THE HEAVYLIFT ENGINEER

...managing & delivering heavy lift projects

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FEATURE ARTICLES
- DESIGNING QUAYS FOR HEAVY LIFT AND PROJECT CARGO USE
- DESIGN AND BUILD OF LIFT BEAMS
- AN INSIGHT INTO ANCHOR SELECTION
- FACTORY ACCEPTANCE TESTING (FAT)

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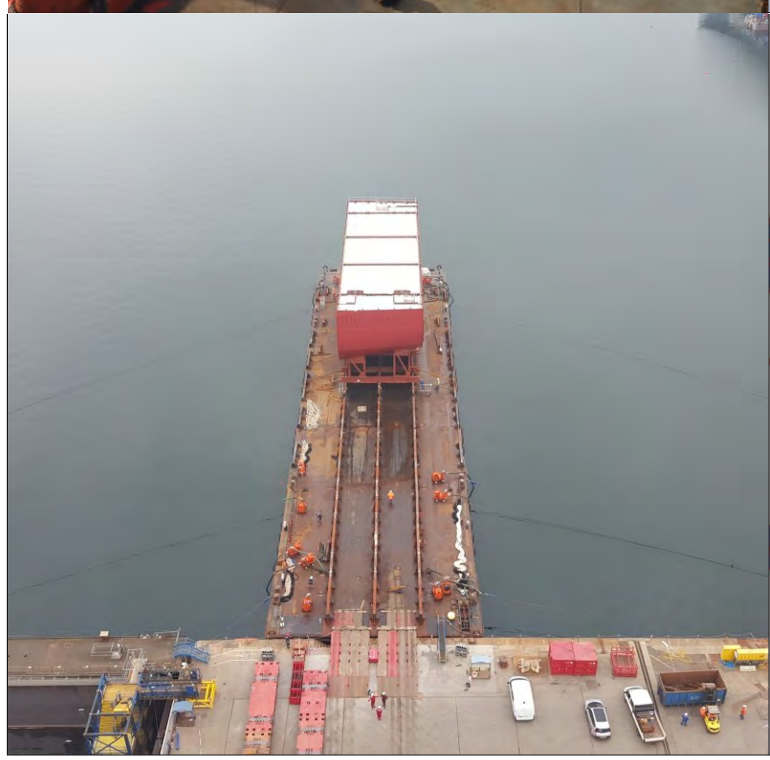

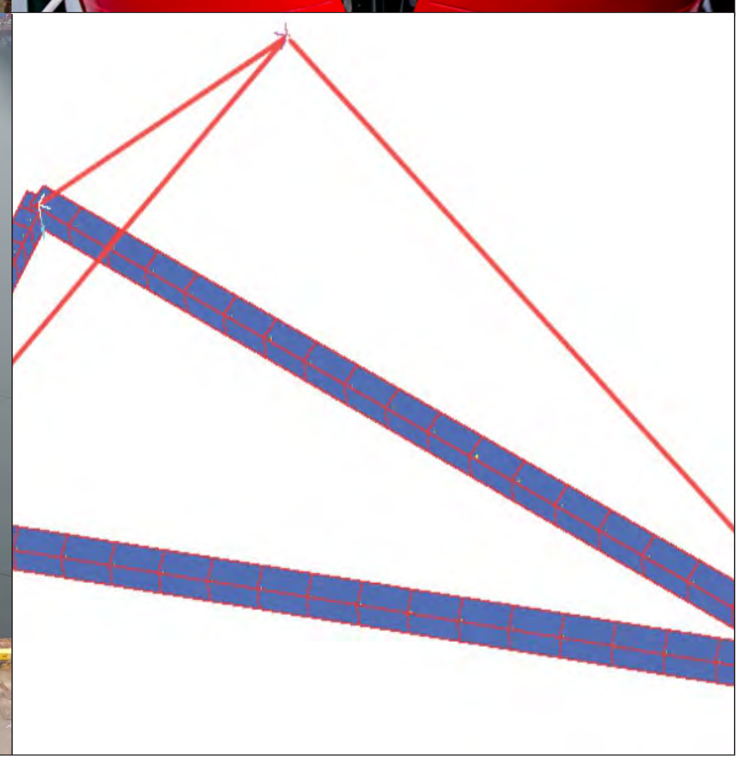

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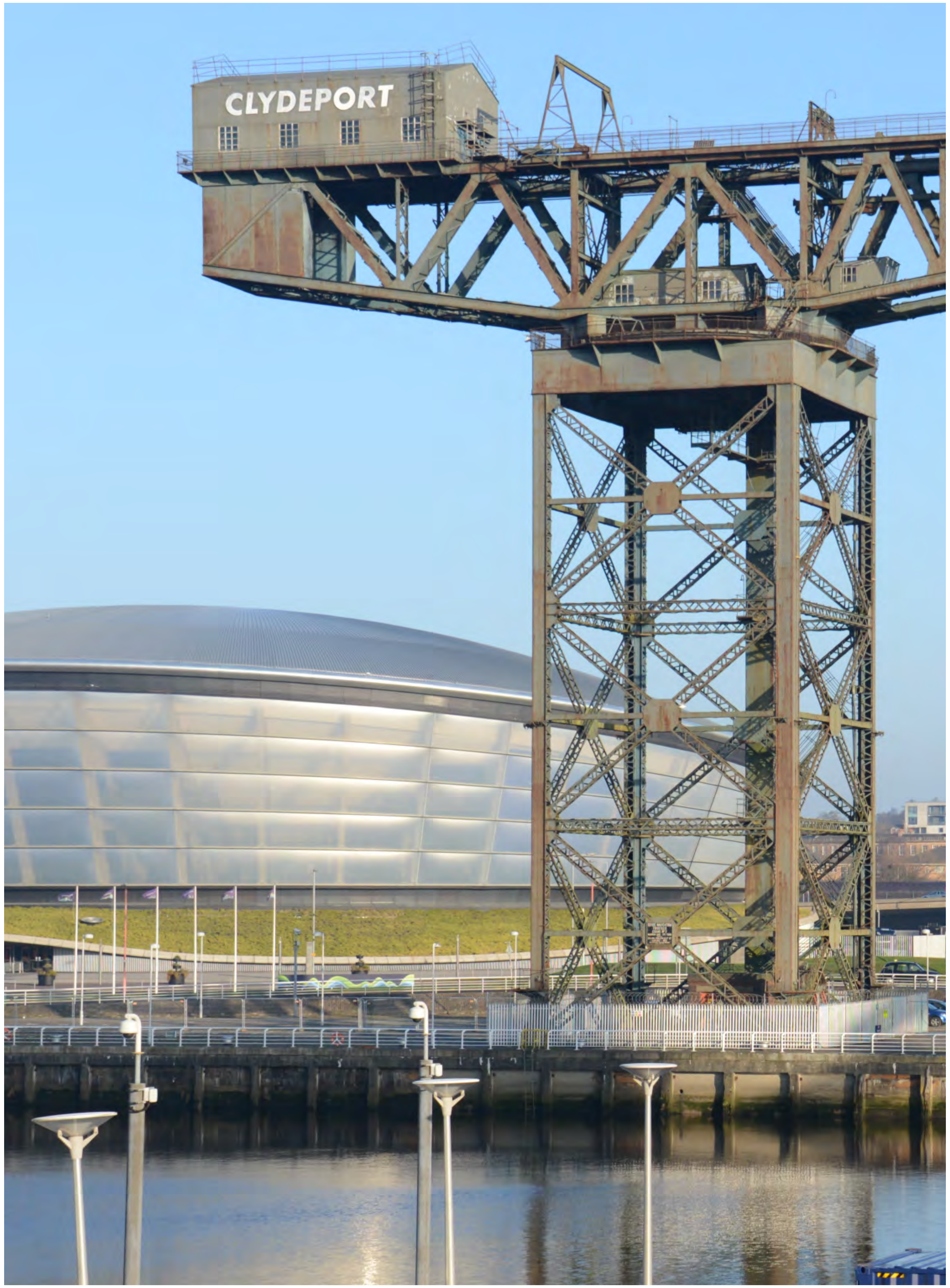

EDITORIAL

JOHN MACSWEEN, MANAGING DIRECTOR AT MALIN GROUP

Welcome to our spring edition of the Heavylift Engineer. This is our fifth edition, and you can find all previous issues to download on our website as well as being able to sign up to be notified as soon as new editions become available for downloading. (www.heavyliftengineer.com/magazine).

It has been great to hear all of your responses and feedback to date and I look forward to your views on our latest edition.

The past year has been a real struggle for us all, both professionally and personally. Across the country many have balanced home and work responsibilities, whilst others have had to keep themselves busy whilst on furlough - tough times for all. With a vaccine now being rolled out, and pathways in place, we can all now move forward together. Reflecting on my own time in lockdown, whilst at times trying, it has also highlighted new ways of working, and reminded me of my love of learning new skills and sharing knowledge across the industry and beyond.

This edition aims to share knowledge across a range of heavy lift areas, from an overview of factory acceptance testing (FAT) and of anchor selection, to an interesting piece pondering quayside design for heavy lift and project cargo scopes. This is teamed with a piece outlining the considerations when designing lifting beams.

We have a selection of our helpful heavy lift tips, covering everything from Solidworks to open circuits and pivot points – and of course our book reviews, to offer some helpful recommendations for your next read.

Whether you are in shipbuilding, heavy fabrication, power generation or mining, the heavy lift engineer's skill set is critical. No other engineering discipline, if you decide to dive deep enough, offers such a range of technical challenges. We hope that this edition reflects that variety, offering something of interest to you, regardless of your background.

Please do get in touch if you have a topic you would like to see covered or would like to guest feature for a future release – and I hope you enjoy this new edition!

We would love to hear from you! Please send any questions to:
heavyliftengineer@malingroup.com

Please also sign up for future editions at:
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DESIGNING QUAYS FOR HEAVY LIFT AND PROJECT CARGO USE

A fundamental, yet often overlooked, aspect of heavy lift projects is the quayside infrastructure itself; it acts as an interface between the land based operations and seagoing vessels for onward transport.

Quayside infrastructure comes in many forms, whether aged, modern, purpose-built or temporary and each have challenges in accommodating specialised cargo transfers between land and vessel.

This article will focus on easily implemented features for new quays, designed specifically with heavy lift operations in mind and will provide some high level considerations for designers of such facilities. It is worth stressing that this has not been written by a civil engineer, but rather by a regular user of quay side facilities for, what is often, very specialist operations.

Therefore this article will not look at design methods of such facilities but rather focus on details that, if incorporated, may make specialist heavy lift operations much easier. They may also realise significant through life operational cost savings which are far in excess of the cost of incorporation at the outset.

To understand quay requirements for heavy lift projects, it is first important to consider the three main methods of cargo transfer to and from a floating vessel. These are:

- by crane (Lift On/Lift Off – LoLo);
- by trailer (Roll On/Roll Off – RoRo); or
- by semi submerging alongside a quay to float cargoes over the vessel (Float On/Float Off – FloFlo).

