Ardrossan Ferry Terminal

Berth Compatibility Study

Caledonian Maritime Assets Limited

25 January 2016

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PB3783

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1. INTRODUCTION

1.1 The Project

Caledonian Maritime Assets Limited (CMAL) is tendering for two new circa 100m vessels, which will have the capacity to carry around 130 cars. The initial plans are that these vessels will operate on the Ardrossan to Brodick route and the Skye triangle (Uig, Lochmaddy and Tarbert Harris). CMAL commissioned Royal HaskoningDHV to undertake a berth compatibility study to comment on the ability of the existing ferry berth at Ardrossan to accommodate these new vessels.

1.2 Study Approach

A review was initially undertaken of all the records held by CMAL in their archives. No original calculations were found however a number of record drawings were provided and reviewed. A list of the relevant drawings is provided in Table 1.1 and these are attached as Appendix A.

Table 1.1 Record Drawings

Drawing No.	Title
HM1094-1-43	Ardrossan Harbour and Approaches
101 – Rev C	Contract General Arrangement (New Vessel)
UKHO Chart 1866-1	Ardrossan Harbour Extract
Ardrossan Harbour DWG.1	Ardrossan Harbour Site Plan & Main Berth
Cal Isles GA1	M.V. Caledonian Isles General Arrangement
81-22368	M.V. Caledonian Isles Stern Door/Ramp Installation Arrangement
81-22486 (2 sheets)	M.V. Caledonian Isles Bow Door/Ramp Structural Main Assembly
81-22487 (3 sheets)	M.V. Caledonian Isles Bow Door/Ramp Installation Arrangement

RHDHV's Engineer undertook a site visit to Ardrossan on the 6th of January. The aim of the visit was to understand the existing condition of the berth, the associated structures and the current use of the berth. Photographs were taken and are presented in Appendix D.

The information gathered was input into an assessment to determine the adequacy of the existing fenders and mooring bollards. Geometric checks were undertaken where possible to determine the suitability of the linkspan and current provisions for passenger access.

A topographic survey of the site was commissioned and was carried out by Aspect Surveys Ltd on 6th January. A copy of the survey is included in Appendix A.

2. ARDROSSAN FERRY TERMINAL

2.1 Ferry Berth

Ardrossan Ferry Terminal is a fully operational ro-ro berth, with daily services operating to and from Brodick on the Isle of Arran and a further four sailings per week to Campbeltown in Kintyre between May and September.
The existing berth is approximately 86m long and is a masonry and steel sheet piled sea wall with a reinforced concrete cope. The berthing face is fendered by Trellex MV Element Fenders.

2.2 Vessel Data

The MV Caledonian Isles (below left) is the current vessel that operates out of Ardrossan. The current relief vessel is the MV Hebrides (below right). Details of these vessels are provided in Table 2.1 below. Details of the proposed '100m vessel' are also provided for comparison.

Table 2.1 *Vessel Details*

	MV Caledonian Isles	*MV Hebrides*	*100m Vessel*
Length (OA) (m)	94.25	99.4	102.4
Length (BP) (m)	85.2		unknown
Beam (m)	16.32	16.32	17.0 (17.5m including belting)
Draught (design) (m)	3.165	3.3	3.4
DWT (Tonnes)	735	660	900 at 3.4m draught 1200 at 3.6m draught
Gross Tonnage (Tonnes)	5221	5506	unknown
Displacement (Tonnes)	3139	3493	4300-4400 at 3.4m draught 4600-4700 at 3.6m draught

