LIMPET® TECHNOLOGY

Pioneering Total Height Safety

Limpet® System Installation Proposal

Rev 01.B

Installation of the Limpet® Multifunctional Height Safety System

CONFIDENTIAL

Summary

On the (date), engineers from Limpet Technology Ltd. carried out a pre-installation survey of a (make and model) wind turbine at (site, country). Onsite they surveyed Wind Turbine Generator (WTG) 1 and identified an installation solution for the Limpet® multifunctional height safety system. The Limpet® would provide fall prevention, 90% climb assist, evacuation, remote rescue and work positioning on the main ladder.

The following document provides technical details of the installation for a single Limpet® system.

Customer:

Date:

Site:

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1 Introduction

1.1 Background

The Limpet® is the world's only integrated fall protection, climb assist, rescue, evacuation and work positioning system; a total height safety solution that provides five key functions in one simple, reliable and cost-effective system. The Limpet's climb assist function increases productivity and reduces expensive downtime, while its "always-on" fall prevention technology prevents the accidents that cost lives, money and reputation. Combined with market-leading rescue, evacuation and work-positioning technology, reduced maintenance and servicing requirements, and a minimum 25-year lifespan, the Limpet® offers significant cost of ownership benefits.

1.2 Aims and Objectives

The purpose of the onsite survey was to allow Limpet® engineers to assess the suitability of providing a total height safety solution to (customer name and site) wind farm, (country). This involved evaluating conventional ladder access to the nacelle, identifying an appropriate installation platform for the Limpet® unit and suitable safety line path, appropriate power supply and location for correct Limpet® operation, and installation compatibility with respect to the OEM design and fall arrest systems already *in situ*. For each installation, Limpet® work to exceed all current safety standards and specific company directives, supporting employers' corporate responsibilities.

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2 Site Survey Details

On the (date), engineers from Limpet Technology Ltd. carried out a pre-installation survey of WTG 1, a (make and model) turbine on the (owner and site and country). The following sections record the site findings and describe, in detail, the installation proposal for a single Limpet® system and line return.

2.1 Internal WTG Configuration

The (make and model) turbine has an approximate hub height of XXm. Inside, there is a single ladder used by personnel to gain access to the nacelle, where this is the only method of access. The ladder (L_1) measures a distance of ~xxm between the ground floor and the yaw platform. There are four platforms, including the yaw floor, as shown schematically in Figure 1. All platforms are protected with hinged aluminium chequered plate hatches. Each floor (with the exception of the yaw floor) consists of fabricated steel chequered panels, thickness 6mm, where the floor is stiffened by steel ribs welded and bolted on the underside and at the perimeter to bosses welded to the turbine wall. The yaw floor is constructed from fully welded 6-7mm steel sheet and is also fully welded around it's perimeter to the turbine wall. The Limpet® system would provide fall prevention, 90% climb assist, evacuation and rescue functionality on L_1.

A HACA fixed rail (EN 353-1 type) fall arrest system is installed on L_1, where the nominal ladder width is 490mm. The HACA rail runs down the centre of the ladder, therefore the Limpet® head pulley structure would be installed asymmetrically, permitting the Limpet® safety line to run down either to the left or the right of the rail. The Limpet® has been installed successfully alongside similar guided systems.

The main access ladder (L_1) extends ~1.1m above the yaw platform and the base of the nacelle ladder measures ~1.4m above the platform. The nacelle ladder is mounted off the nacelle and yaws around the yaw ring. The dimensional arrangement of the main and nacelle ladder dictate that the maximum height of any Limpet designed pulley structure above the main ladder must be less than 0.3m, although this dimension can be turbine specific. Should this dimension be exceeded then the nacelle ladder would impinge on the pulley structure during yaw.

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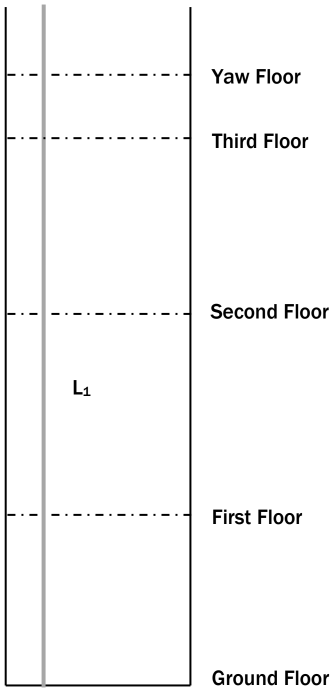

Figure 1: Schematic of turbine layout showing; the single ladder configuration in grey, L_1, and four internal platforms including the yaw floor.

The yaw platform measures ~3m in diameter and in the centre a steel stanchion frame allows operatives to step up and onto the nacelle ladder. This third platform also measures ~3m in diameter and has two cable conduits running through it. To avoid restricting the working space available on the yaw platform, the simplest installation arrangement would be to mount the Limpet® off the ladder on the third floor.

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3 Installation

This section describes a single Limpet® system retrofit into a (make and model of wind turbine). The Limpet® will be installed to provide access protection to the entire ladder length.

3.1 Summary

The Limpet® unit will be mounted off the back of the main access ladder on the third platform (Figure 2). The position of the Limpet® ensures that operatives are not restricted when accessing the yaw room to gain access to the nacelle. The safety line[1] will exit the Limpet® and will pass straight up the back of the ladder to a head pulley mounted off Limpet's installation framework (Figure 3). New Limpet® metalwork has been designed to fit alongside the existing HACA fall arrest system and is capable of withstanding a 20kN safety line load to comply with EN50308 (anchor load rating during evacuation). The framework provides a convenient load bearing point, satisfying both the load requirements and the practical requirements to allow users to step safely off the ladder, whilst still maintaining access to the nacelle ladder. The height of the pulley above the floor has been designed to maximise the distance between the floor and the operative's sternum attachment point, allowing the user to climb through the hatchway and close the cover before disconnecting from the Limpet®. The Limpet® will be supplied on mounting rails which will be fastened to the ladder using a Limpet® designed mounting frame. The three closest ladder rungs will be reinforced with M16 threaded bar and two steel side plates, to provide extra stiffness.

All safety hatches will remain to protect the user when accessing intermediate platforms and the nacelle, and during entry/egress to the Limpet® system. The front of all hatches (and any other potentially abrasive surfaces) will be fitted with a means of edging protection, such as a small roller to eliminate safety line abrasion (Figure 4). The yaw deck hatch will be replaced with a specifically designed hatch to compliment the head pulley metalwork.

A single-phase 230V, minimum 14A supply is required to power the Limpet®, via a standard Limpet® uninterruptable power supply (UPS). The UPS typically provides forty minutes of battery operation should mains power be interrupted. The UPS will be securely located on anti-vibration feet and positioned adjacent to the Limpet®.

[1] Dyneema® core with a Technora® sheath, MBL 29.4kN, or Dyneema® core with Polyester sheath MBL 24kN.

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There is a 230Vac socket available on the third floor, to the left hand side of the ladder (when climbing). Should power be made available from this location, the Limpet® may be plugged straight in using a short 2m length of cable. The cable specification for the Limpet® mains supply is standard 3-core H07RNF cable, 1.5sq.mm and would be terminated with a standard plug.

Control units for the Limpet® system will be placed at the yaw platform and bottom of the main access ladder (L_1). These will be accessible to the operative without obstructing access/egress to the ladder.