Each of these methods drives very specific design features that, if considered early, can dramatically reduce operational costs of carrying out a heavy lift operation at a facility.

By crane – LOLO or cranes on quays

All mobile, and some fixed, cranes are governed by the fact that the heavier the load you want to lift and the further out you want to lift it, the greater the reaction load under the outriggers and into the quay itself.

It is not unusual to find modern quaysides to have designated "heavy lift pads" where the quay deck has been thickened, with larger piles located in the area to allow for greater concentrated loads from a crane's outriggers.

Comparing the outrigger spread from a range of modern large capacity cranes across manufacturers we can see, as shown in figure 1 (lifted from the relevant manufacturer's technical specifications) that, despite the range of manufacturers and lifting capacities, at this size of crane, the pad locations tend to be very similar. This allows opportunities for the design of the heavy lift pad on a quay to be suitable for a wide range of cranes.

Designing a single, very specific, location for the placement of a crane may restrict the use of that quay considerably. However, by recognising these common centres and spacing them in accordance with a well designed and optimised pile arrangement, the best of both worlds may be achieved.

By trailer - RoRo or skidding over quays

For the load-out and load-in of heavy cargoes, specialist trailers are employed, often in conjunction with temporary ramps anchored to the barge or floating vessel by means of an articulating hinge. This is shown in figure 2.

These ramps can apply some large edge loadings to the quay surface and installation of embedded bearing strips can greatly increase the life of the quay surface. An example may be seen in figure 3.

fig. 1 / Comparison of outrigger sections of modern, large capacity mobile cranes

With these temporary ramps installed to the barge and bearing on the quay, the barge deck must be above the quay level to allow a RoRo operation to proceed. This in turn reduces the cargo carrying capacity of the barge and/or reduces the number of useable tides that any given operation requires. An alternative to having the hinge plates mounted on the barge is to have them mounted to a recess on the quay edge, as shown in figure 4, specially designed for this purpose. This can reduce required tide heights by between 300mm and 500mm, greatly increasing the useability of a quay for high capacity loadouts.


fig. 2 / Linkspan pieces being installed to barge for loadout

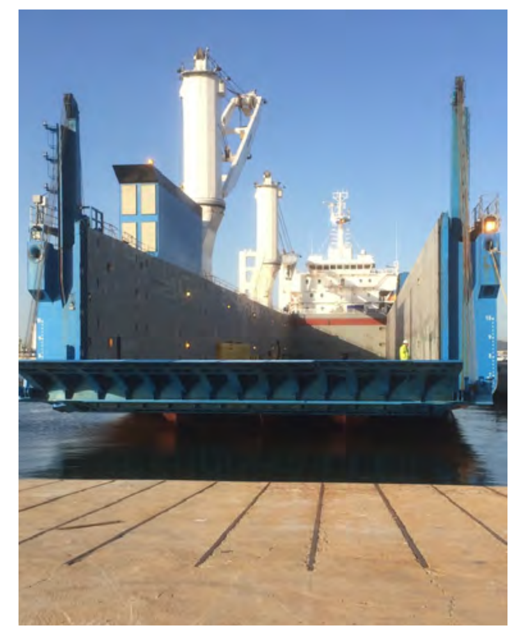


fig. 3 / Embedded bearing bars on RoRo berth

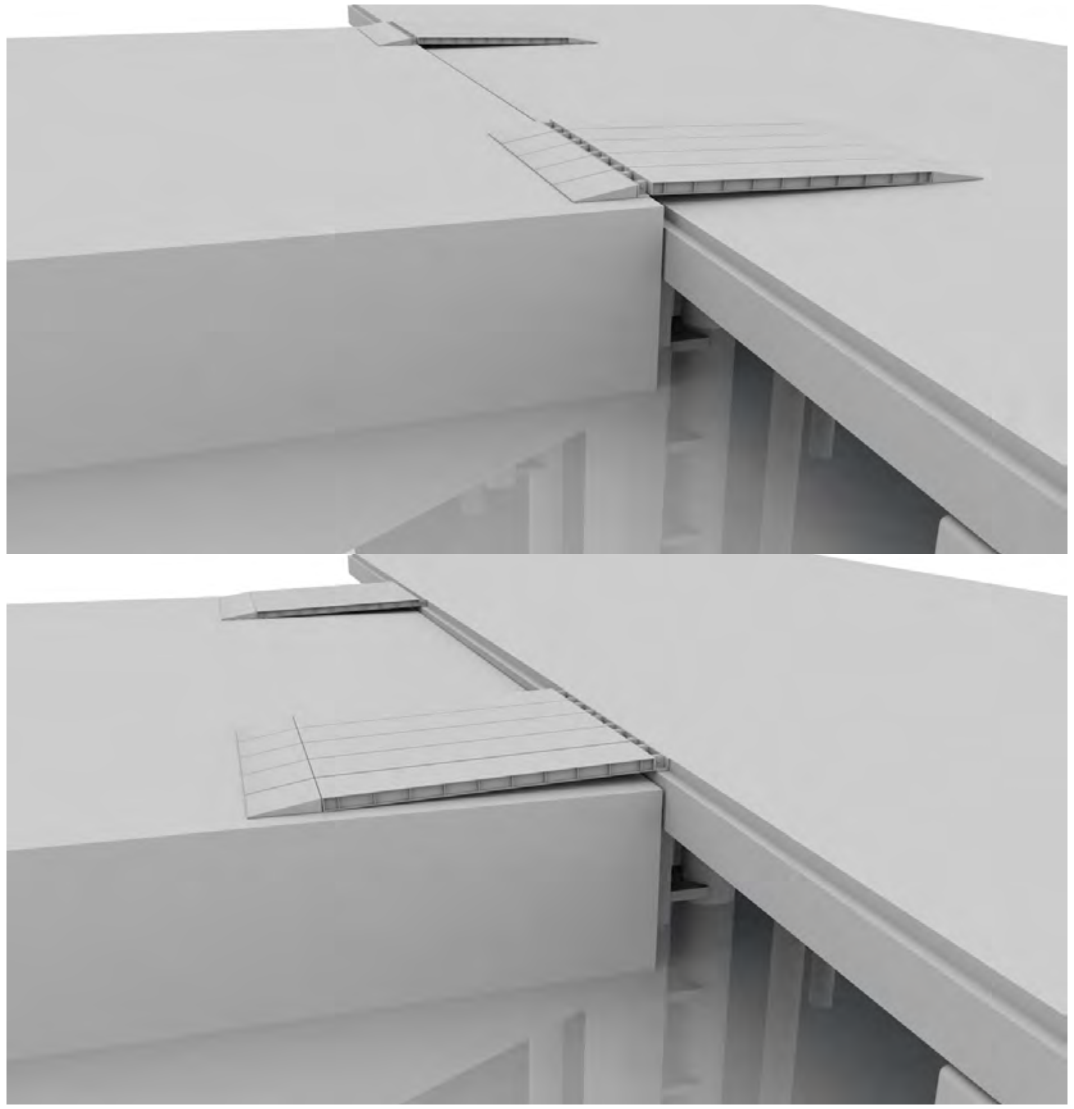


fig. 4 / Linkspan hinge recess Vs linkspan hinge on the vessel itself

Quayside equipment and general considerations

For typical heavylift operations, and specifically RoRo or skidding operations, the arrangement of quayside furniture and equipment is critical. The placement of bollards must consider the swept path of loadout operations so as to ensure that they do not clash with trailer or skidding lines.

Handrails should be removable and preferably use slotted posts flush with the quay deck rather than bolted ones. Services, service ducts and terminations as well as lighting should all be well away from the quay edge and demountable if they risk obstructing movement of an oversized load to and from the quay edge.

The quay deck should be flush to the quay edge with no edging or kick plates/kerbs and should be capable of taking high loadings right up to the seaward edge. Loading out oversize cargoes can often require very long trains of heavy trailers or skidding tracks and gradients from the quay edge back into any hardstanding area behind the quay should be minimised or, preferably, be negligible.

Mooring barges and dead vessels to quays

When mooring vessels alongside for heavylift loadouts using floating or land based cranes, vessels will normally be moored in a conventional manner. In such circumstances, bollard positioning and capacities for any commercial quay should be satisfactory.

When considering loadout situations, the loads on bollards and their positioning will be much more onerous and specialised. Figure 5 shows a

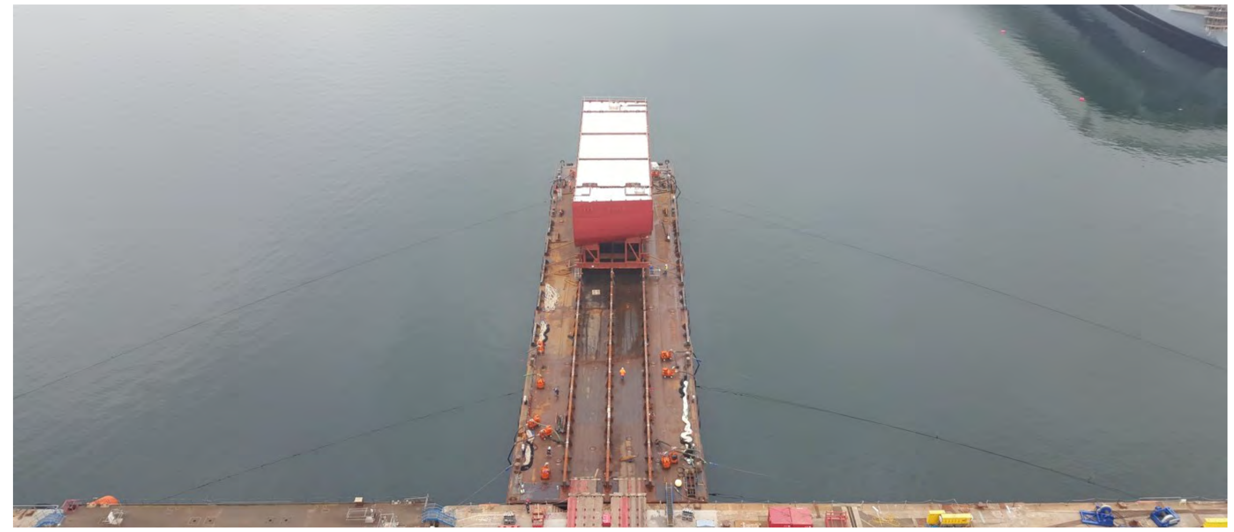


fig. 5 / Barge moored stern to quay for RoRo operation

deck cargo barge moored "stern to" a quay for the loading of a heavy cargo. As illustrated, these barges are moored using winches with wire rope anchored to the quayside. The means by which these arrangements can be more easily implemented should be considered. This can involve:

- Bollard selection and design such that they permit application of force parallel to the quay edge.
- Bollards set off from quay edge to permit a winch to be adequately and safely sited.
- Bollards or anchor points located inland so that redirecting sheaves are not required or their requirement is minimised.
- Panama fairleads or means of redirecting a wire mooring line to accommodate a range of barge types, capacities and positions relative to the quay deck.
- Conduct a range of mooring analyses for typical barge sizes and windages to current heavylift operational guidelines to size the required capacity of the bollards in question.
- Allow for the passage of wire ropes under tension to an anchor point on the deck of the transportation barge that may be under load during periods when the deck of the barge is below the quay level.