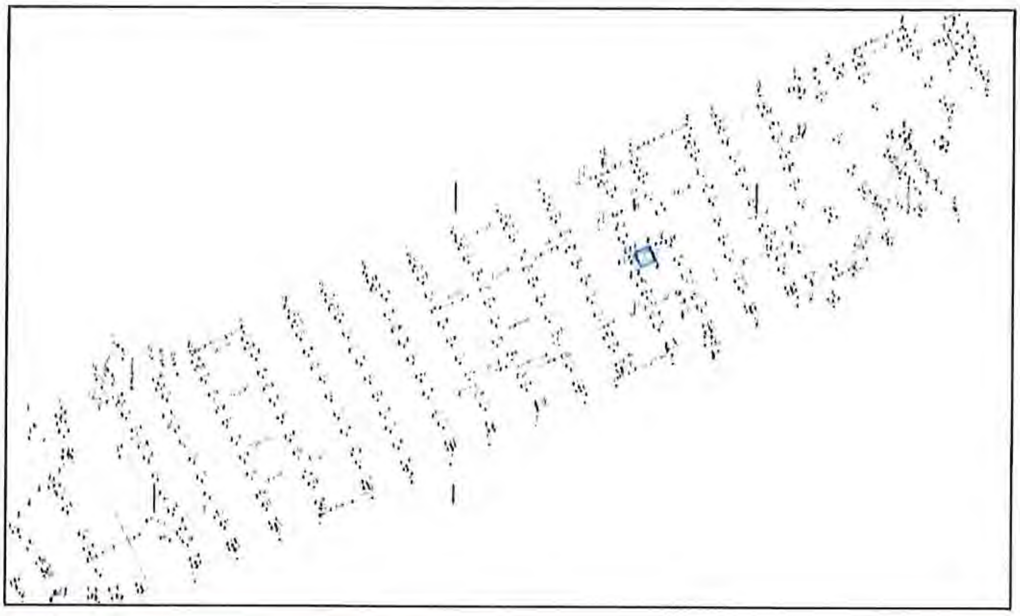
General arrangement drawings of the existing vessels are provided in Appendix A. It should be noted that the general arrangement drawing of the proposed vessel is a working drawing (Revision C) and was correct at the time of writing this report.

2.3 Length of Pier

From the information provided by CMAL, the proposed vessel is some 102.4m long. This is 3.0m longer than the MV Hebrides which is 99.0m long and can be seen on the berth in the photograph below. It can be seen in the drawings provided in appendix B that the proposed vessel, when berthed bow-in, would extend approximately 13m beyond the roundhead (approximately 17m when stern-in). It would be prudent to consult with Calmac Ferries Limited (CFL) site staff to identify any potential rope handling issues that the additional length may create. A review of the proposed mooring arrangements would also identify any potential problems in relation to bollard positions.

2.4 Marshalling Facilities

The marshalling area at Ardrossan Ferry Terminal currently has 7 lanes providing a total length of 878m for vehicles (length taken to 'stop' lines).



A breakdown of the marshalling space available can be found seen in table 2.2 below.

Table 2.2 Marshalling Area Breakdown

Marshalling Lane	Length (m)	Car Capacity
1	120	26
2	120	26
3	130	28
4	130	28
5	130	28
6	124	27
7	124	27
TOTALS	878	190

The drawings provided by CMAL show that an average car spacing of 4.5m is used to calculate the car carrying capacity of the vessels. Applying this assumption to the vehicle lanes suggests the capacity of the marshalling area is approximately 190 cars.

Published data suggests that the MV Caledonian Isles has a capacity of 110 cars whilst the MV Hebrides has a capacity of 90 cars. The proposed '100m vessel' has a capacity of 136 cars.

The current and potential marshalling area requirements are summarised in table 2.3 below.

Table 2.3 Marshalling Lane Requirements – Actual Vessel Capacity

Operating Vessel	Total Vessel Capacity (cars)	Lane Length Required (m)	Lane Length Deficit (m)
MV Caledonian Isles	110	495	0
MV Hebrides	90	405	0
'100m Vessel'	136	612	0

The current vessel operator, Calmac Ferries Limited (CFL) has a policy whereby the desirable marshalling provisions on a site are a contingency of 50% of the vessel capacity. Table 2.4 below shows the current and potential marshalling area requirements for the desirable contingency.

Table 2.4 Marshalling Lane Requirements – 50% Contingency

Operating Vessel	Total Vessel Capacity (cars)	Lane Length Required (m)	Lane Length Deficit (m)
MV Caledonian Isles	165	743	0
MV Hebrides	135	608	0
'100m Vessel'	204	918	40

It is apparent from the tables above that the marshalling area is adequate and also provides the desirable 50% contingency for the current service vessels. The marshalling area also appears adequate for the proposed vessel and could provide the vast majority of the 50% contingency.

In addition, there is a large long-stay car park situated directly adjacent to the marshalling area.