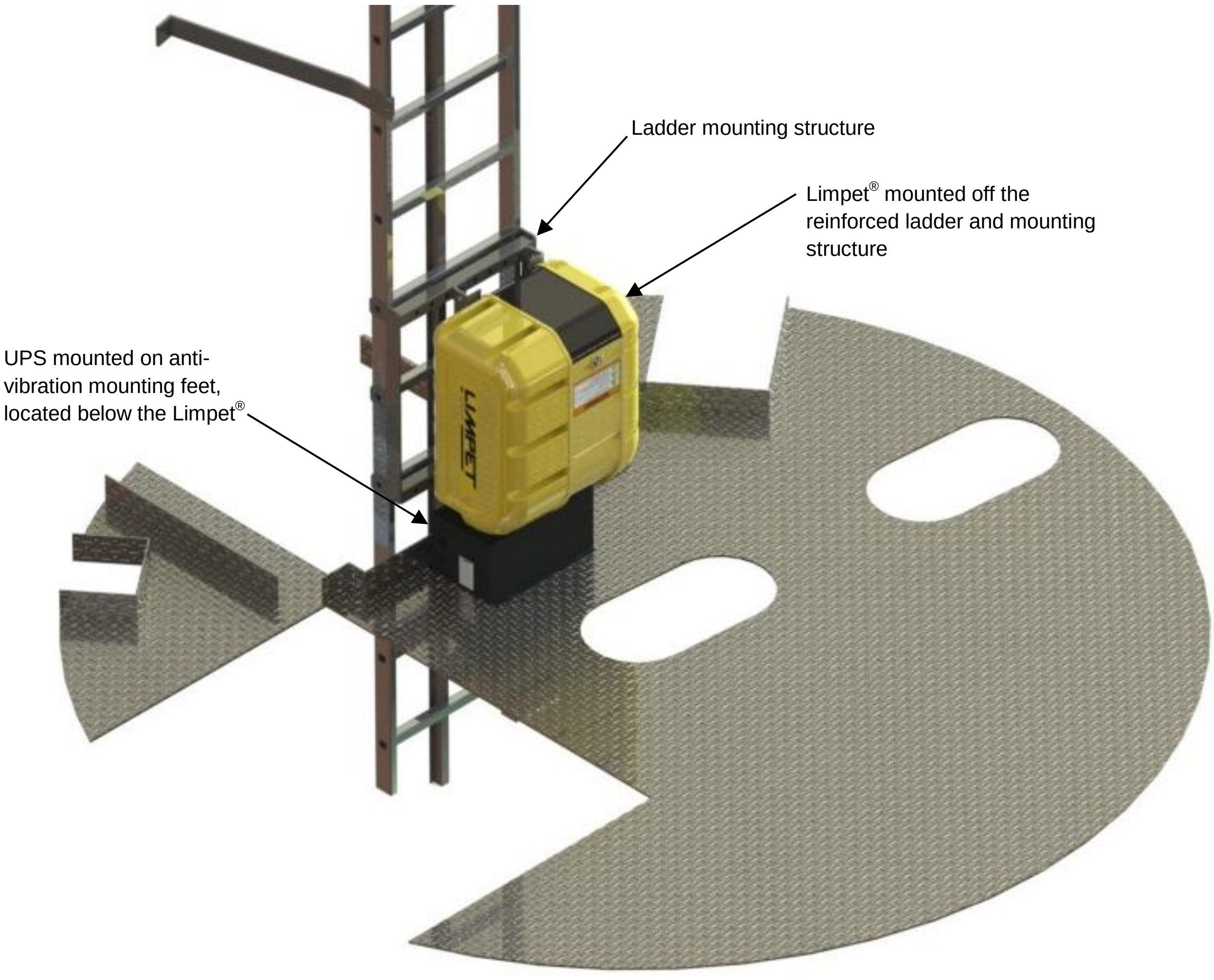

Figure 2: CAD representation of Limpet® height safety proposal showing; third platform, the Limpet® main unit, UPS and Ladder Mounting Structure (cable conduit hidden for clarity)

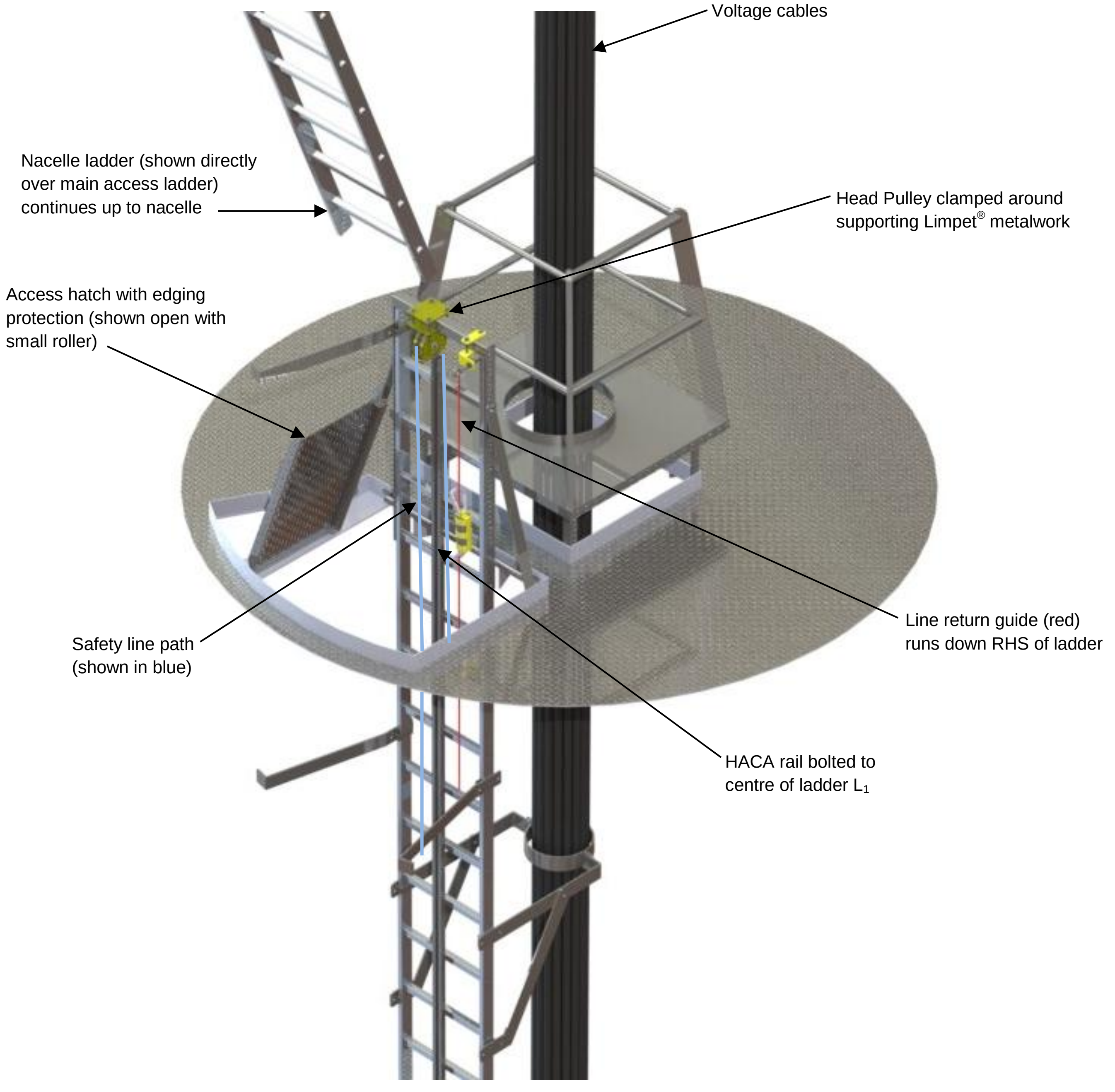

Figure 3: CAD representation of Limpet® height safety proposal showing; yaw platform, the Limpet® Safety Line path, Head Pulley Location, and Line Return Wire

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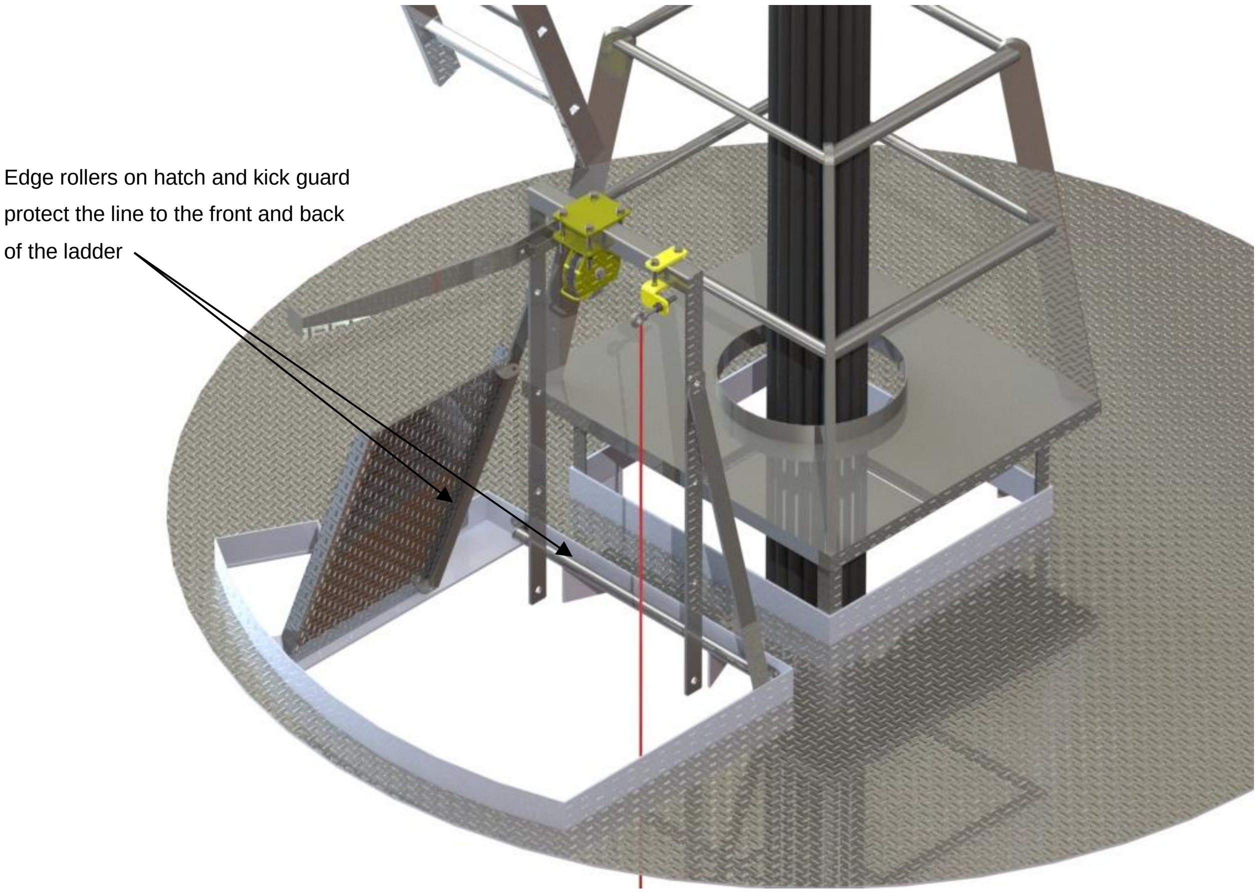

Figure 4: Yaw floor detail showing rollers for edge protection (ladder and HACA rail hidden for clarity)

3.2 The Limpet® System

The single Limpet® system consists of one Limpet® unit with a Dyneema® core safety line, one UPS, two control units, one RF remote, one Head Pulley and mounting metalwork and one Line Return guide.