Rubbing strakes and fendering

When mooring barges to a quay for Ro Ro or skidding operations, the barge will usually be turned into a position similar to that shown in Figure 5, at a point well before high water. During this period the mooring system will normally be pre-loaded and so the rubbing strakes must be able to, as a minimum:

- Allow the barge transom to slide freely up and down the rubbing strake.
- Be able to take high lateral loading into the quay face or seaward piles (see figure 6).
- Extend far enough down to ensure that at all states of the tide, the barge cannot "slip" under the fendering.

By semi-submersible - FloFlo or use of quay

We will close this article with a final note on key considerations for operations that will require a barge or vessel to submerge alongside a quay to float a cargo on or off. Many of the points above will still apply but special attention should be paid to the following:

- When submerging, many semi-submersible vessels will touch the sea bed or come very close to it, therefore the make-up of the bed around the quay should be well understood with no hard points which could impart high point loadings on the submerging vessels hull.
- Rubbing fenders on the piles or quay face will need to extend much deeper to account for the fact that the flat of vessel side will be considerably below the water line.
- Lead angles for mooring and/or winch lines will run to the quay edge and then drop down to the termination point on the semi-submersible deck and so the quay edge should have rubbing strakes or fairleads that permit this.

We hope that the article has provided a number of points that may guide or inform your operations in the future. We would love to hear your feedback on the application of the points enumerated – or indeed any additional suggestions or notes of practice which we may share in a subsequent article.

Written by John A. MacSween, Managing Director, Malin Group

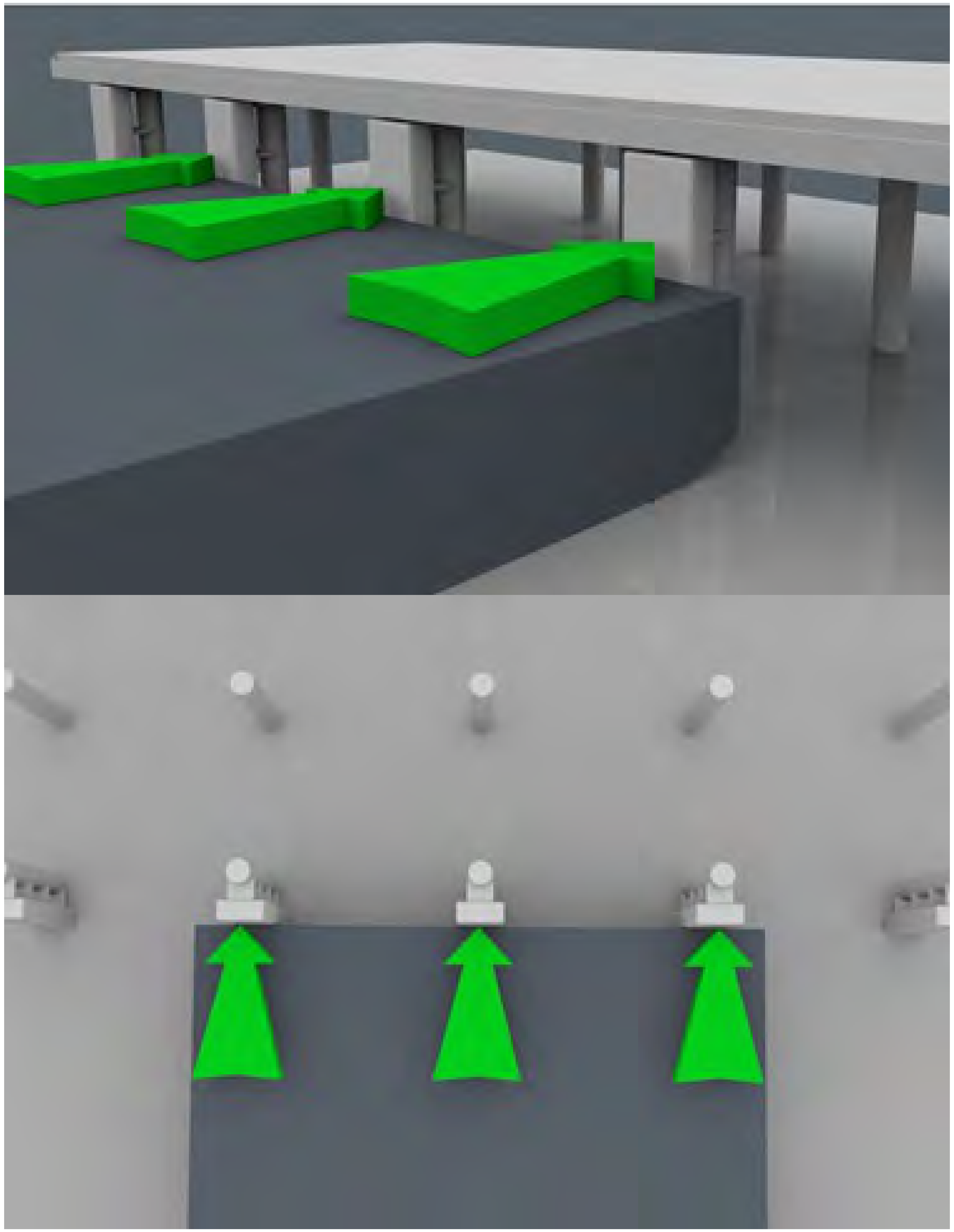
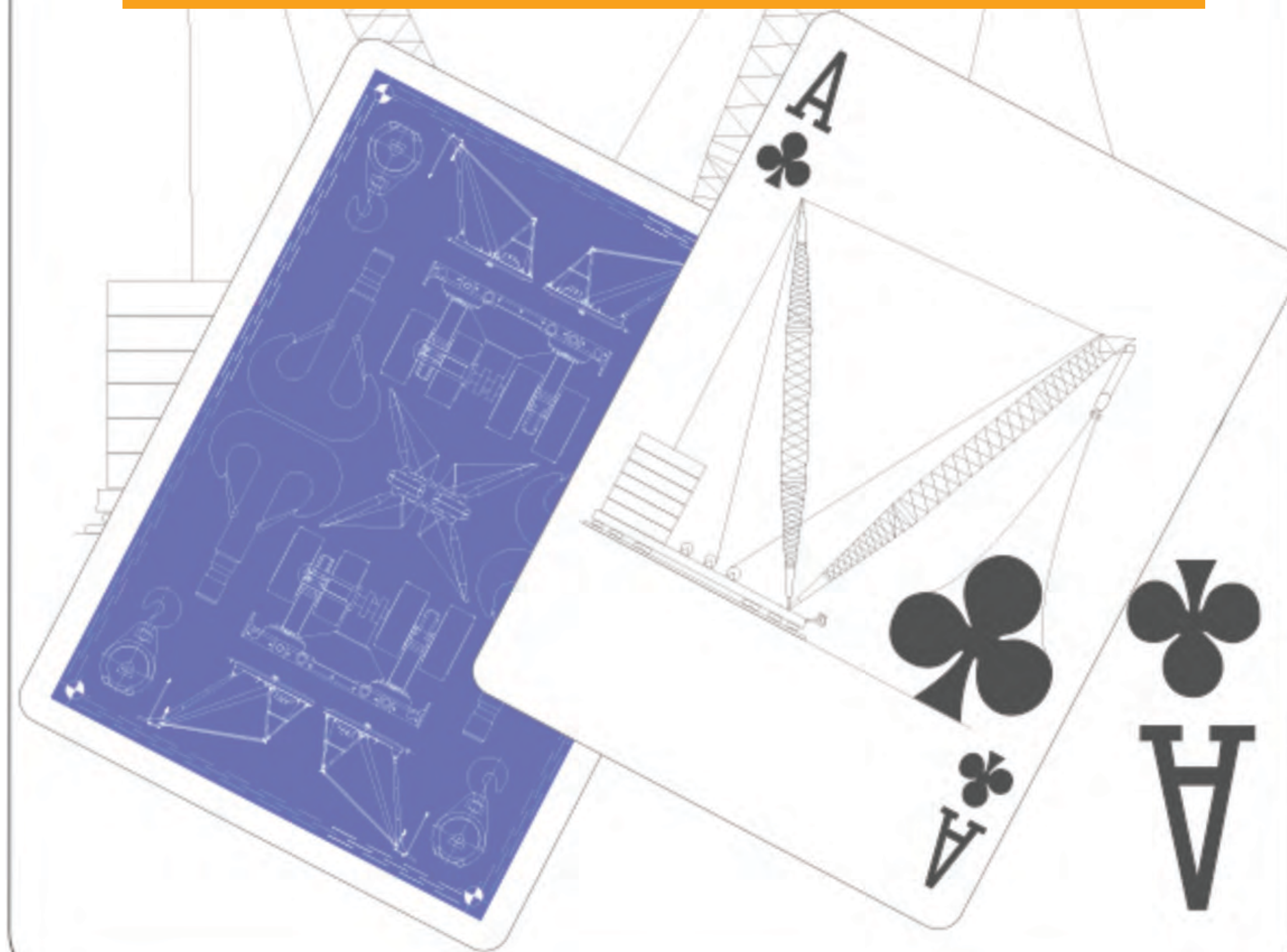


