiring work sequences to align closely with predicted tide tables rather than a fixed construction schedule.

5.3 Verification and Quality Control Measures

For the CORE-LOC™ units themselves, the primary quality control mechanism is a formal inspection carried out by the consultant, rather than the mechanical rock-testing regime used for armourstone. Each cast unit is visually and dimensionally inspected and classified into a grade — typically Grade A, Grade B, Grade C, or UI (Under Inspection) — based on surface finish, dimensional accuracy, and the presence or extent of any defects such as chipping or cracking. Units under the UI classification are held back from placement until the consultant completes a further review and assigns a final grade. This approach reflects the broader principle set out in CIRIA's Rock Manual (C683), which specifies that every precast armour unit be individually identifiable and screened for structural integrity, with any unit showing more than 10% loss of mass from breakage or defects discarded outright, and units between 1–10% mass loss rejected unless the loss falls below 5% and damaged units are not concentrated in one area. Alongside grading, each unit's weight is checked against the specified design weight — the Rock Manual itself calls for at least 2% of

production to be individually weighed, with actual mass required to fall within $\pm 2\%$ of the expected value — since a unit that is significantly under- or over-weight can affect both its hydraulic stability on the slope and its ability to interlock as intended with neighbouring units. Only units that pass both the grading inspection and the weight check are approved for transport to the stockpile and eventual placement.

The wider armor system also depends on the surrounding rock materials — the underlayer, filter layer, and core — which are subject to their own, separate testing regime as armourstone rather than precast concrete. Gradation tests confirm that stone sizes fall within the specified distribution, while density and water absorption tests verify mass and porosity properties relevant to hydraulic stability. Mechanical strength and durability are assessed through the Point Load Strength Index, the Los Angeles Abrasion Value (LAV), and the Aggregate Impact Value (AIV), while the Drop Test evaluates breakage resistance under free-fall conditions — each targeting a different aspect of how the rock will withstand handling, placement, and long-term wave action. Long-term durability against the marine environment is further verified through soundness testing — typically the magnesium sulphate or sodium sulphate soundness test (per EN 1367-2) — which simulates weathering from sea salt precipitation in intertidal and splash zones. Together with the CORE-LOC™-specific grading and weight checks above, this testing regime provides the full verification framework connecting material supplied on site back to the assumptions made in the original hydraulic and structural design.

6. A Month on the Breakwater

Watching CORE-LOC™ units move from engineering drawings to physical placement on an active breakwater offered a perspective no textbook could fully capture — the discipline required to translate precise design tolerances into real-world execution, under the constant influence of tide, weather, and the sea itself. This article reflects a small part of that experience, and hopefully offers useful insight to others encountering coastal armor unit design and construction for the first time.

About the Author

Nabeel Vellakutty Naushad is a civil engineering graduate (B.Tech, APJ Abdul Kalam Technological University) with hands-on experience spanning consultancy, airport infrastructure, and marine construction. He gained early exposure to civil and structural design, along with technical documentation processes, during his time with Arabian Gulf Engineering Consultancy. He went on to complete a civil/infrastructure engineering internship with Adani Airport Holdings Limited, followed by a one-month internship as a Civil Engineer Intern — Marine with Detonator Engineering Company Co LLC, contributing to marine construction works on an active breakwater project in Oman. Building on this diverse exposure across consultancy, design, and site execution, he plans to pursue an MBA, with the long-term goal of transitioning into real estate development — bridging technical construction knowledge with the financial and strategic dimensions of building the built environment.

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