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3.3 Mechanical Installation

3.3.1 Limpet®

The Limpet® unit will be installed just above the third platform, on the back of the ~74m main access ladder (L_1). The position of the Limpet® is such that the operative's path while on the ladder and in the yaw room will remain unobstructed.

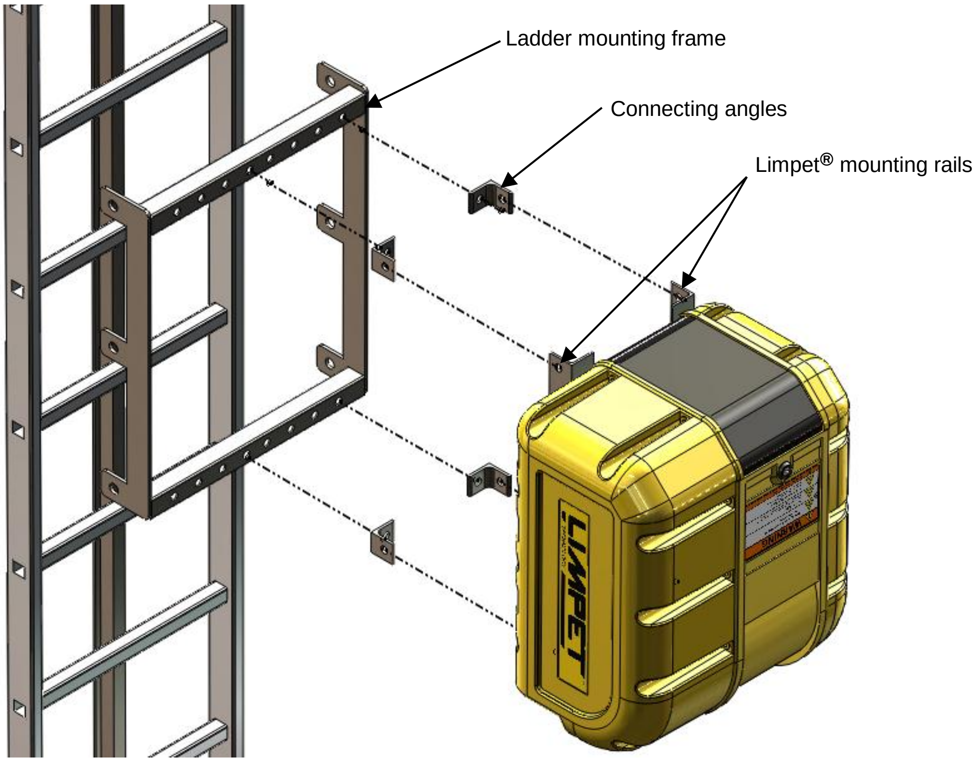

Figure 5: Exploded assembly showing the ladder-mounted Limpet®

The Limpet® unit will be supplied on mounting metalwork (see Figure 5) which will be bolted to the ladder by 3No M16 Grade 8.8 threaded bars which will also reinforce the rungs at the Limpet® location. The metalwork has been designed to help distribute and minimise loads imposed on the ladder during use – load is carried by the reinforced ladder stiles, rather than introducing point loading directly to the rungs. The horizontal members of the mounting frame will be positioned to be in-line with the top surface of the ladder rungs to give operatives more toe-space when climbing the ladder. The Limpet® mounting structure has been rated to withstand a 20kN line load, where both the Limpet® and mounting rails have been certified under the Machinery and PPE directive and load tested to 22kN.

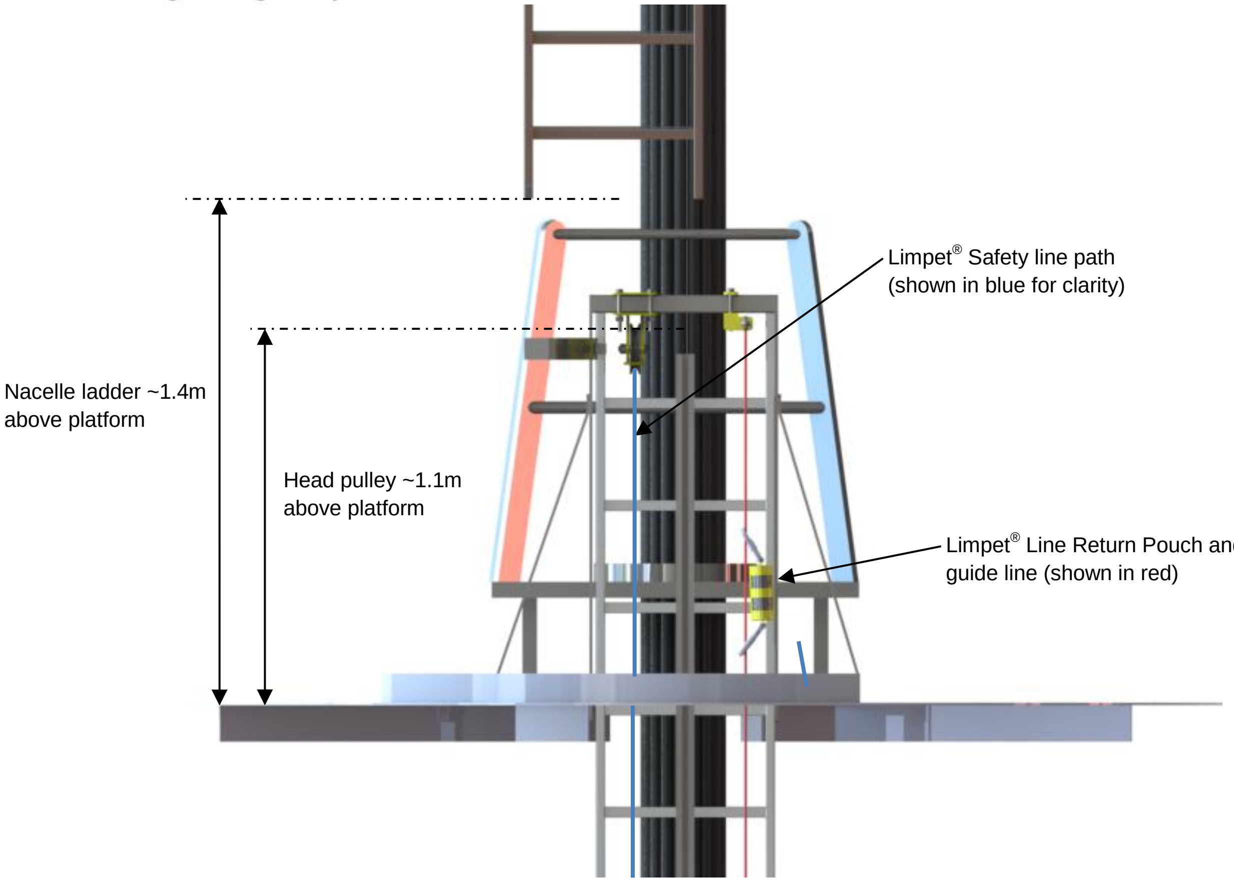

Figure 6: CAD image of the yaw platform showing the safety line path up to the head pulley structure.

The Limpet® safety line will exit the machine and travel up to the head pulley structure mounted ~1100mm above the floor, passing the existing structure in the centre of the yaw platform and ladder brackets, see Figure 6.

To prevent abrasion of the safety line and to ensure a clear path between the head pulley and the third floor, Limpet® propose that the yaw floor hatch, manufactured from aluminium checker plate, should be fitted with a roller bolted to the underside of the hatch. The roller surface will extend forward of the hatch edge flange, providing protection against any sharp edges.

3.3.2 Uninterruptable Power Supply

The uninterruptable power supply (UPS) will be installed on the yaw platform alongside the Limpet®. This keeps cable runs to a minimum. The location of the UPS is flexible, dictated only by the location of the single phase mains input, see Section 3.4.1.

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3.3.3 Single Limpet® Head Pulley Structure

The head pulley will be mounted above the ladder, to the left hand side (LHS) of the HACA rail, keeping both the Limpet® line and the HACA rail separate and free from fowling. The position and height of the pulley has been designed to make it convenient for the operative to climb out onto the yaw platform. Furthermore, the framework has been designed to allow users to stand on the structure when entering the nacelle and all sharps have been removed to minimise injury in case of a fall from the nacelle. The framework will be fastened to the ladder and kick-guards using Limpet® designed metalwork (see Figure 7) where the structure has been designed and rated to withstand a 20kN line load.