fig. 6 / Barge loadings on fendering at low water



HEAVY LIFT TIP
OPEN CIRCUITS AND PIVOT POINTS 2

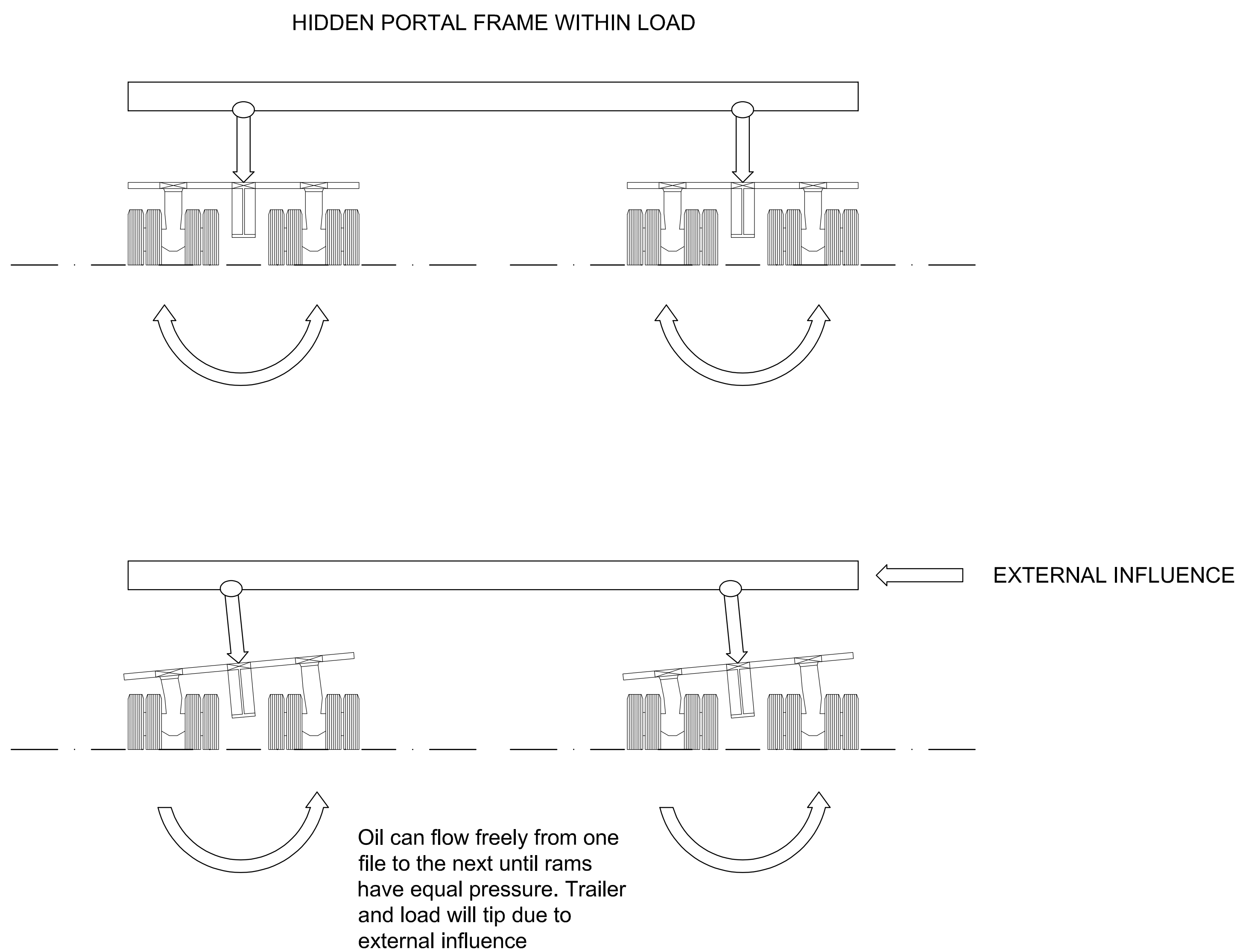


fig. 7 / Single point of contact

OPEN CIRCUITS AND PIVOT POINTS 2

Previously we covered the topic of open Hydraulic circuits. One of the basic issues/ pitfalls involving self propelled modular trailers (SPMTs) is unintended rotation around pivot points. We looked at the pivot point created at the point of rotation of the axle. Now let us look at the other pivot points that can be created and the compounding effect they could have on the system.

Looking further up from the trailer, we have packing and then the interface with the cargo. Most cargo designers will insist on a single, discrete loading point into the structure, this is for the obvious issues of simplifying the design and analysis of the structure. Unfortunately, as can be seen in figure 7, the single point of contact has inadvertently created a narrow point of contact, which acts as a pivot point. Multiplying this to other points, means that the potential exists to create, in essence, a pin jointed portal frame.

This is the obvious example. It can also occur, when it would appear that good load-bearing has been achieved.

- If all the load-spreading supports are tied into a single support on the cargo underside, this can create a pivot point.
- If the cargo is a tubular construction and the support is a saddle, there is the possibility that the saddle can rotate around the tubular.

Solutions to both of these examples are strong shear stops (tubular) and lashings or support props to a different part of the cargo.

Written by James Bowie, Engineering Director, Malin Abram

FACTORY ACCEPTANCE TESTING (THE GOOD, THE BAD AND THE UGLY)

fig. 8 / Archimedes Waveswing pre black build

Factory acceptance testing (FAT) is a critical part of any physical product realisation. It should be the opportunity to prove product performance to the end client, is often a significant payment milestone in the contract and is the last opportunity to fine tune the product in a controlled environment.

The reality however is often very different and the FAT becomes the start of the breakdown of the relationship between supplier and client, opening the door to debate, disagreement, formal dispute and financial consequences – why?

The discussion below is not intended as a checklist for undertaking a successful FAT although many versions of such checklists exist; rather it is intended to be more of a distillation of the lessons learned, both good and bad, during a variety of such events in a range of industrial and commercial settings.

The good (often discussed, less frequently incorporated)

Experience indicates that a successful FAT is the culmination of a process which starts with the tender submission, continues through the development and manufacturing cycle and ends with the client acceptance of the equipment and the approval to ship it to the job site.

Key to this is the ability to understand and define what a successful FAT is for the equipment in question. Basically:

- Can the FAT replicate the full range of operation of the equipment i.e. is the equipment a stand-alone item or part of larger system (which may or may not be available for the FAT).
- If a full functional test is not possible how are the inferred performance criteria defined and accepted/rejected.
- What are the defined and agreed performance criteria which can be undertaken during the FAT.
- How will they be measured.
- Who will carry out these measurements to ensure the results are accepted by all parties.

And...

- Who carries the cost of the FAT including the mobilisation & demobilisation of the supporting equipment? This should be clarified as part of the contract negotiations.
- Who pays for the cost of overruns in the FAT programme and any re-tests if required.
- Who is responsible for equipment damage as a result of the testing, should this occur.

Failure to tackle these questions in advance will result in the FAT being no more than a test or tests carried out under the auspices of best endeavours, often witnessed by the client and other interested parties.

The bad (well understood but often ignored)

- The acceptance criteria have not been defined in sufficient detail and are ambiguous.
- The recorded results are disputed.
- The FAT requires to be re-run and the delivery milestone and associated payment is missed.

The ugly (seldom considered a possibility, usually results in contractual re-negotiation)

- No performance and thus test criteria have been defined and are generated during the FAT.
- The equipment does not achieve these generated test criteria.
- The equipment fails under test.
- The client has the option to reject the equipment or invoke a delay / discount / damages clause in the contract.

Getting out of jail (or more accurately, not going to jail)

- Understand and agree the performance criteria as early as possible and incorporate these into the contract. These effectively form a substantial portion of the design specification.
- If this is not possible, define at which point in the development programme / project plan it will be possible to define and agree these criteria.
- Define a mechanism for discussion, negotiation and arbitration should it be required.
- Agree the costing mechanism and the impact on the project plan timeline.
- Make this a progress stage gate and payment milestone to ensure it is not bypassed in the rush to develop the product.
- Define how these criteria will be assessed, measured and recorded. Include feasible tolerances for criteria which are not yes / no.
- Define who will carry out these measurements to ensure the results are accepted by all parties.

Where do you fit?

You need to understand where you fit in the supply chain, for example, is it a primary supplier i.e. your customer is the end client, or are you a subcontractor? This has a significant bearing on the level of responsibility carried during the FAT and provides clarity on the information flow and pre-FAT testing required by you or for you.
It is critical to understand the responsibilities associated with the incorporation of pre-tested systems and sub-systems to the overall FAT. Examples of this include pipework pressure testing, electrical continuity checks etc. Clarification of these cascaded sub-system tests should ensure, as far as possible, that no potential for damage to the equipment exists during the FAT. This is not always feasible and where this is the case it is critical to define any residual risks in advance of the FAT commencing. Responsibility for subsequent damage due to untested sub-systems should also be clarified at this stage. This should cover replacement of components, time and cost associated with delays and if applicable, financial damages.

Third party approvals

Although often not recognised as FAT's, it is essential to understand the requirement for third party testing and approval as these are in effect third party FAT's which can have much more severe consequences associated with failure or sub optimal performance. These often include CE Marking (if not conducted in-house and self-certified), EMC testing, testing and approval under the pressure systems regulations etc.

You need to be clear on the different requirements for stand-alone systems and those incorporated into larger systems e.g. a stand-alone machining centre and a packaging machine, which is part of a high-speed production line.

These must be incorporated into the design, build and test schedules at the appropriate times to ensure that the completed equipment is fit for purpose, can be insured and sold. These are often in addition to any third-party approvals requested by the client.

The Sequel - Site Acceptance Testing (SAT)

So we have successfully completed the FAT and the product has shipped to the client. Time to relax? No, it's time to prepare for a bigger challenge and one with many more variables and significantly less control.

What's different? Using a football analogy...

- If the equipment is stand-alone then it is a replay of the FAT at a different ground. If it is part of a larger system then it's an away match so no home team advantage this time.
- Different crowd, bigger and possibly a little more hostile.
- Know where the edges of the pitch are i.e. the boundary conditions.
- You are in the premier league now; the rewards are bigger, the final milestone payment.
- Failure to qualify at this stage is financially very painful indeed, and relegation is a very real possibility.
- Hope for the best, plan for the worst.

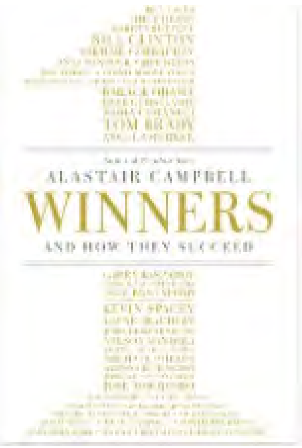
A successful FAT is the best possible preparation for a successful SAT but not a guarantee of a repeat result. If the equipment is stand-alone then the SAT will often be a repeat of the FAT in the final location with a few differences e.g. mains power in place of generators, different ambient temperature etc. If the equipment is to be incorporated into a larger system and this normally means interfacing with other equipment then the SAT is a much more complex undertaking.

Interested? Then look out for The Sequel – SAT where we examine the fine detail, potential pitfalls and rewards of Site Acceptance Testing.

Written by Jim Casey, Chief Technical Officer and Lead of Malin Skunks, Malin Group

BOOK RECOMMENDATIONS...

WINNERS: AND HOW THEY SUCCEED BY ALASTAIR CAMPBELL



A motivational piece, by the well-known communications guru, Winners: And How They Succeed is an illuminating and insightful investigation into the traits and qualities shared by winners across various spheres: politics, sport, entertainment. As you would expect from Campbell and his communications background, the book is clearly constructed with simple yet effective messaging, with the main posited point being the importance of objectives, strategy and tactics. Some of his examples are a little forced, some lack critical reflection, yet others are illustrative, enlightening and enjoyable.

He clearly demonstrates that hard work, practice, making mistakes, owning those mistakes and learning from them and ultimately never giving up, all are common traits found in winners. Definitely one to gently inspire!

THE INFINITE GAME BY SIMON SINEK

This book looks at two fundamentally different approaches to work and life by comparing and contrasting a closed, finite view on goals and purpose versus an open, infinite one. Now while this sounds very high brow, it can be boiled down to the simple ethos of deciding to play to simply win or play for the love of playing itself and defining commercial success as enough to allow you to continue playing. The former may drive short term successes, or even some long term ones, but the latter is much more likely to create an enterprise that will survive the most trying of times.