3. REVIEW OF BATHYMETRY

3.1 Main Berth

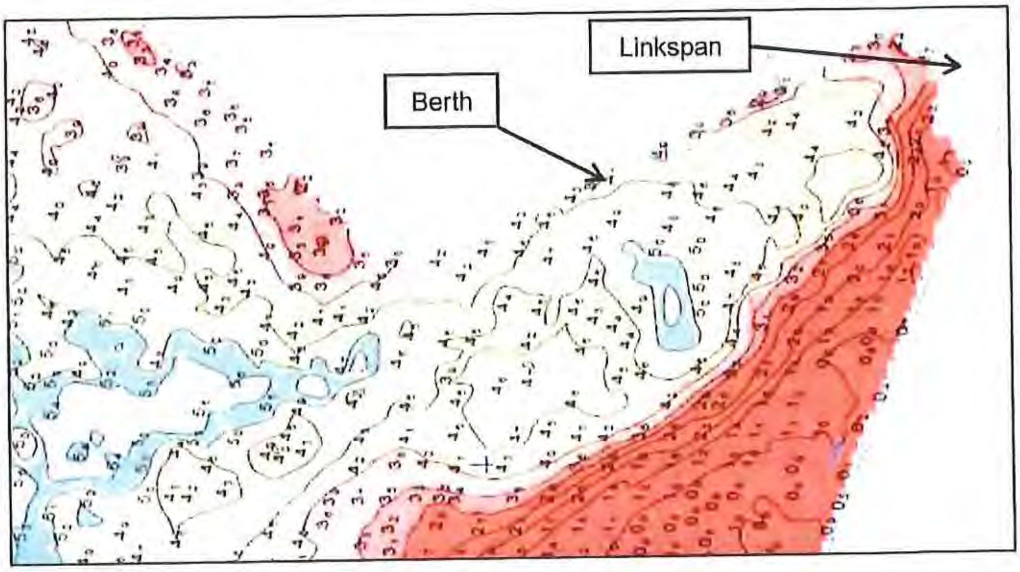
3.1.1 Bathymetry

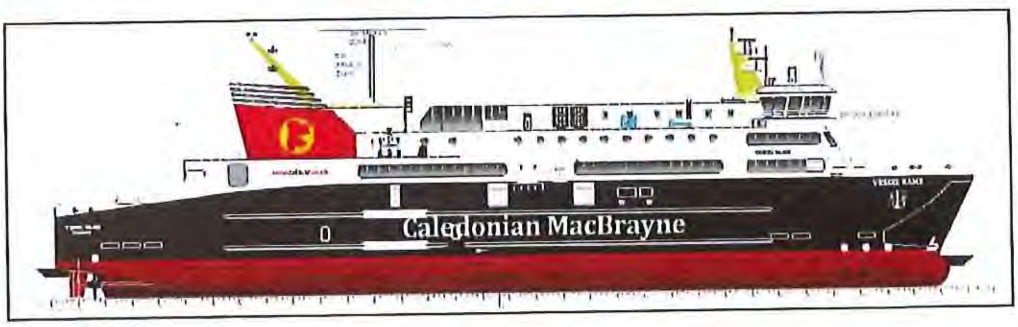
Peel Ports Group commissioned a bathymetric survey which was carried out in December 2014 by Clydeside Surveys Limited. No other information was available

In previous studies undertaken by RHDHV to investigate the ability of CMAL linkspan berths to accommodate new vessels it has been desirable to have 0.75m under keel clearance at the lowest astronomical tide. The draught of the proposed vessel is 3.6m meaning that a bed level of -4.35mCD would be desirable at LAT.

Fig 3.1 below is an extract from the 2014 bathymetric survey. Whilst it is apparent that the bed level is generally of sufficient depth along the berth and on the approach (yellow areas on fig 3.1), it is relatively shallow directly in front of the linkspan ramp. This may require some localised dredging to accommodate the bulbous bow of the proposed vessel at extreme low tides (see illustration below).

Figure 3.1 Extract from bathymetric survey





4. REVIEW OF VESSEL EMBARKATION

4.1 Linkspan – Horizontal Fit

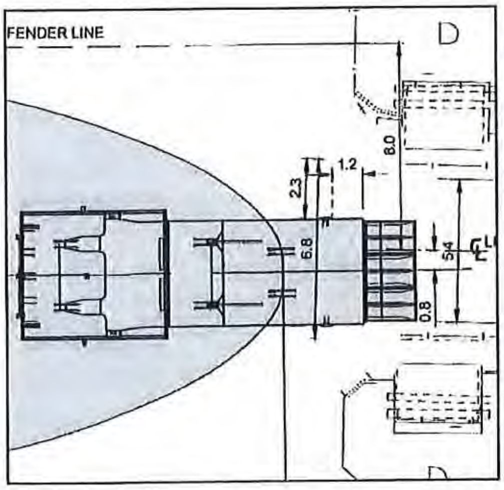
The original linkspan was designed and installed around 1968. The original configuration comprised a single lane ramp unit supported on wheel bearings at the shore abutment end and wire rope winches at the offshore end. There was originally a limited overhang past the supporting front beam, with the nose of the ramp probably recessed behind the line of the supporting structures. This would require the vessel to berth up against, or very close to, the supporting structures.