The structure consists of a 50x50x5mm square hollow section (SHS) steel member, welded to two 8mm thick side plates. The side plate will be attached to the ladder by M16 bars inside the ladder rungs which reinforce the rungs and give the ladder extra stiffness. To provide additional lateral support, the frame will also include two folded flat bar members which will bolt into the kick-guards at either side of the opening. Bolting to the kick-guard rather than the floor will preserve the sealed yaw floor, which is intended to prevent oil leaks.

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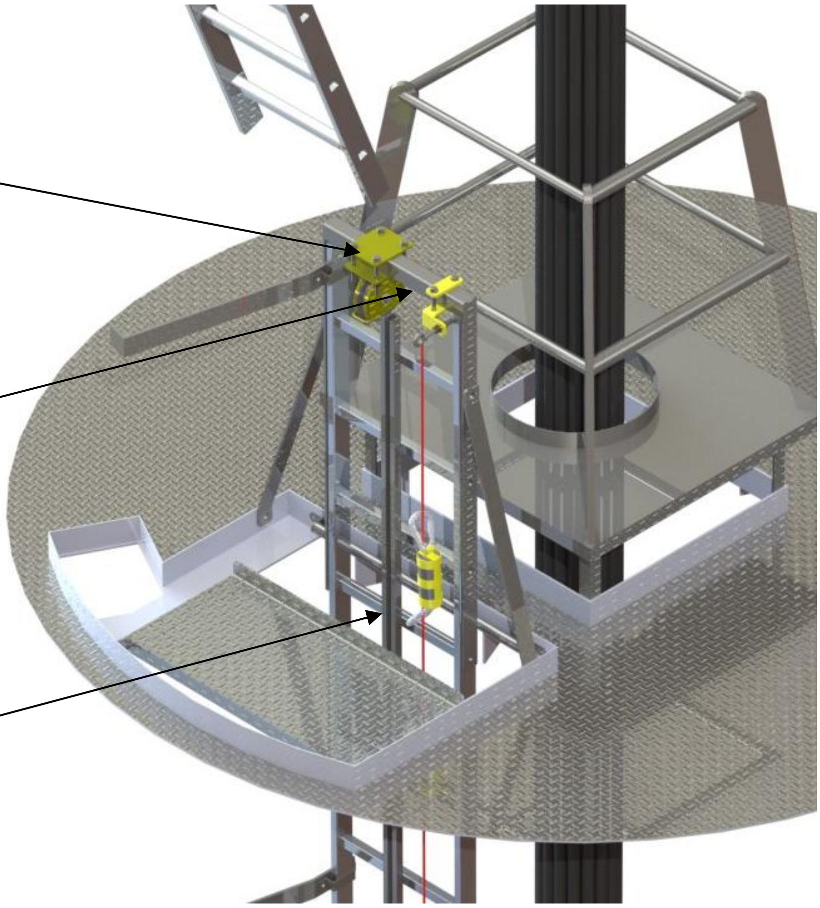

Figure 7: CAD model showing the Limpet® head pulley clamped to the Limpet® cross-member. The Limpet® pulley is mounted on the LHS to minimise fowling with the HACA rail.

The Limpet® pulley is clamped about the support structure with four M12 fasteners (minimum property grade 8.8) and has gone through certification testing as part of the Limpet® PPE test method. The test specification included applying a 15kN line load to the pulley sheave with a wrap angle of 180°, causing a 30kN load to act through the axle. This was held for three minutes before a peak line load of 29.23kN was applied (58.46kN at the axle); the test was subsequently stopped with no obvious fractures or damage post-test.

3.3.4 Control Units

Two wired control units for the Limpet® will be supplied and installed. One, positioned at the bottom entry/egress point of L_1 and the second, at the top entry/egress point of L_1. Limpet® supply two mounting options; using 32 x 7mm shielded Neo pot magnets, or a standard mounting plate to be drilled and bolted.

For this installation; Limpet® recommend using the magnet mounting method against the internal turbine wall at the bottom of the main ladder, where the position will be as close to the

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ladder as possible without obstructing access/egress. The same magnet mounting method, fastened directly to the turbine wall, 1100mm above the yaw platform, will be used for the top control box installation.

3.3.5 Safety Line Return

The Line Return system provides users with a method of lowering the Limpet® karabiner to the foot of the ladder to allow others access. The Line Return system must be installed when there is only a single Limpet® system installed/available for use within a WTG.

The Line Return system consists of a guide wire (3mm, 7x19 galvanised steel cable sheathed in P.V.C) tensioned between stainless steel eyebolts installed at the yaw floor and bottom of L_1. The eyebolts will be bolted to the top and bottom RHS ladder brackets and will be positioned to keep the guide away from the ladder. Limpet® tension the guide wire to 60kg. To return the karabiner the user clips the safety line to the pouch and activates the "Pay-Out" command on the control unit. The Limpet® pays out at maximum of $1ms^{-1}$, taking just over one minute to return the karabiner to the base of the ladder, L_1.

3.3.6 Safety hatches

To prevent abrasion of the safety line and to ensure a clear path between the head pulley and the ground floor, Limpet® propose that the first, second, third and fourth floor safety hatches should be moved back as far as possible, to allow a minimum 160mm gap between the edge of the hatch and the front of the ladder stiles. Where a 160mm gap cannot be achieved, Limpet® will provide new retro-fitted hatches. This is only likely to be necessary at the yaw platform.

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3.4 Electrical Installation

Details of the Limpet® system and electrical certifications are listed in Section 7.

3.4.1 Power Supply

The Limpet® system is electrically powered from mains (230-240V, 50-60Hz). Mains power is fed into an Uninterruptible Power Supply (UPS) and the UPS then feeds the Limpet® unit. In the event of a power failure the UPS enables the user to reach a point of safety. The Limpet® will operate for a period of time in this mode. The Limpet® will enter an error mode until the power is restored (the error will clear if/when power is restored along with all Limpet® functionality)

Limpet® suggest that electrical power could be taken directly from the 230Vac, 14A supply on the third platform. The cable specification for the Limpet® mains supply is standard 3-core H07RNF cable, 1.5sq.mm and would be terminated with a standard blue single phase plug.

Power consumption is approximately 50W when the unit is on, but not in use. When in use, power consumption depends on the type of use – this can vary from 50W to 2.2kW, but will typically be around 720W when a user is climbing using climb assist.

The Limpet® is internally protected by a 16A fuse on the mains input.

3.4.2 Wired Control Units

The control units are connected via screened communications cable. Cable runs will be kept as short as possible whilst following existing cable routings as far as possible.

3.4.3 Wireless RF Remote

The wireless remote control used with the Limpet® is battery powered (3.3V) and operates in the 433.050 to 434.790 MHz range. This will be permanently attached to the end of the safety line in a small pouch.

3.5 Wall Notices

Limpet® will provide operational information in the form of wall mounted basic instruction cards and warning notices, these will be fitted alongside each control unit.

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4 Design of New Structural Elements

4.1 Limpet® Mounting Structure

The Limpet® unit will be bolted to the lower and upper box sections (Figure 8). Box sections will move the Limpet® further away from the ladder rungs, making it easier to users to climb past the unit on the climbing side of the ladder. There will be several sets of pre-drilled holes through the box section to allow flexibility in the positioning of the Limpet®. The capacity of the box-section used has been verified by hand-calculations (see 'Appendix A – Limpet® Mounting Structure') and finite element analysis has been carried out on the box-section and side plate to verify that imposed loads will not cause excessive stress around the drilled holes.

Finite element analysis carried out for ultimate loading (20kN tension in the safety line), showed that stresses and deflections in both the side plates and box sections remained within acceptable limits.