There is a particularly interesting section in the book that looks at the responsibility of businesses and argues very strongly against the notion of Friedman that the purpose of businesses is to serve its shareholders by delivering profits back to them. He contrasts this with the view of Adam Smith who argued that businesses are there to serve consumption and the consumer while being aware of the desire of self interest for this to be defined in terms of production rather than the end goal of serving a need.

The book also has lots of advice on everything from your mission (defined as your Just Cause), to leadership styles and team work.

AN INSIGHT INTO ANCHOR SELECTION

Anchors have a long history, dating back as far as the existence of vessels themselves. Despite this, the subject of anchor selection is often overlooked. This article will explore this topic in more detail, investigating the differing anchor types, their benefits, disadvantages, and common types of usage.

Anchors ensure that a vessel remains steadfast when tethered, whether this is to the seafloor or to a permanent fixture such as a quayside. Although early anchors were often primitive and simple, anchor design has evolved to provide various novel and a full range of innovative, versatile solutions. As engineering advances, so too must anchor design and development – whether it be to anchor a 400m long cargo vessel, a semi-submersible drill rig or a series of offshore wind turbines. Each of these applications require a specific anchor, however, not all anchors can be used for all applications.

There are various considerations when selecting an anchor, however the primary driving factors are:

- Inshore or offshore mooring
- Water depth
- Size and mass of moored vessel

Inshore Mooring

Inshore moorings require the least complex anchors and usually quayside bollards are used. These bollards allow a vessel to moor "alongside" a quay or berth, by connecting the vessel's own mooring wires/ropes to the bollards and then tensioning the lines to provide holding capacity. In most cases, as the weather exposure tends to be less as quaysides are designed to provide sheltered mooring, bollards prove suitable to hold a vessel in place. However, in the case that the mooring bollards do not provide enough capacity, mobile mooring winches can be installed along the quayside and are used in the same manner. This is illustrated in figure 9.

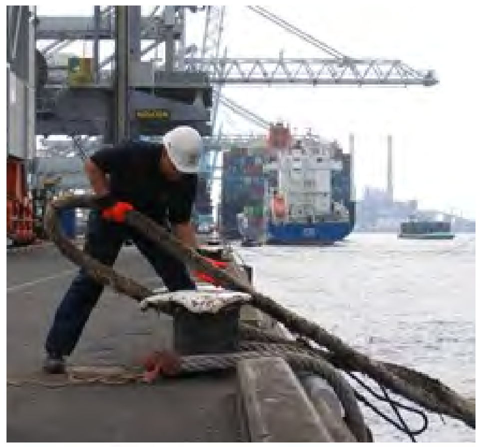


fig. 9 / Quayside bollard and mobile mooring winch

Mooring winches are offered in various sizes, with a range of holding capacities and brake loads - a very widely used solution when mooring large vessels alongside a quay or berth.

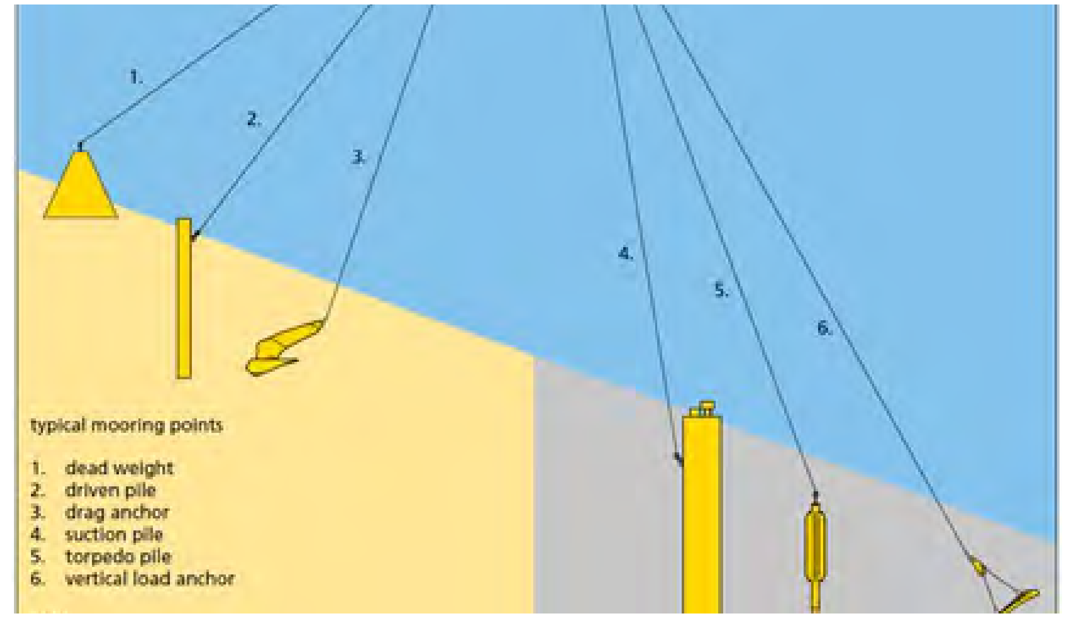


fig. 10 / Various offshore anchoring methods

Offshore Mooring

Unlike inshore moorings, offshore applications have more anchoring methods, as shown in figure 10, where the anchor selected is based on the water depth:.

Deadweight Anchors

Of the above, deadweight anchors are the simplest solution, and are still regularly and widely used. The working principle of a deadweight anchor is in the name; they rely on sheer weight to provide anchoring capacity, usually being a concrete or metal block, which is dropped to the seafloor, enabling vessels to then hook up. An example is provided in figure 11.

The main benefits of this anchor are twofold: versatility and cost effectiveness. As the mass of the anchor provides the holding capacity, they may be deployed on any seafloor condition, where other anchor types require a certain seabed profile or seabed material. Secondly, the cost of such an anchor may be far less than other alternatives, as they require no complex engineering, manufacture, or testing. In short, they are easy to design and fabricate.

However, deadweight anchors do have some limitations, particularly their holding capacity efficiency. Some modern-day anchors may provide holding capacity nearing 50 times that of the actual anchored mass, whereas a dead weight anchor's capacity is relatively close to the mass of the anchor itself (in direct tension and negating buoyancy). As such, these anchors tend to be reserved for light applications, in relatively calm conditions, for example, near shore mooring of small crafts or vessels.

fig. 11 / Deadweight anchor just before it is dropped to the seafloor

Drag Embedment Anchors

Drag embedment anchors are some of the most versatile and best performing anchors available today. They rely on being "dragged" along the seabed by an anchor handling vessel, which coupled with their design, forces the anchor to submerge itself in the seabed. The deeper the anchor is laid; the more holding capacity is provided.

There are various shapes and designs available for a drag embedment anchor, however recent developments have resulted in a two-piece system, comprising of a "fluke" and a "shank" where the fluke can be set to different angles to suit different seabed characteristics. These high holding capacity anchors can provide up to ~50 times their own weight in holding capacity (in the right conditions) and are considered very easy to handle and install.

fig. 12 / Two piece drag embedment anchor

An example is shown in figure 12.

Drag embedment anchors are widely used in the offshore industry, primarily for drill rigs, production platforms and FPSO's due to their high holding capacity. They are limited to deployable water depth however, as the deeper the water becomes, the longer the catenary is, and as such the weight of the anchor line itself increases. They require a relatively shallow catenary to ensure little to no uplift is subject on the anchor, as this can result in dislodging. As well as a shallow catenary, engineers will routinely design a drag embedment mooring line to allow for a length of grounded line in front of the anchor, to assist in reducing uplift. This adds to the line length and as the line length increases so too does the footprint of the anchor spread and the weight of the mooring line, which must be taken up by the vessel fairleads which may become over utilised.

Pile Anchors

As illustrated in figure 10, there are various types of pile anchor, namely: driven pile, gravity pile and suction pile. All these types use the same working principle and share common characteristics; they are all also capable of withstanding horizontal and vertical loads and are designed to resist vertical loading primarily. The benefits of pile anchors are that the mooring spread footprint may be reduced in size, in comparison to a drag embedment spread, as the normal angle between the seabed and the mooring line can be increased. In some spreads, such as those which utilise taut leg mooring, 90-degree mooring lines can be laid - it is these characteristics which make pile anchors popular in ultra-deep-water applications.

The theory behind pile anchors is that the mass is submerged into the seabed and the depth of submersion provides the holding capacity, coupled with some clever engineering in the case of the suction pile. The installation of gravity piles relies on the mass of the anchor being dropped from the back of a vessel and the kinetic energy gained as the anchor falls through the water column will provide enough impact force to drive the anchor into the seabed.

In comparison, driven pile anchors are lowered to the seafloor via a crane, as illustrated in figure 13, and the initial impact will result in some embedment of the anchor. However, the installation workpiece includes a large "hammer" which will then drive the pile further into the seabed until the desired embedment depth is achieved.