The linkspan was modified in 1993 by extending the ramp forward approximately 3m. The existing support mechanisms remained unaltered, and to mitigate the increased loads, floatation tanks were installed below the front support beam. These consist of a pair of cylindrical units supported on a frame below and to the front of the support beam.

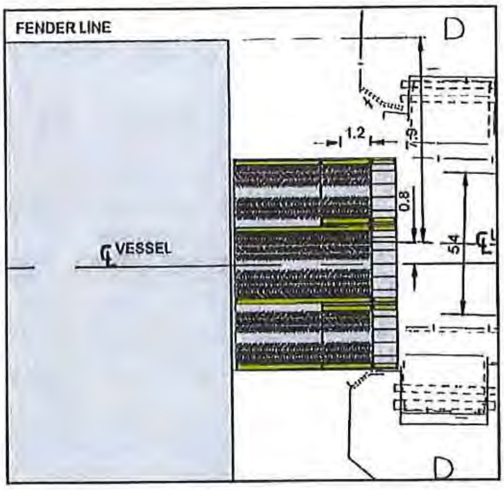
The linkspan is a single lane linkspan, 6.8m wide at the nose and the distance between the traffic barriers is 5.4m. The distance from the centreline of the linkspan to the existing fender-line is approximately 7.9m. The beam of the proposed vessel is 17.5m (including belting) meaning that the centreline of the vessels would be approximately 0.85m seaward of the centreline of the linkspan ramp.

The current berthing arrangement at Ardrossan is bow-in. From the information provided by CMAL it is proposed to have a 3.5m wide bow ramp, located centrally on the proposed vessel. It should therefore be possible to land the entire vessel ramp upon the linkspan ramp as illustrated on drawing PB3783-104-002 (extract below left).

It is proposed to have a 3 section stern ramp on the 100m vessel, two outer sections, each 2m wide, with a 2.5m wide central section. It would therefore be possible to land the mid and landward sections on the linkspan at Ardrossan giving a 4.5m wide vehicle ramp. This is illustrated on drawing PB3783-104-003 in appendix B of this report (extract below right).



'100m Vessel' Bow-In



'100m Vessel' Stern-In

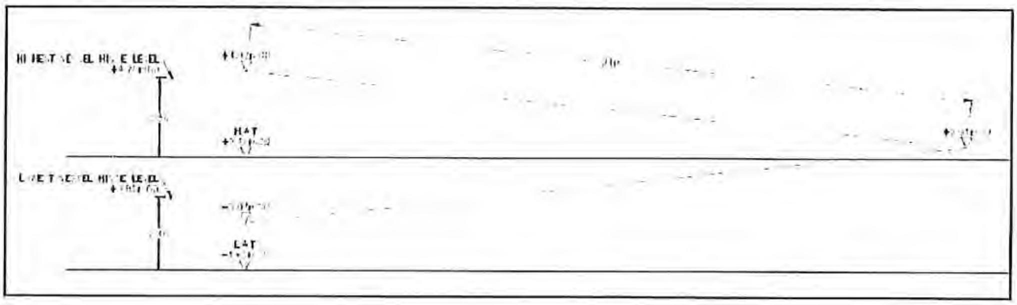
4.2 Linkspan – Vertical Fit

During the site visit on 6th January the linkspan operator positioned the ramp at the highest and lowest possible positions to allow the ramp level to be surveyed. The survey confirmed the possible range of movement is from the upper limit of +4.92mOD to the lower limit of -0.03mOD.

From the information provided by CMAL the minimum and maximum freeboard of the proposed vessel are 2.4m and 2.6m respectively.

Considering these freeboards at LAT and HAT gives a potential vessel hinge level range for the proposed vessel of +4.7mOD to +0.8mOD. If the vessel information provided is correct the linkspan should be able to accommodate the proposed vessel at the full tidal range from HAT to LAT. This check is summarised in figure 4.1 below.

Figure 4.1 Linkspan Vertical Alignment Check – '100m Vessel'



4.3 Passenger Access

4.3.1 Existing Gangway

The current provision for passenger access at Ardrossan is a 25m long gangway that is hoisted onto a latch-bar at the passenger door once the ferry is secured on the berth. The gangway is hoisted by deck mounted winches upon a fixed steel frame. This gangway has two lanes with clearances of 1.1m and 0.84m between handrails.

This gangway is in a fixed position to suit the MV Caledonian Isles and cannot move along the berth. It is therefore extremely limited and can accommodate very few vessels.