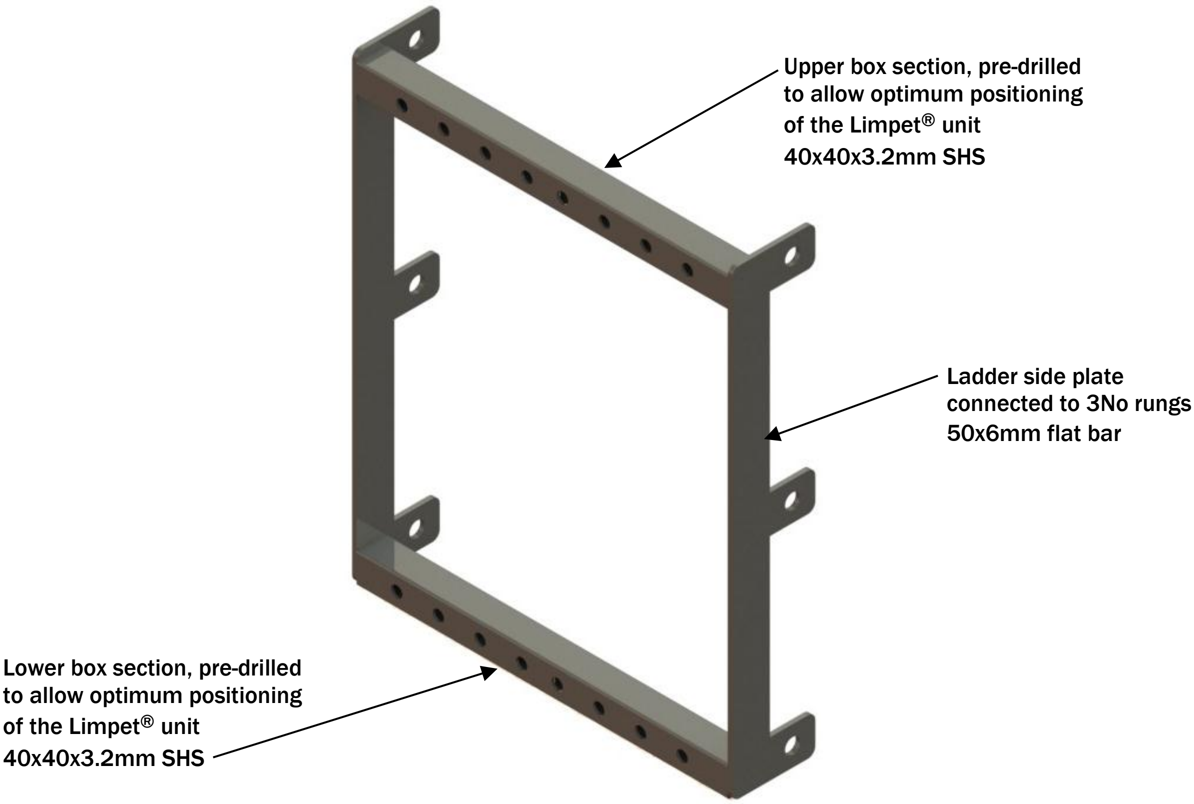

Figure 8: CAD render of Limpet® ladder mounting structure

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The worst case reaction produced at the supports of the upper box section was found to be 6.12kN (the derivation of the applied load can be found in 'Appendix A – Limpet® Mounting Structure'). The reactions were calculated on the assumption that the four Limpet® bolts all carry 5kN of shear load each, under the ultimate line loading of 20kN. The reactions at the right and left are unequal since the Limpet® is positioned eccentrically. The 6.12kN load was applied in an upward direction to the side plates, distributed evenly over the three drilled holes. Application of this loading produced stresses well below yield and very small deflections, see Figure 9.

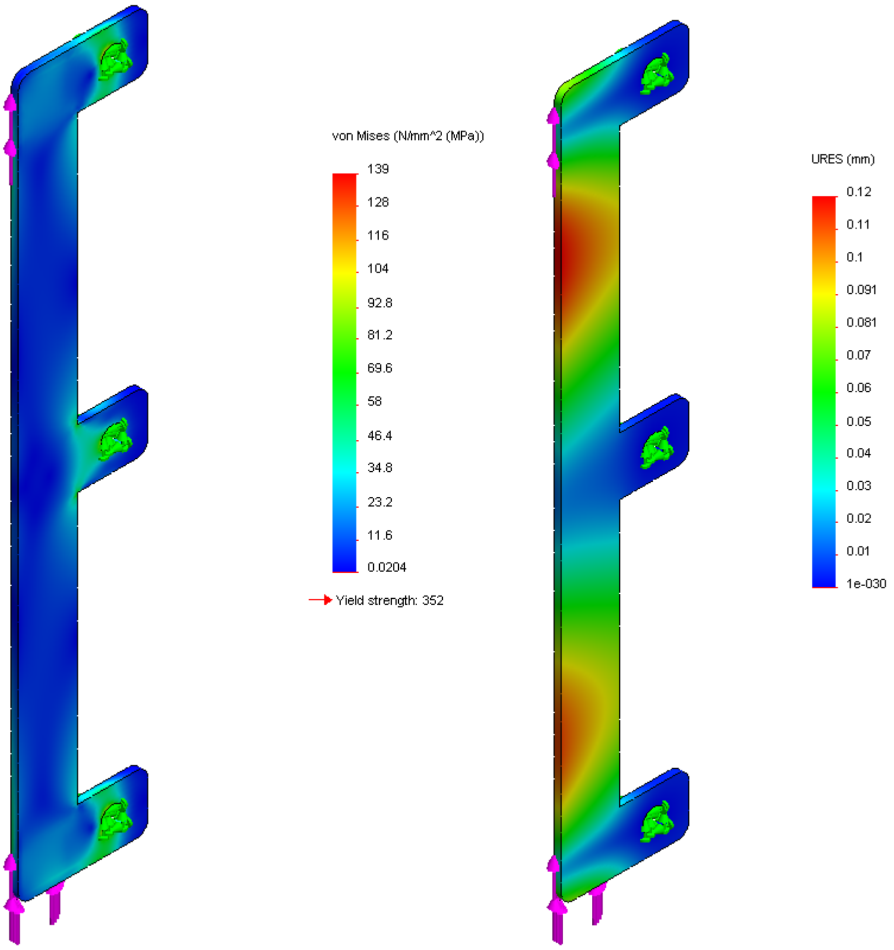

Figure 9: Von Mises stresses (left) and displacement (right) in side plate of ladder mounting bracket. Maximum stress = 139MPa, Maximum displacement = 0.12mm

As described above, the loading applied to the box section was taken to be two 5kN loads applied to one pair of drilled holes – assuming that the Limpet® bolts carry 5kN each. This loading produced stresses that were well below yield and deflections below the serviceability limit (which is normally taken as the total span in millimetres over 200 - in this case 2.45mm) – see Figure 9 and Figure 10 below.

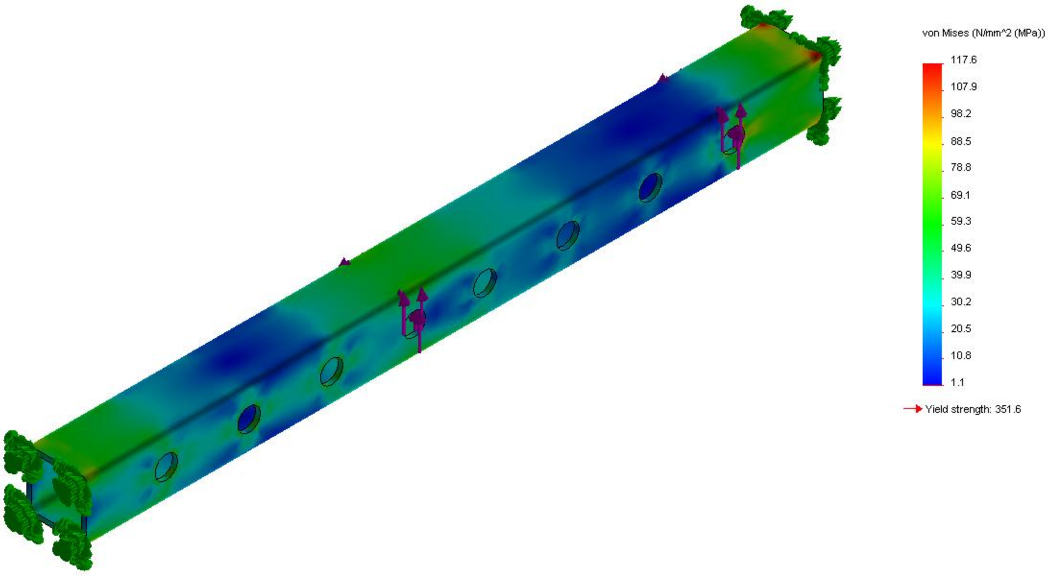

Figure 10: Von Mises stresses in horizontal member of ladder mounting bracket. Maximum stress = 117.6MPa

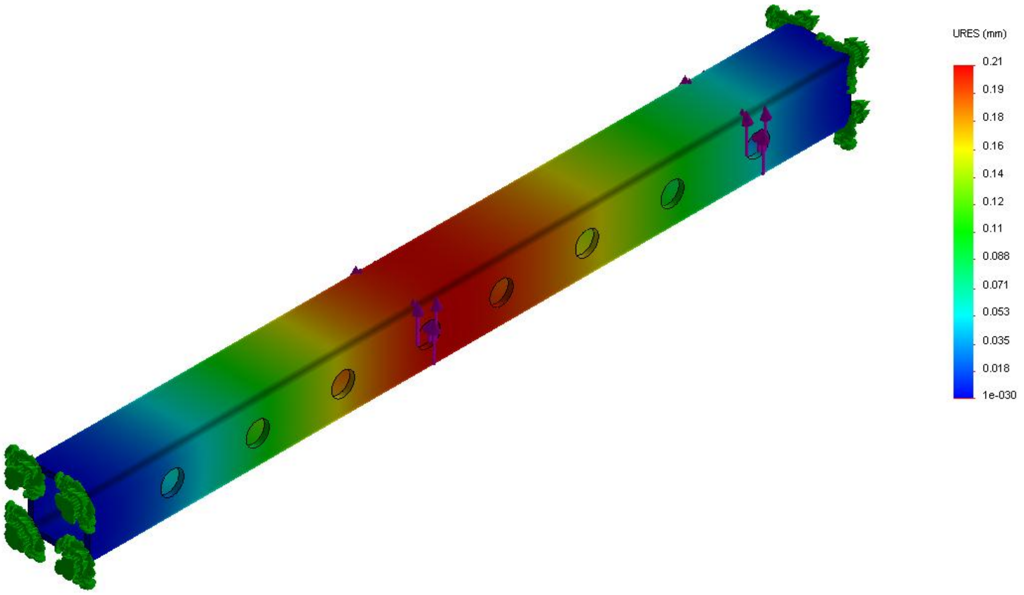

Figure 11: Displacement in horizontal member of ladder mounting bracket. Maximum displacement = 0.21mm

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4.2 Head Pulley Structure

The head pulley structure consists of a top beam which bears onto the ladder stiles and is welded to the ladder side-plates. The side plates will provide extra stiffness and will connect the M16 reinforcing bars in the rungs together. As part of the installation kit and to prevent lateral movement, Limpet® will install flat steel bar bracing to the sides of the ladder. These will bolt into the kick-guards, avoiding the need to drill through the yaw floor, which is sealed to prevent oil leaks.