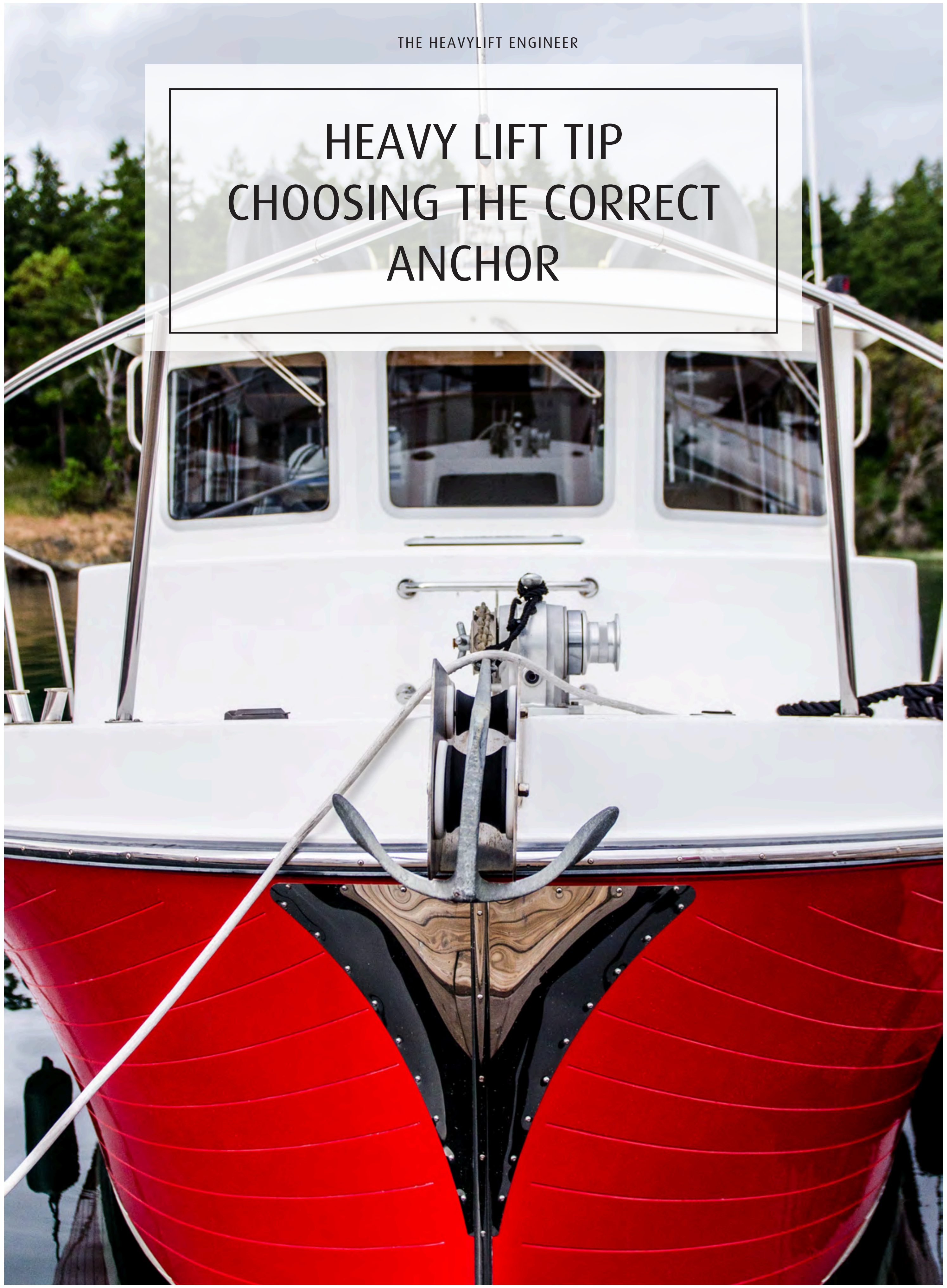
Finally, suction piles are the most complex of the available pile anchors and have an interesting working principle which relies on creating a vacuum within the anchor to provide the holding power. The suction pile anchor relies on its hollow shape to ensure holding capacity – the pile can be described as a hollow, capped cylinder where the underside remains open. The restraint is provided by dropping the large "can," as shown in figure 14, to the seafloor where >~60% of the mass will submerge under its own weight (in optimal cases). A remote operated vehicle (ROV) is then used to activate a valve on the topside of the can to discharge the trapped water between the seabed and the capped end of the can, which creates a vacuum.

As this brief insight into anchoring illustrates, modern engineering has made it possible to moor in ever increasingly difficult locations, water depths and environments with a solution for any application.

Written by Calum Reid, Graduate Naval Architect, Malin Abram

fig. 13 / Drive pile anchor lifted by crane

fig. 14 / Suction pile anchor



CHOOSING THE CORRECT ANCHOR

So you have been tasked with designing a mooring system for an offshore installation? Do you know which anchor is going to be best suited for the job? And what about any considerations you must take into account to reach the right decision?

Not all anchors are suited to all applications: although some are more versatile than others, there are some which simply will not work in certain environments. To help ensure that you make the best selection, there are some key factors you must consider when selecting an anchor:

- What is your mooring depth?
- Do you know your seabed condition?
- How large is the moored vessel?
- Is this an offshore or inshore mooring?
- Are you mooring alongside a quay?

These are all very important questions to pose when selecting the correct anchor. Only when you know all this information as a base point, can you then make an educated decision on what mooring system is to be used.

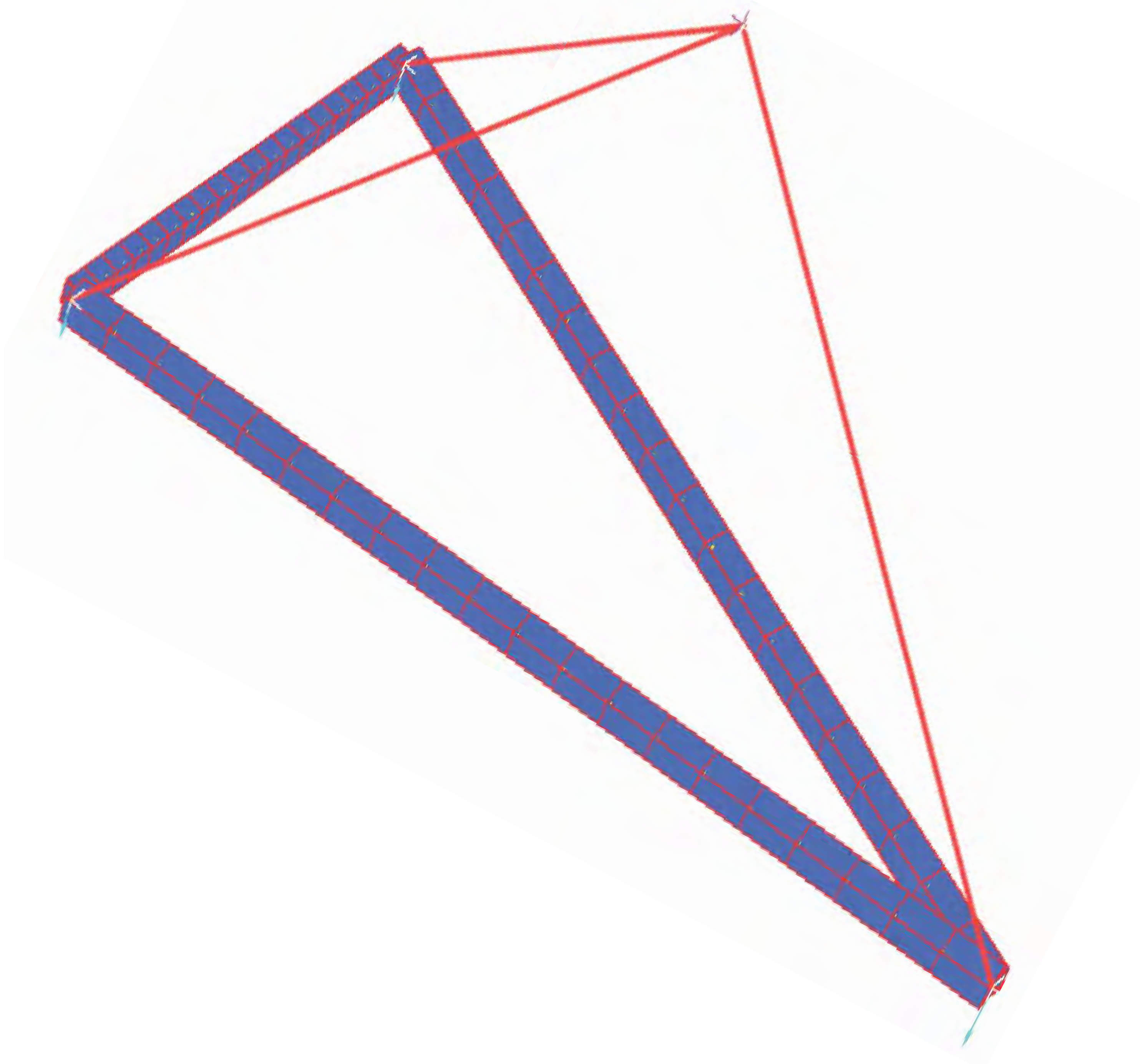
Assuming that you are not mooring alongside, in which case your options become lessened, probably the most versatile and widely used anchors is the “Drag Embedment Anchor”.

These anchors come in a range of sizes, from small 1 tonne units, to bespoke 50+ tonne anchors which can also be ballasted with concrete to provide additional holding power. Drag anchors can also be optimised by changing the angle of the “fluke”, where the fluke is the bit that does the digging, like a shovel. This ensures that the anchor embeds itself correctly in the seabed and reaches the desired depth – which is paramount in ensuring the anchor does not slip during operations. Alternatively, if the fluke is not set to the correct angle, you risk the anchor not embedding at all and simply skidding across the seabed – incurring cost and time delays in resetting.

There are a lot of anchoring options available on the market, however, following a structured list of considerations such as this will ensure that you make the right choice.

Written by Calum Reid, Graduate Naval Architect, Malin Abram

DESIGN AND FABRICATION OF LIFT BEAMS



The design and fabrication of lift beams is an involved process requiring both practical knowledge of their function and use as well as technical understanding involved in the structural/mechanical design. Within the body of regulations Lifting Beams are defined as 'lifting accessories' such that they are not attached to lifting machinery, allow a load to be held, are placed between the machinery and load and are independently placed on the market. The key pieces of legislation relating to lifting beam are as follows:

Design

- Supply of Machinery (Safety) Regulations 2008

Operation

- Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)
- Provision of Use of Work Equipment Regulations (PUWER)

It should be noted that Supply of Machinery (Safety) Regulations do not apply to seagoing vessels, mobile offshore units and machinery installed on such vessels. In this case a suitable certification authority is required such as Lloyds Register, DNV, ABS, BV, etc.

This article will discuss the design process for lift beams which is broadly similar for lift beams used in onshore and offshore applications. Note that where the term 'lift beam' is used, it can also be extended to include spreader beams and other types of similar lifting accessories. It is also assumed that these take a similar form consisting of lift point(s) and structural members.

Design

When an object is lifted there is a change in support conditions and as such a change to the load path from the object to the ground now via lifting equipment, accessories and rigging. Lifting and spreaders beams are used as a means of controlling and directing the load path and as such allow objects to be lifted in a safe and controlled manner.

It is suggested that lifting requirements should be considered throughout the design of any heavy, large, or otherwise cumbersome object or structure.

There are several key considerations required for the design of a lift beam.

- Weight of item to be lifted
- Centre of Gravity (CoG) of item to be lifted
- Practicalities
  - Space envelopes
  - Hook height available or required
  - Fabrication

Weight

The overall mass of the object can be determined in a range of ways, varying in accuracy, such as material take-offs, 3d model or physically weighing the structure – it may also be provided by a client. Note: Weight control information should stem from a well-defined and documented system. Depending on the reporting of the weight and maturity of the design it is good practice to include a weight contingency factors. Guideline figures for increasing the weight are provided in the table below.

Once the weight is known, the lift beam can be designated a Safe Working Load (SWL) or Working Load Limit (WLL). The SWL/WLL should also account for rigging required. The SWL/WLL is a value, or set of values, based on the operational requirements of the lifting beam and is the maximum load that the lifting beam can safely lift, provided it is rigged in the correct manner. It is possible for a lifting beam to be certified to a range of SWLs and corresponding geometric limits. In any case, the SWL/WLL is to be clearly marked on the lift beam.

Centre of Gravity (CoG)

The second key consideration is the Centre of Gravity (CoG) of the item to be lifted. The CoG can also be determined in a number of ways from manual calculations to output from a 3d model – or again it may be provided by a client. Similar to the weight accuracy factor it is also prudent to account for centre of gravity accuracy. There are two primary methods for accounting for CoG inaccuracy

Table 1 Guideline weight contingencies

Discipline	Conceptual design	Detailed design		Weighed items
		Agreed basis of design	AFC take off/final supplied weight data sheet	
Non-structural	25%	20%	10%	3%
Structural	25%	10%	5%	3%

There are two primary methods for accounting for CoG inaccuracy in the design with the chosen implementation depending on the type of lift and sensitivity of shifting the CoG:

- Considering a CoG envelope – used for operation where resulting load effects, or operations, are more sensitive to change of CoG position. This is depicted in the following images, or;
- Applying CoG contingency loads factors – used where there is a more linear relationship between CoG shift and resulting load effects.