A second 12m long gangway is used by other vessels and is hoisted by the vessel mounted winch onto a latch-bar at the passenger door once the vessel is secured on the berth. The use of this gangway is limited by the level of the tide and during the site visit on 6th January foot passengers were embarking the MV Hebrides via the linkspan.

There is no code of practice for passenger access bridges or gangways although BS6349 Part 8 does give some guidance. RHDHV are experienced in the design and specification of passenger access systems and have found that the building regulations, including the Disability Discrimination Act offer the best guidance. It is acknowledged however that these are specific to a static building.

In simple terms the slope at extremes (LAT or HAT) should not be greater than 1 in 10 for the design of a passenger boarding bridge (PBB) or 1 in 12 at springs. However for short sections of ramp, maybe from the boarding pod inside the vessel over a distance of 1.5 m to 2.0 m a steeper gradient could be justified although not if it reaches 1 in 8.

The width between handrails in the main body of the PBB is usually designed to be as wide as possible, typically 1.5m to 2.0m. The final section of hand railing where it enters the vessel often, however, has to go down to 1.0m to get through the opening in the vessel shell plate.

The passenger door on the existing vessel, the MV Caledonian Isles, is approximately 10.8m above the keel. With the design draught of 3.15m this leaves the bottom of the door 7.65m above water level whilst the passenger door on the MV Hebrides is approximately 8.0m above water level. In the information provided by CMAL, the passenger door on the proposed vessel will be approximately 12.4m above the keel. With the design draught of 3.4m this leaves the bottom of the door as much as 9.0m above water level.

If the 100m vessel were to become the service vessel from Ardrossan it is assumed that the existing 25m gangway would be relocated to suit. If the vessel were to berth at HAT it would result in a gangway slope of 1 in 3.38 or 16.5°.

A full summary of the gradients for both gangways are included in tables 4.1 - 4.4 below for comparison.

Table 4.1 Summary of (25m) Gangway Gradients (Expressed as 1 in X)

Vessel	*Draught (m)*	*Gangway slope at HAT (1 in X)*	*Gangway slope at MHWS (1 in X)*	*Gangway slope at MLWS (1 in X)*	*Gangway slope at LAT (1 in X)*
MV Caledonian Isles	3.15	4.23	4.66	10.15	12.15
MV Hebrides	3.2	3.87	4.23	8.42	9.75
MV Hebrides	3.3	3.94	4.31	8.71	10.15
100m' Vessel	3.4	3.38	3.65	6.50	7.28
100m' Vessel	3.7	3.54	3.84	7.07	8.00

Table 4.2 Summary of (25m) Gangway Gradients (Degrees)

Vessel	*Draught (m)*	*Gangway slope at HAT (deg)*	*Gangway slope at MHWS (deg)*	*Gangway slope at MLWS (deg)*	*Gangway slope at LAT (deg)*
MV Caledonian Isles	3.15	13.30	12.12	5.62	4.70
MV Hebrides	3.2	14.48	13.30	6.78	5.85
MV Hebrides	3.3	14.24	13.06	6.55	5.62
100m' Vessel	3.4	16.50	15.31	8.74	7.82
100m' Vessel	3.7	15.78	14.60	8.05	7.12

Table 4.3 Summary of (12m) Gangway Gradients (Expressed as 1 in X)

Vessel	*Draught (m)*	*Gangway slope at HAT (1 in X)*	*Gangway slope at MHWS (1 in X)*	*Gangway slope at MLWS (1 in X)*	*Gangway slope at LAT (1 in X)*
MV Caledonian Isles	3.15	1.83	2.06	4.79	5.77
MV Hebrides	3.2	1.64	1.83	3.94	4.60
MV Hebrides	3.3	1.68	1.87	4.09	4.79
100m' Vessel	3.4	1.36	1.52	3.00	3.38
100m' Vessel	3.7	1.45	1.62	3.28	3.74

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Table 4.4 Summary of (12m) Gangway Gradients (Degrees)

Vessel	Draught (m)	Gangway slope at HAT (deg)	Gangway slope at MHWS (deg)	Gangway slope at MLWS (deg)	Gangway slope at LAT (deg)
MV Caledonian Isles	3.15	28.63	25.94	11.78	9.84
MV Hebrides	3.2	31.39	28.63	14.23	12.27
MV Hebrides	3.3	30.83	28.09	13.74	11.78
100m' Vessel	3.4	36.28	33.37	18.46	16.46
100m' Vessel	3.7	34.52	31.67	16.96	14.97

4.3.2 Vessel Passenger Door

The general arrangement drawing provided by CMAL shows the centre of the passenger door as 50.0m from the bow of the vessel and 52.4m from the stern.