The structure has been designed to comply with the British Standard for Structural Steel, BS 5950, for hand calculations for the box-section, flat bar and M16 bar capacity, see 'Appendix C – Head Pulley Structure'. Finite element analysis has also been carried out on the structure and shows that stresses under the ultimate load case do not exceed the yield stress of the steel and that deflections are within acceptable limits.

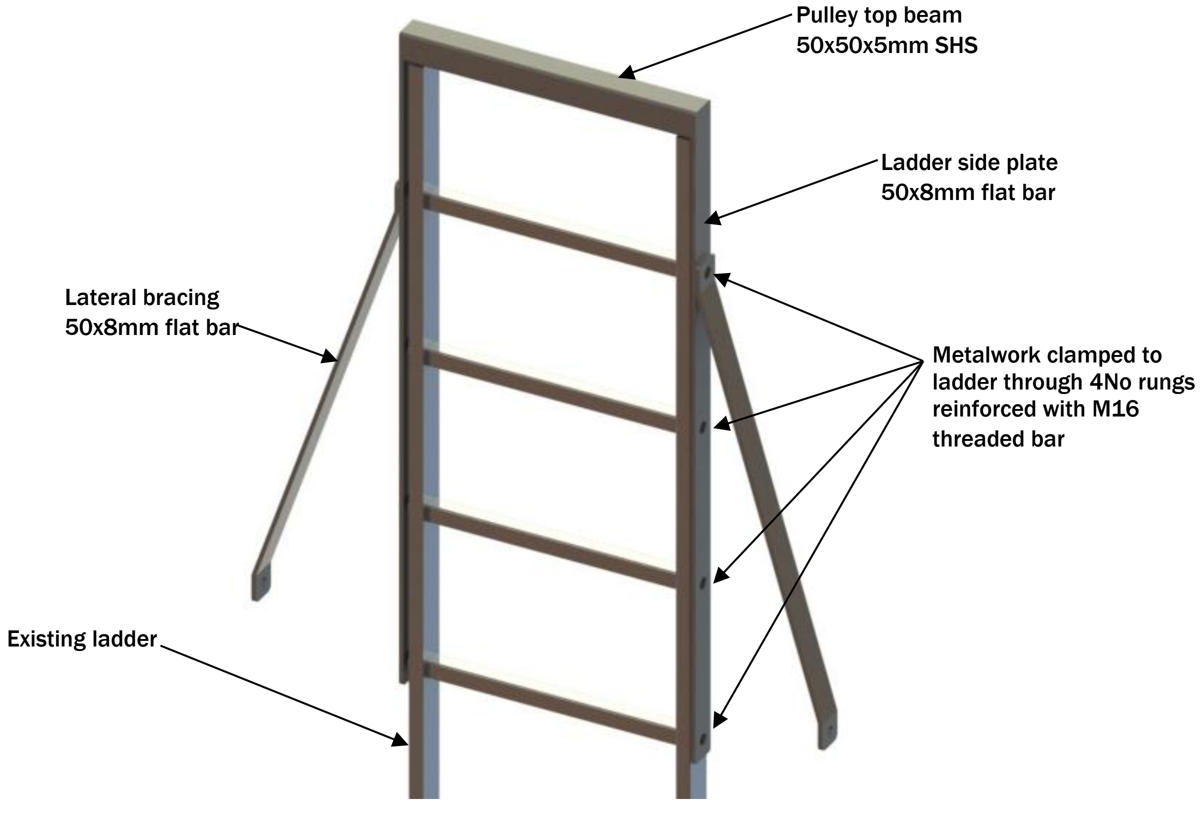

Figure 12: CAD Render of head pulley structure and ladder.

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The worst case resultant force produced by the pulley on the top beam was found to be 40kN (the derivation of the applied load can be found in 'Appendix C – Head Pulley Structure'). The force was calculated on the worst-case assumption that the wrap angle of the safety line around the pulley was ~180° and that the system is under the ultimate line loading of 20kN. The 40kN load was applied as a remote load, dragged over the top surface of the beam. Application of this loading produced stresses well below yield and deflections within the serviceability limit of 2.5mm – see Figure 13 and Figure 14 below.

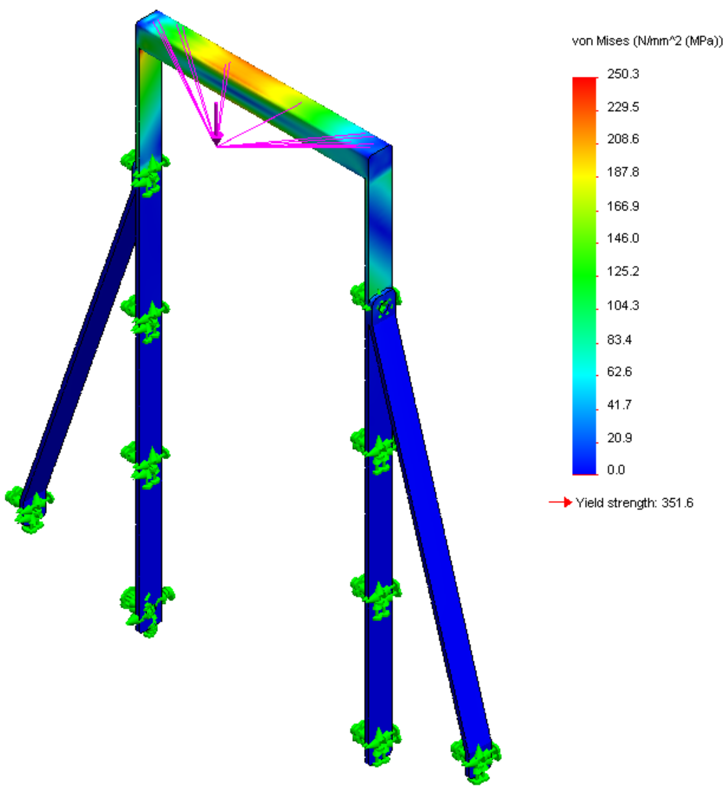

Figure 13: Von Mises stresses in pulley structure. Maximum stress = 250.3MPa

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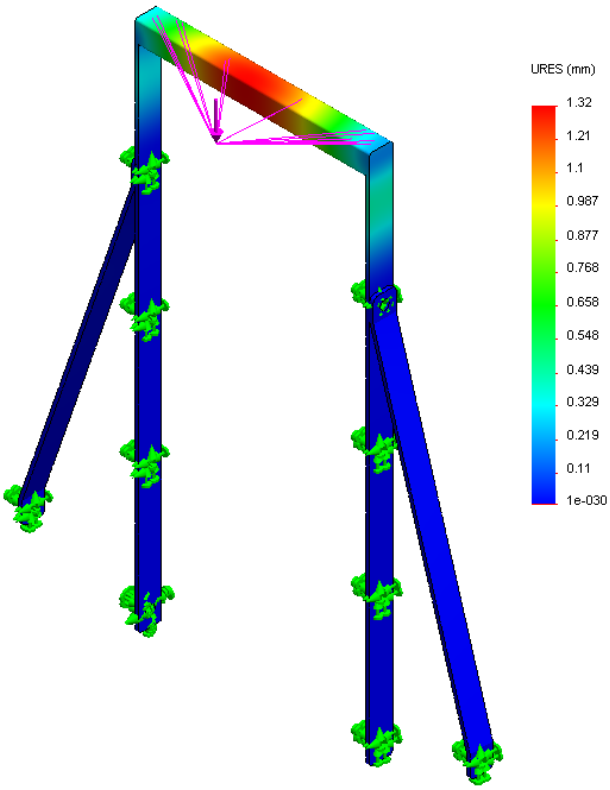

Figure 14: Displacement in pulley structure. Maximum displacement = 1.32mm

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5 Comparison of Forces on Ladder

5.1 Summary

As an alternative to ladder-mounting the Limpet®, it would also be possible to mount the Limpet® on the third floor platform. However, adopting this arrangement results in more severe ladder loading, since no beneficial 'cancelling out' can be taken from the upwards force on the Limpet® itself. All models are based on a 20kN ultimate line load – the maximum working load on the system is 1.4kN.