The first of these considers CoG in extreme positions of a defined envelope and the second increases the entire weight and as such increases the full load but does not change basic load distribution. The size of a lift envelop will be determined by the appropriate design standard – typically these could bed in the region of 0.05L x 0.05B x 0.05H for an early stage design. In the design the most onerous CoG position should be adopted.

The location of the CoG will determine the position of the lift hook point, and from this, the rigging arrangement, and overall lengths. The lift point is to be located in-line with the centre of gravity. Rigging lines typically have a minimum angle of 45° with a preference for 60° (to the horizontal).

Practicalities

Alongside the weight and CoG consideration of the practical elements such as, but not limited to, space/geometry envelopes, crane hook height, fabrication limitations and operational conditions. These factors will influence the type of lifting beam that is designed. To fully understand the practical considerations desktop and/or site survey will be required, in order to fully understand such things as the limits of the lifted item, site, fabrication facility and craneage available.

Lift beam design

Once the above information has been obtained the initial arrangement and sizing can be determined – oftentimes from simplistic, manual calculations. The SWL/WLL is determined from the Static Hook Load (SHL) which consists of gross weight combined with rigging weight. A conservative estimate is often required for the rigging weight which is then revised once the rigging is finalised. It should be noted that it is generally good practice to round up with static hook load to provide a round SWL/WLL number.

The dynamics of the lift are accounted for by applying a Dynamic Amplification Factor (DAF). The DAF is determined through consideration of aspects of the lift beam use such as the location (offshore/ inshore/onshore), the gross weight and lifting speed.

From this a basic dynamic load is determined. Further to this a proof load is to be determined based on the safe working load of the system. The Proof Load Factor (PLF) is determined from a suitable lifting code such as Lloyds Register of Shipping Lift Appliances in the Marine Environment (LAME).

Gross weight = calculated/measure weight x weight contingency factor (x CoG accuracy)

Duty Factor = A factor depending on the frequency and severity of the load lifted

Static Hook Load (SHL) = Gross weight + Rigging weight (x Duty factor)

Dynamic Hook Load (DHL) = SHL x DAF

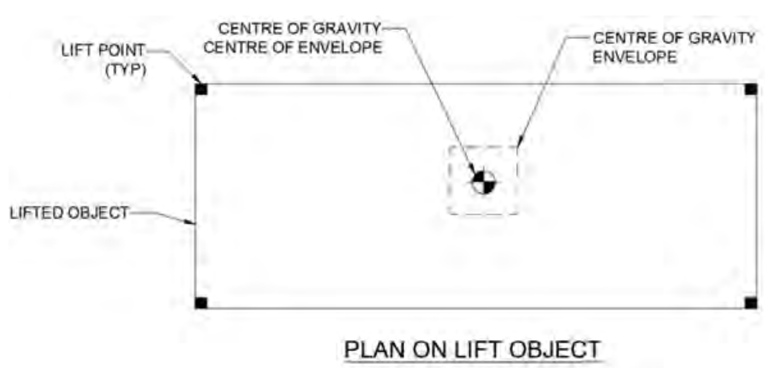


fig. 15 / Plan of lift object with CoG in centre of envelope

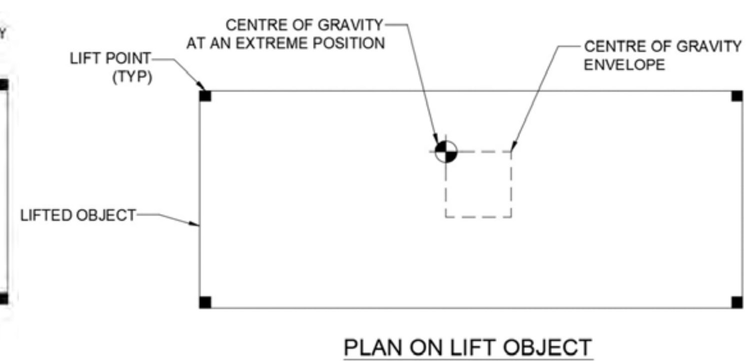


fig. 16 / Plan of lift object with CoG at extreme position centre of envelope

Proof Load Factor (PLF) = Additional load factor used for testing the lift beam - typical values are given below taken from the International Labour Organisation Register of Lifting Appliances and Items of Loose Gear [1]

Proof load = SWL x PLF

Proof load factors

These are applicable to lifting beams, spreaders, lifting frames and similar devices as provided by ILO [1]

Table 2 Proof load factors from ILO [1]

Load rating	Proof test load
SWL ≤ 10 tonnes	2 x SWL
10 tonnes < SWL ≤ 160 tonnes	1.04 x SWL + 9.6 tonnes
SWL > 160 tonnes	1.1 x SWL

Additional load factors (not all are always applicable) are applied to determine final dynamic load which are dependent on the use of the lift beam. Factors include:

- Skew Load Factor (SKL)
- 2-hook Lift Factor
- 2-Part Sling Factor
- CoG Shift Factor
- Tilt Angle

With the loads calculated calculations can be undertaken to determine the loads in the rigging and lift points. Rigging items are rated items and as such can be specified based on the SWL. It should be noted that where rigging is used in a marine environment (dynamic) consideration should be given to ensure the SWL of the item has sufficient capacity for application.

fig. 17 / Spreader beams as used in a complex rigging arrangement

Lift points

The geometry of lift point (also referred to as pad eyes) is initially dictated by the size of shackle, and associated pin, required. The width of the pad eye is typically required to be at least 75% the width of the shackle jaw and similarly the hole is typically sized such the pin is 94% the size of the hole.

The pad eyes are to be assessed individually considering the resultant sling force – accounting for in and out of plane actions. The pad eyes are, normally, aligned with the rigging such as to minimise any out of plane loading. It is however both good practice, and a requirement of some codes, to include a nominal out of plane loading, typically 3-5%. The assessment can either be done by manual calculations or finite element analysis. Manual calculations are the preferred method given that pad eyes are, normally, simple structures. The following critical checks are required in order to fully verify the pad eye structure to a relevant national or international design standard.

The following should be assessed as a minimum:

Considering the Resultant Sling Force (RSF) the following should be considered:

- Bearing stress
- Tear out stress
- Check plate welds

The tensile and shear components of the RSF checking at both the hole, base and any other critical locations:

- Direct tension
- Direct in-plane shear
- Direct out of plane shear
- In-plane bending
- Out of plane bending
- Combined stress

Padeye connection to beam

The connection of the pad eye to the lift beam is to be assessed as well as the structure local to the padeye. The preference for welding is full penetration welds over fillet welds however it is not always possibly to achieve this. Common weld arrangements for penetration welds include direct butt and slotted arrangements. Slotted details are often preferred from a structural point of view as they can eliminate issues such as laminar failings or local stress concentrations – this may not be the case for fabrication. However, the main pad eye plate is often required to be tapered to match the mating structure. Alternative arrangements could include lap welded details, using fillet welds, this may result in additional eccentricities to consider.

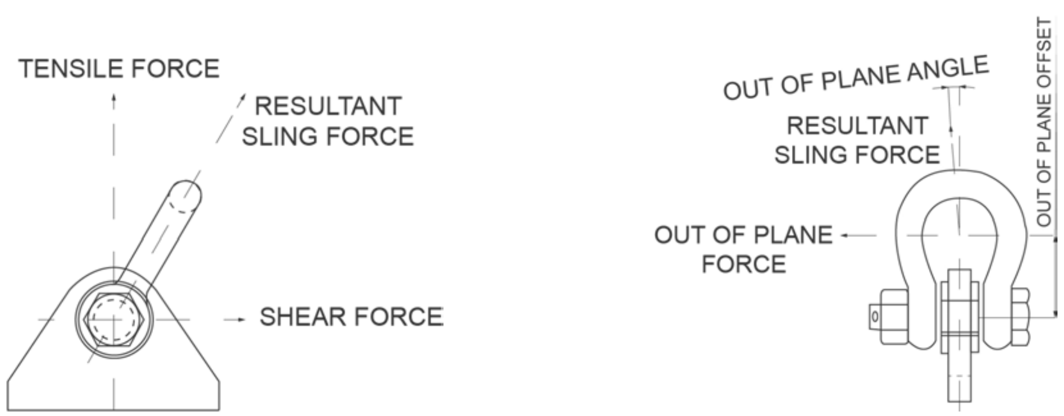


fig. 18 / Force acting on a lift point

The engineer should strive to avoid local stress concentrations through good detailing practices. If these are unavoidable for practical reasons, the engineer should ensure they fully understand the load path and verify all aspects.

Lift beam design

The lift point and rigging arrangement will determine the how the forces are transferred through the structure. For example, a lift beam with a single hook point in the centre will be in bending whereas a spreader beam will largely be in compression. This can influence the type of section with spreader beams often fabricated from Circular Hollow Sections (CHS) or other closed sections.

The lift beam itself is to be designed in accordance with a suitable national or international design standard considering the most onerous combination of loading acting on the beam. Typical design codes for this would include Eurocode 3, AISC or Lloyds Register Code for Lifting Appliances in the Marine Environment – with the engineer taking note of the design philosophy (ASD or LRFD). As for the pad eye it is often sufficient to verify the beam by manual calculations, however framework or finite element analysis tools may be required if the beam is sufficiently complex. When using such tools, it is imperative that the engineer has a good understanding of the tool and its limitations, particularly understanding where additional local calculations may be required to fully verify the structure.

Fabrication, marking and testing

The fabrication of a lift beam should be undertaken in accordance to an agreed fabrication standard. Once a fabrication standard has been determined agreement is required on such items as weld procedures, qualifications of welders, non-destructive testing (NDT) procedures, NDT personnel qualifications and NDT acceptance criteria. These items should all in line with the relevant standards.

Proof Load Testing

There are two main means of "justification" for a lift beam – firstly by calculation and secondly by proof load testing.

Lifting points, lifting frames and spreader bars intended for non-routine operations do not require to be proof loaded tested, provided full design calculations are provided and verified by competent person(s) alongside a full programme of inspection. However, where practical proof load tests should be undertaken. The proof load requirements are determined dependent on the SWL and its application, as discussed in the section above.

Where a load test is to be undertaken the test must be representative of the actual design loading conditions with measures taken to ensure the accuracy of the testing equipment. Applied loads should be within +/- 2% - of the proof load requirement and verified by use of calibrated load cells or pre-weighing test weights. Acceptance criteria should be agreed prior to the test and verified after the test.