This information has been illustrated in the plans and sections in Appendix B. These drawings assume a 1.2m overlap of the vessel ramp on the linkspan. It is apparent from the drawings that the passenger door is not compatible with the existing fixed passenger access system, falling 5.0m beyond it when berthed bow-in and 9.7m beyond it when berthed stern-in.

Extracts from the drawings showing the horizontal door positions are shown in figures 4.2 and 4.3 below.

Figure 4.2 Proposed Vessel Berthed Bow-In

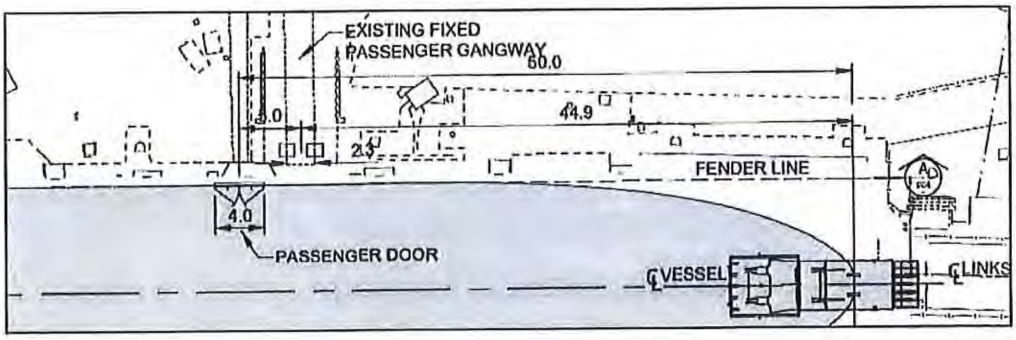
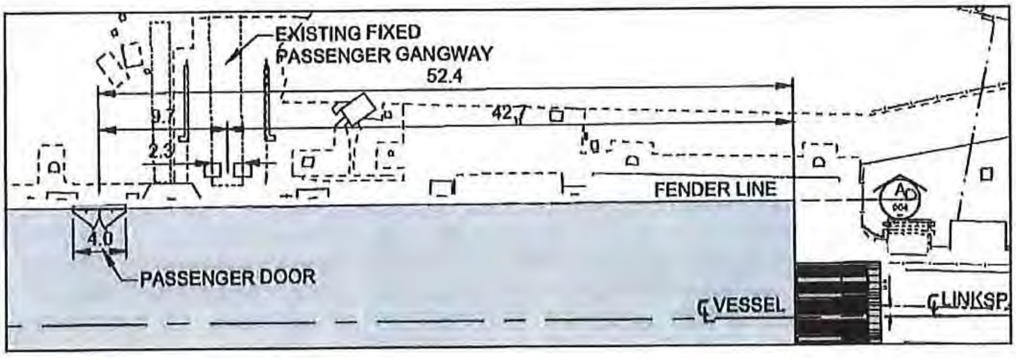


Figure 4.3 Proposed Vessel Berthed Stern-In



5. BERTHING AND MOORING ANALYSIS

5.1 Berthing

5.1.1 Existing Facilities

No details were made available regarding the history of the fendering to the ferry berth. During the site inspection it was noted that the fendering to the roundhead at the end of the berth comprises Trellex MV750 element fenders whilst the fenders along the berth are Trellex MV600 element fenders. The condition of the fenders is generally poor and evidence of strengthening was apparent to many. It was further noted that several of the fenders had missing or damaged face shields. Two of the roundhead fenders have been removed and are currently sitting on the deck awaiting replacement.

Layout and details of the fenders are provided in the record drawings in Appendix A of this report.

5.1.2 Berthing Energy Calculation

There are two commonly accepted means of calculating the berthing energy to be absorbed by fenders. PIANC WG33: Guidelines for the Design of Fender Systems: 2002 calculates the berthing energy using the deadweight tonnage (DWT) of the vessel whereas BS 6349: Part 4: 2014 Code of practice for design of fendering and mooring systems uses the vessel displacement. Whilst the DWT and displacement are usually similar for a vessel it is widely accepted that this is not the case for Ro-Ro vessels where they are quite different. BS 6349 is therefore considered more acceptable in this instance and shall be adopted for the purposes of this report.

The approach velocity is the most significant factor of the berthing energy calculation. The berth at Ardrossan is relatively sheltered and as such velocity curve 'a' from figure 9 of the code was considered the most applicable. Anecdotal evidence suggests that the problems encountered at Ardrossan are primarily in navigating around the breakwater into the port. It was therefore considered prudent to carry out the calculations using curve 'b' for comparison. Table 5.1 below shows the approach velocities for each of the vessels being considered under each of the BS6349 curves.