5.2 Forces on Ladder for Ladder-Mounted Limpet®

Figure 15: Ladder mounted Limpet® and maximum and ultimate force in line

Based on geometry, the wrap angle that the safety line contacts around the top pulley is ~180°. Therefore, the resultant force (F_R) exerted down through the pulley sheave can be approximated as:

$$F_R = 2T\sin\left(\frac{\theta}{2}\right)$$

$$F_R = 40\sin\left(\frac{180}{2}\right)$$

$$F_R = 40\text{kN}$$

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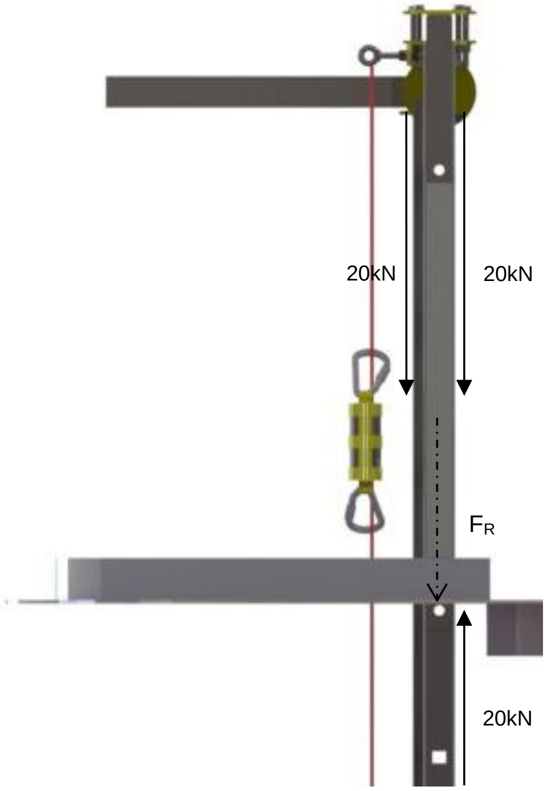

Figure 16: Forces on head pulley and ladder for ladder mounted Limpet®

Assuming vertical equilibrium, the resultant force on the ladder will be a compressive load of 20kN (during ultimate loading). Since the ladder is a PPE clipping point, it must be rated to 20kN, therefore ladder mounting the Limpet® will keep forces within the acceptable limits.

5.3 Forces on Ladder for Floor-Mounted Limpet®

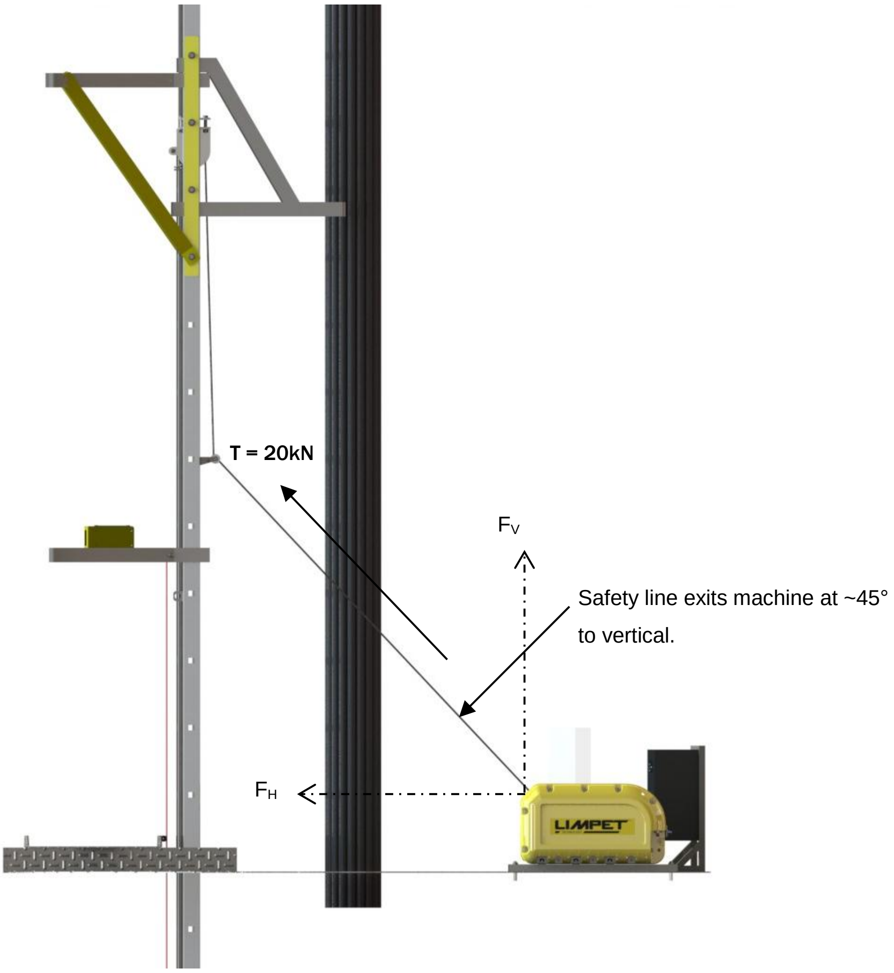

Figure 17: Alternative Limpet® mounting solution on third floor

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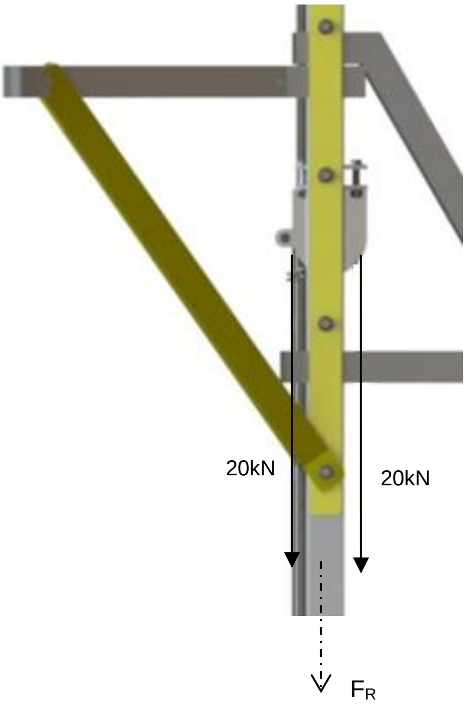

Figure 18: Resultant force on ladder with alternative arrangement

As for the alternative arrangement, the wrap angle on the head pulley will be ~180° therefore a total compressive load of 40kN must be resisted by the ladder and its supports. This is double the net load on the ladder using the ladder-mounted Limpet® arrangement.

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6 Installation Method Statement and Risk Assessment

Limpet® proposes to lift all system components using the external nacelle hoist (rated to 250kg) and then lower the components through the nacelle hatch and down to the yaw platform. The smallest dimensions of the nacelle hatch measure 700mm x 440mm, greater than the Limpet® cross-section of 500mm x 370mm. A method statement and risk assessment can be supplied for further details of all installation activities and operations.

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7 Certification Details

7.1 Limpet® System

The Limpet® unit has been certified under the Machinery Directive (2006/42/EC) as well as the PPE directive (89/686/EEC) and carries the appropriate CE markings to reflect this.

Mains power cable used in the installation is H07RNF, rated to 22A and complies with IEC 60228 class 5.

Mains connectors comply with DIN VDE 0606 T200; VDE 0110 IEC 60999: UL2238; CSA: C22.2 No 182.2-M1987

Industrial power connectors used for temporary installation comply with EN 60309-1 and EN 60309-2

Communications cable used is manufactured to UL 2919.

The Limpet® system complies with the following standards for Electromagnetic Compatibility (EMC):

EN 61000-6-2:2005 – Electromagnetic compatibility (EMC), Emission standard for residential, commercial and light-industrial environments.

EN 61000-6-3:2007 – EMC Emission for residential, commercial and light- industrial environments.

EN 61000-3-2:2006 – EMC Limits for harmonic current emissions.

EN 61000-3-3:1995 + A1:2001 + A2:2006 – EMC Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems

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7.2 Uninterruptable Power Supply

EN 60950 - Safety of information technology equipment

EN 50091-1-1 - General and safety requirements for UPS used in operator access areas

IEC 146 (CE122): Semiconductor electronic converters

The UPS has also been tested for CE marking according to European Directive 89/336 for electromagnetic compatibility.

Standards used for showing compliance with the essential requirements for the directive:-

EN 55022:1988 Class A

EN 61000-3-2:1995 +A1: 1988 +A2: 1998

EN 61000-3-3:1995

EN 55024:1998

EN 61000-4-2:1995 +A1: 1988 Class B

EN 61000-4-3:1996 Class A

EN 61000-4-4:1995 Class B

EN 61000-4-5:1995 Class B

EN 61000-4-6:1995 Class A

EN 61000-4-8:1993 Class A

EN 61000-4-11:1994 Class C

7.3 Wireless Remote Control

The Wireless remote control EN300 220-1 v1.3.1 (2000-2009)

EN300 220-3 v1.1.1 (2000 – 2009)

RTTE Directive 1999/5/EC – Radio and Telecommunications Terminal Equipment.