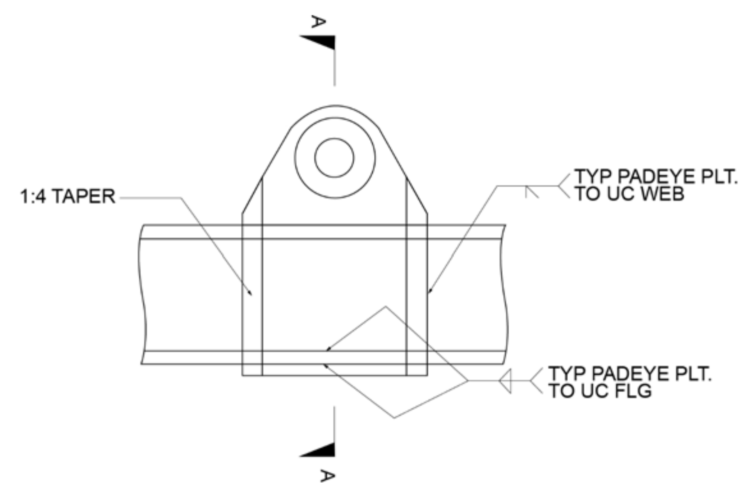


fig. 19 / Slotted connection

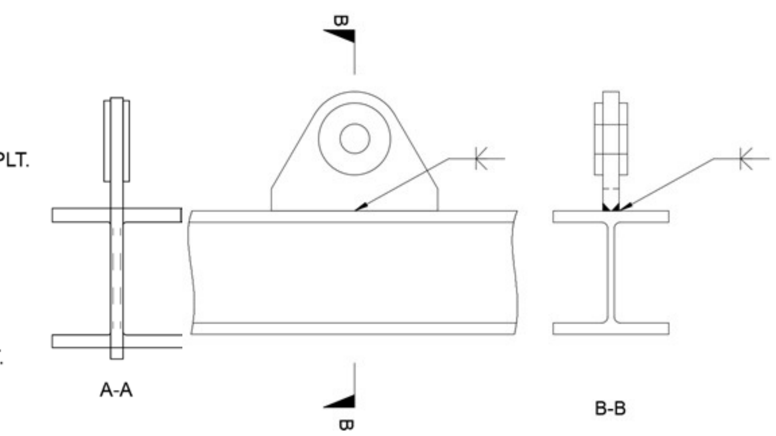


fig. 20 / Butt welded connection

fig. 21 / Lift beam and spread beams in used

fig. 22 / Lift being under test load

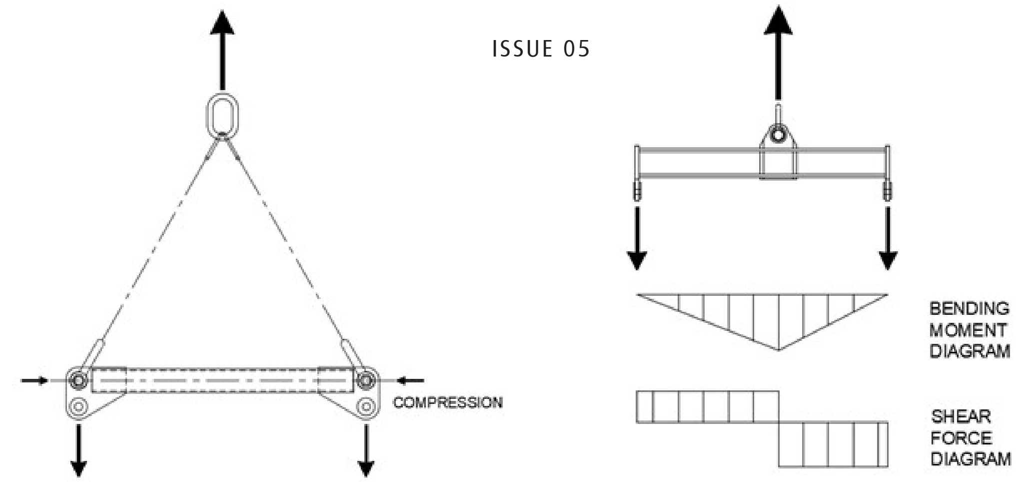


fig. 23 / Forces acting on a spreader beam (L) and lift beam (R)

Inspection

Fabrication materials shall comply with the relevant standards ensuring full traceability.

The lift beam will typically be inspected by assessment of the primary structural arrangement and workmanship, ensuring they are as detailed in the approved plans. Where work is not as detailed in the plans it shall be rectified.

Non-Destructive Examination is to be carried out by sufficiently qualified personnel. Note that this should be undertaken prior to painting. Typical requirements for welded construction are given as follows, where a critical weld is one where failure will result in loss of the load, primary welds are those in the main load path and secondary welds do not form part of the main load path (platforms, service fittings, etc).

Butt welds

- Critical welds - 100% Visual, 100% Magnetic Particle Insepction (MPI) & 100% Ultrasonic Inspection
- Primary welds- 100% Visual, 100% Magnetic Particle Inspection (MPI) & 20% Ultrasonic Inspection
- Secondary welds - 100% Visual

Fillet welds

- Critical welds - 100% Visual, 100% Magnetic Particle Insepction (MPI)
- Primary welds - 100% Visual, 100% Magnetic Particle Inspection (MPI)
- Secondary welds - 100% Visual

In addition to welds, it is also often required to inspect the material local to the lift point for laminar discontinuities.

Painting and Marking

Once the testing and inspection has been completed the lift beam can be painted and marked up with required information – specifically the SWL/WLL. For lift beams subject to the Supply of Machinery (Safety) Regulations the following markings are required:

- Marked for UKCA (or EC, if applicable)
- Name and address of the manufacturer
- Serial number
- Year of construction
- Total mass of assembly
- SWL/WLL – including all configurations (where appropriate)

Markings should confirm with published standards such as BS EN ISO 7010 or other appropriate legislation.

References

1. International Labour Organisation, Register of Lifting Appliances, and Items of Loose Gear, 1985

Written by Alasdair MacDonald, Team Leader & Senior Structural Engineer, Malin Abram

HEAVY LIFT TIP CONFIGURATIONS TIPS IN SOLIDWORKS

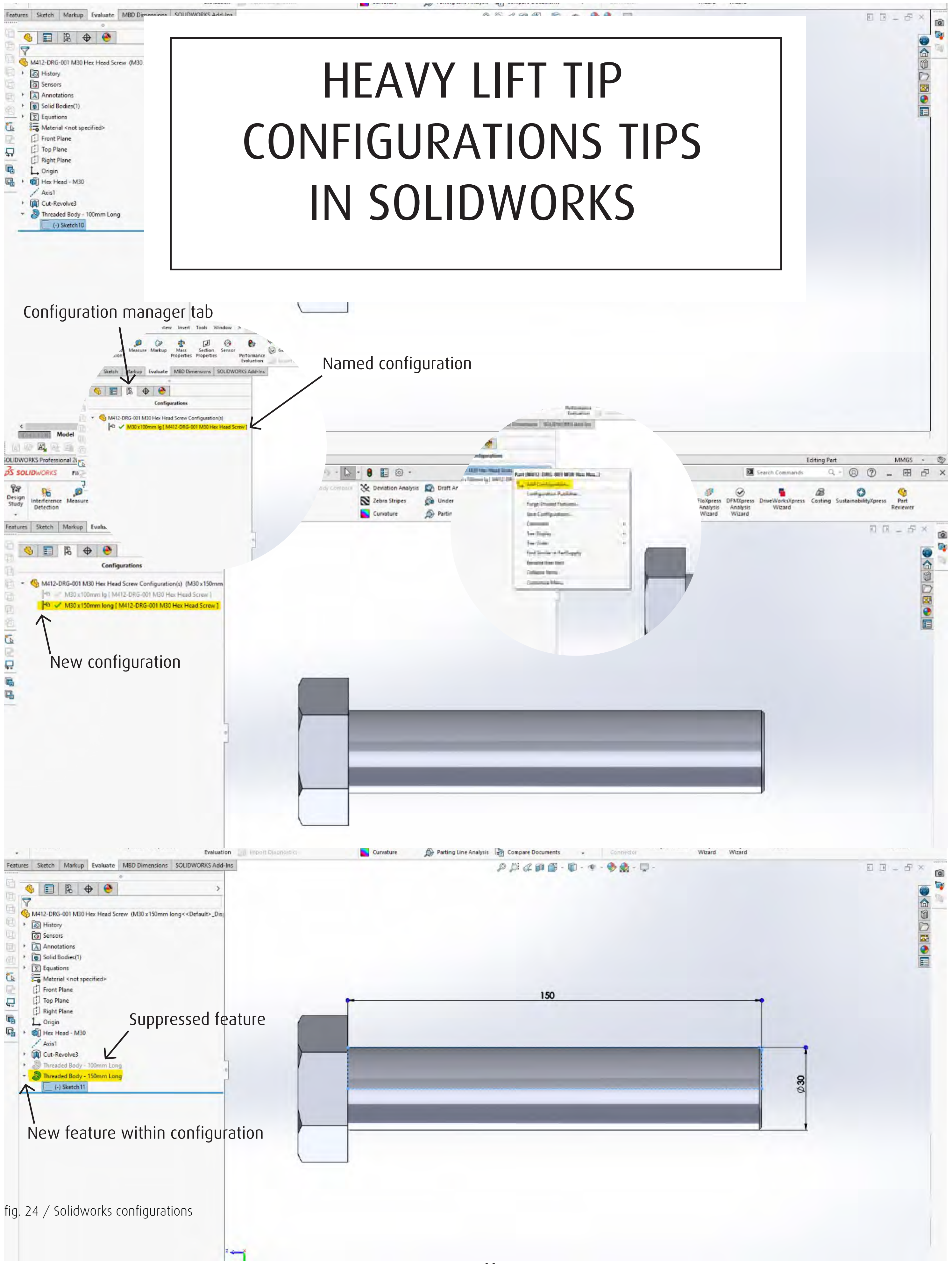


fig. 24 / Solidworks configurations

CONFIGURATIONS TIPS IN SOLIDWORKS

SOLIDWORKS configurations are used to create multiple versions of a part or assembly within a single file number. The differences between the configurations can consist of changes in dimensions, the suppression of different features or the modification of parameters.

Configurations are mostly used to create simplified versions of a single part, for use in assemblies. An example of this could be a hex head screw.

When creating your initial screw size, M30x100mm long, you would create a part number and add your description within this e.g., M412-DRG-001 M30 Hex Head Screw. Notice you would not state a particular length within the description as the main purpose of this is to build up configurations of different lengths for the same diameter screw within this single part number.

Once your component is created and your threaded dimension length is at 100mm long, you then go into the configuration manager tab, and name your first configuration, M30 x 100mm long.

After this, you right click the top item and add configuration, naming this with your new length, M30 x 150mm long:.

Within your new configuration, you then suppress the original 100mm long feature created in your initial configuration and create a new threaded dimension length at 150mm long.

You will now have two different lengths of screw within your single component; this means that you can easily select either one within your assembly. This process may be repeated with as many different lengths of M30 screw as required.

Written by Barry Leitch, Draughtsman, Malin Abram

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