Table 5.1 Vessel Approach Velocities – BS6349 (m/s)

	MV Caledonian Isles	*MV Hebrides*	*'100m Vessel'*
Displacement (Tonnes)	3139	3496	4700
Curve A	**0.12**	**0.12**	**0.11**
Curve B	**0.27**	**0.26**	**0.24**
Curve C	0.39	0.38	0.36
Curve D	0.51	0.50	0.47
Curve E	0.64	0.62	0.57

During the RHDHV site visit the MV Hebrides was observed berthing. From the observed berthing exercise it is apparent that both the roundhead and the berth fenders can be contacted by the vessel between the quarter point and approximately midships.

The velocity at the point of impact with the main deck is very low indeed, as this is generally a point of secondary contact as the vessel straightens up along the berth or a primary contact during favourable wind and wave conditions.

In order to provide a conservative assessment, and to make allowance for berthing in adverse conditions, berthing was assessed as a midship contact on the roundhead and a quarter point contact with a berthing angle of 5° for the side fenders on the berth.

5.1.3 Roundhead – Trellex MV750 Element Fenders

The exact details of the roundhead are unknown however it appears to be a continuation of the sheet piled quay wall with a reinforced concrete cope. The roundhead is fendered with Trellex MV750 element fenders with a 100mm thick UHMWPE face shield. For the purposes of this study we have conservatively assumed that the fenders are compound B in accordance with the manufacturer's specification.

The existing fender panels extend from approximately +5.35mOD to -1.35mOD. The belting of the proposed 100m vessel would contact between +4.75mOD and +0.8mOD so the fender panels should be able to accommodate this vessel.

The belting on the vessel restricts the spread of load at the point of impact so the energy absorption of only some of the elements can be taken into account depending on how the fender panel deforms at the belting. If six elements are taken into account then the energy capacity is: 6 * 92 kNm – 10% = 497kNm with a reaction of 6 * 267 kN + 10% = 1762kN, possibly 2000kN in total adding partial reaction from elements above or below the contact point.

This should not be exceeded by the any vessel to avoid damaging the dolphin and possibly the vessel. If a larger vessel is used without replacing the fenders then in poor weather, with higher wind speeds, there is the likelihood of the vessel hitting the dolphin at a greater velocity (normal to the fender) and permanently damaging the dolphin or fenders.

Therefore the maximum velocity of approach normal to the fender that can be accommodated by each vessel is:

- MV Caledonian Isles 0.325 m/sec
- MV Hebrides 0.308 m/sec
- Proposed 100m vessel 0.265 m/sec

5.1.4 Main Berth – Trellex MV750 Element Fenders

The exact details of the berth are unknown however it appears to be a sheet piled quay wall with a reinforced concrete cope. The berth is fendered with Trellex MV600 element fenders with a 100mm thick UHMWPE face shield. For the purposes of this study we have conservatively assumed that the fenders are compound B in accordance with the manufacturer's specification.

The existing fender panels extend from approximately +5.35mOD or +4.35mOD to -1.35mOD. The belting of the proposed 100m vessel would contact between +4.75mOD and +0.8mOD so the higher fender panels should be able to accommodate this vessel.

When assessing the performance of the fenders it is apparent that the maximum load in the fender would be at HAT with contact close to the fender. The worst berthing mode here would be quarter point berthing and the energy capacity is 99kNm – 10% = 89kNm.

Therefore the maximum velocity of approach normal to the fender that can be accommodated with the two vessels is

- MV Caledonian Isles 0.348 m/sec
- MV Hebrides 0.328 m/sec
- Proposed 100m vessel 0.279 m/sec

5.1.5 Fender Utilisation

Using manufacturer's data from Trelleborg the utilisation of each fender was calculated for berthing at the approach velocities for curves 'a' and 'b'. The vessel approach velocity for each fender at capacity was also calculated. A summary of the approach velocities at capacity can be found in table 5.2 below.

Table 5.2 Summary of Vessel Approach Velocity at Fender Capacity

	Approach Velocity at Fender Capacity (m/s)			
	Main Berth Element Fenders	Roundhead Element Fenders	BS6349 Curve A	BS6349 Curve B
MV Caledonian Isles	0.348	0.308	0.120	0.270
MV Hebrides	0.328	0.308	0.120	0.260
100m Vessel	0.279	0.265	0.110	0.240

Full calculations for both vessels can be found in Appendix C of this report and the results are summarised in table 5.3below.