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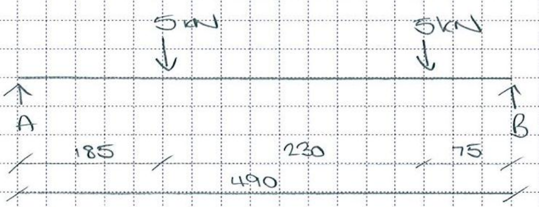
8 Appendix A – Limpet® Mounting Structure

LIMPET® TECHNOLOGY Pioneering Total Height Safety	Job/ Part description: REPOWER MM92 KIRF LIMPET STRUCTURE	Job/ Part number	Page
80/3 Commercial Quay, Edinburgh, EH6 6LX T: 0131 551 2727 F: 0131 551 2748	Calculation by: R MARR	Date: SEP 12	Checked by	Date

LIMPET WILL BE MOUNTED TO LADDER ON 2No SHS BEAMS. EACH LIMPET BOLT WILL EXERT A POINT LOAD ON EACH SHS. AS IN PREVIOUS CALCULATION, ULTIMATE LOADING WILL RESULT IN 5kN SHEAR ON EACH BOLT – SHEAR IN BOLT WILL PRODUCE A VERTICAL LOAD ON THE SHS.

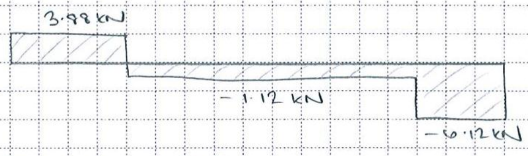


TAKING MOMENTS ABOUT 'A' (+) – $\Sigma M_A = 0$;

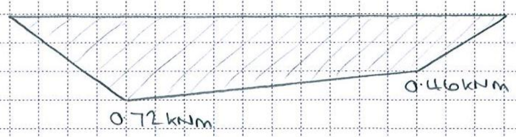
$0.185(5) + 0.415(5) - 0.49B = 0 \therefore B = 6.12\text{ kN}$

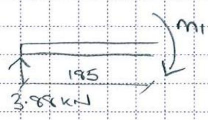
$\Sigma F_V = 0;\ A = 3.88\text{ kN}$

SHEAR FORCE IN SHS:

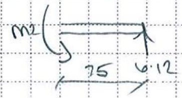


BENDING MOMENT IN SHS:





$\therefore m_1 = 0.72$



$m_2 = 0.46$

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LIMPET TECHNOLOGY Pioneering Total Height Safety	Job/ Part description REPOWER MM92 KIRF LIMPET STRUCTURE		Job/ Part number	Page
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MAXIMUM BENDING = 0.72 kNm

SECTION CAPACITY

SMALLEST AVAILABLE SHS – 40 x 40 x 3.2 mm

FROM TATA STEEL 'BLUE BOOK'

MOMENT CAPACITY = 2.18 kNm ∴ OK ✓

LIMPET STRUCTURE WILL BE ATTACHED TO LADDER USING STEEL SIDEPLATES, JOINED TO REINFORCED LADDER RUNGS

USING M16 BAR TO REINFORCE RUNGS IN 10mm STEEL SIDE PLATE

SAY 20kN ULTIMATE LOAD OVER 3 RUNGS – 6.7 kN EACH

CAPACITY OF M16 BAR

SHEAR CAPACITY (DOUBLE SHEAR), P_s = 117.8 kN

BEARING CAPACITY (10mm BEARING), P_b = 44.2 kN

∴ CAPACITY EXCEEDS APPLIED, 6.7 kN OK ✓

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9 Appendix B – Limpet® Bolts

LIMPET® TECHNOLOGY Pioneering Total Height Safety	Job/ Part description: REPOWER MM92 KIRF FORCE ON LIMPET BOLTS		Job/ Part number	Page
80/3 Commercial Quay, Edinburgh, EH6 6LX T: 0131 551 2727 F: 0131 551 2748	Calculation by: R MARR	Date: SEP 12	Checked by	Date

IF LIMPET IS MOUNTED VERTICALLY AGAINST THE LADDER, HOLDING DOWN BOLTS WILL BE IN PURE SHEAR.

LOAD IN SAFETY LINE

UNDER ULTIMATE LOADING – 20kN IN LINE

LIMPET HELD DOWN BY 4No BOLTS ∴ 5kN SHEAR / BOLT

BOLT CAPACITY

ASSUMING 4No GRADE 8.8 M12 BOLTS

SHEAR CAPACITY, P_v = 31.6 kN / BOLT

BEARING CAPACITY, $P_{bb} = d_b t_p p_{bb}$

WHERE d_b = 12 mm FOR M12
t_p = 3.2 mm FOR 3.2 mm SHS
p_{bb} = 1000 N/mm^2 FOR GRADE 8.8 BOLTS

$$\therefore P_{bb} = 12 \times 3.2 \times 1000 = 38.4 \text{ kN}$$

BEARING CAPACITY, $P_{bs} = k_{bs} d_b t_p p_{bs} \leq 0.5 k_{bs} e t_p p_{bs}$

WHERE k_{bs} = 1.0
p_{bs} = 460 N/mm^2 FOR S275
e = 20 mm EDGE DISTANCE

$$\therefore P_{bs} = 1.0 \times 12 \times 3.2 \times 460 \leq 0.5 \times 1.0 \times 20 \times 3.2 \times 460$$
$$= 17.67 \text{ kN} \leq 14.72 \text{ kN}$$

∴ APPLIED LOAD, 5kN < BOLT CAPACITY, 14.72 kN

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10 Appendix C – Head Pulley Structure

LIMPET TECHNOLOGY Pioneering Total Height Safety	Job/ Part description: REPOWER MM92 KIRF HEAD PULLEY STRUCTURE		Job/ Part number	Page
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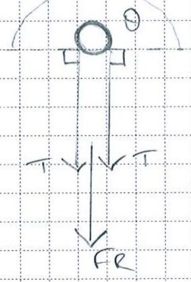
IF SAFETY LINE EXITS LIMPET VERTICALLY, WRAP ANGLE ON TOP PULLEY = 180°



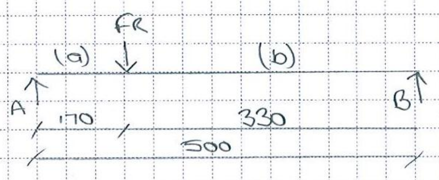
WHEN θ = 180° FR = 2T

DURING ULTIMATE LOADING
T = 20 kN ∴ FR = 40 kN

DURING WORKING LOADING
T = 1.4 kN ∴ FR = 2.8 kN

PULLEY TOP BEAM

PULLEY WILL BE POSITIONED ECCENTRICALLY ON THE TOP BEAM TO AVOID CLASHING WITH THE HACA SYSTEM. THIS WILL RESULT IN A GREATER REACTION AT ONE SIDE.



ULTIMATE LOADING REACTIONS

$$R_A (ULT) = \frac{FR \times b}{L} = \frac{40 \times 0.33}{0.5} = 26.4 \text{ kN}$$

$$R_B (ULT) = \frac{FR \times a}{L} = \frac{40 \times 0.17}{0.5} = 13.6 \text{ kN}$$

$$\text{MAXIMUM BM} = \frac{FR \times ab}{L} = \frac{40 \times 0.17 \times 0.33}{0.5} = 4.49 \text{ kNm}$$

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LIMPET TECHNOLOGY Pioneering Total Height Safety	Job/ Part description: REPOWER MM92 KIRF — HEAD PULLEY STRUCTURE	Job/ Part number	Page
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PULLEY TOP BEAM CONT.

FROM TATA STEEL 'BLUE BOOK'

MOMENT CAPACITY OF 50 x 50 x 5 SHS = 4.94 kNm
SHEAR CAPACITY OF 50 x 50 x 5 SHS = 93 kN

∴ USE 50 x 50 x 5 SHS, GRADE S355

SIDE PLATES

FULL ANALYSIS IN FEA – BUT CHECK BUCKLING BY HAND.

WORST BUCKLING LOAD = 26.4 kN

BUCKLING LENGTH (FROM TOP TO FIRST RUNG BAR)
L = 300mm

EFFECTIVE LENGTH, $L_E = 0.85L$ (FIXED/PINNED)
$= 0.85 \times 0.3$
$= 0.26m$

TRY 8mm THICK BAR – SAY 50 x 8mm S275

$\therefore E = 205 \times 10^3 \ N/mm^2$

$I = \frac{bd^3}{12} = \frac{50 \times 8^3}{12} = 2133 \ mm^4$

EULER CRITICAL BUCKLING LOAD

$$P_E = \frac{\pi^2 EI}{L_E^2} = \frac{\pi^2 \times 205 \times 10^3 \times 2133}{(260)^2} = 63.8 \ kN$$

∴ FOR BUCKLING 50 x 8mm FLAT BAR IS SUITABLE

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LIMPET TECHNOLOGY Pioneering Total Height Safety	Job/ Part description: REPOWER MM92 KIRF HEAD PULLEY STRUCTURE		Job/ Part number	Page
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RUNG REINFORCING BARS

4 RUNGS REINFORCED, IF TOTAL LOAD = 40K
ASSUME 10 KN EACH.

LOAD APPLIED AS SHEAR TO BAR.

CAPACITY OF M16 BAR (FROM TATA STEEL 'BLUEBOOK')

FOR GRADE 8.8 IN 8mm THICK MATERIAL:

SHEAR CAPACITY (DOUBLE SHEAR CASE) = 118 kN
BEARING CAPACITY (OF BOLT / PLATE) = 58.9 kN

∴ STRENGTH OF BAR IS IN EXCESS OF APPLIED LOADS - GRADE 8.8 M16 IS SUITABLE.

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