When considering the vessels approaching at the velocities generated by curve 'a' it can be observed that the required energy absorption for a primary contact on the roundhead or berth are well within the rated energy absorption of the fender system for all vessels.

When considering the vessels approaching at the velocities generated by curve 'b' it can be observed that the required energy absorption for a primary contact on the roundhead or berth remains within the rated energy absorption of the fender system for all vessels. The fenders are found to be up to 68.8% utilised for the MV Caledonian Isles, 71.2% utilised for the MV Hebrides and 81.5% utilised for the proposed vessel.

The actual approach velocity is therefore the key to acceptability of the existing fender system. It is likely that the existing system was originally designed using curve b as the design approach velocity. It is also likely that the system was designed such that the primary contact was with the berthing dolphin or old roundhead. It is therefore apparent that if the vessels approach the berths slowly enough they are within the limits of the system but if adverse conditions affect the berth and the skipper loses some control it is possible that damage could occur to the structures and/or fender systems.

5.1.8 Pier Loading from Fenders

Without the final parameters for the new vessel it will be impossible at this time to carry out a full detailed structural analysis of the jetty to confirm that its capacity is acceptable.

It should be noted that the new vessel is larger than the existing vessels which currently use the terminal and there is the possibility that larger forces may be imparted to the jetty than at present.

It will therefore be necessary to carry out a more detailed analysis of the jetty and fendering system to determine the exact forces being imposed by the new vessel and to confirm that the structural capacity of the existing pier is acceptable.

Table 5.3 *Summary of Fender Utilisation*

		BS 6349 Velocity Curve A		BS 6349 Velocity Curve B	
		Main Berth Element Fender	*Roundhead Element Fender*	*Main Berth Element Fender*	*Roundhead Element Fender*
MV Caledonian Isles	Abnormal Berthing Energy, Ev (kNm)	38	68	191	342
	Required Energy Absorption, ER (kNm)	42	76	212	380
	Rated Energy Absorption of Fender System (kNm)	354	552	354	552
	Utilisation of Fender System (%)	**11.9**	**13.8**	**59.9**	**68.8**
MV Hebrides	Abnormal Berthing Energy, Ev (kNm)	42	75	199	354
	Required Energy Absorption, ER (kNm)	47	83	221	393
	Rated Energy Absorption of Fender System (kNm)	354	552	354	552
	Utilisation of Fender System (%)	**13.3**	**15.0**	**62.4**	**71.2**
100m Vessel	Abnormal Berthing Energy, Ev (kNm)	49	85	234	405
	Required Energy Absorption, ER (kNm)	54	94	260	450
	Rated Energy Absorption of Fender System (kNm)	354	552	354	552
	Utilisation of Fender System (%)	**15.3**	**17.0**	**73.4**	**81.5**

5.2 Mooring

BS 6349: Part 1: 2000 offers guidance on the evaluation of mooring loads however this is largely applicable to vessels with a displacement in excess of 20,000 tonnes. The codes state that for vessels of a lesser displacement, bollards should be provided along continuous quays at intervals of 15m to 30m. Table 8 in the code gives guidance on the necessary capacity of bollards and fairleads. The nominal bollard capacities for each vessel based on interpolating the recommended values from the aforementioned table are provided in table 5.6 below.

Table 5.6 Nominal Bollard Capacities

	MV Caledonian Isles	MV Hebrides	100m Vessel
Displacement (Tonnes)	3139	3493	4700 max
Bollard Loading (kN)	130	137	168
Fairlead Loading (kN)	245	256	301

Drawing PB3783-104-001 in Appendix B shows the position of the existing bollards on the berth at Ardrossan. There are 2 No. bollards located on either side adjacent to the linkspan and a further 9 No. located along the length of the berth. The maximum gap between bollards on the pier is 26m. The capacity of the bollards is unknown.

Using the formulae within the code an assessment of the actual wind forces that may occur was calculated. This assessment assumed the full longitudinal projected area of each vessel with no consideration for shielding from the sea wall or terminal building. Furthermore, the density of air at 0°C was used and drag coefficients of 2.5 (transverse) and 2.0 (longitudinal) were adopted. This assessment is therefore considered extremely conservative. It should be further noted that the prevailing south westerly winds in Ardrossan actually blow the vessel onto the berth. The mooring loads calculated for each vessel are summarised in table 5.7 below.

Table 5.7 Summary of Mooring Loads (Wind Forces Only)

	MV Caledonian Isles	MV Hebrides	100m Vessel
Longitudinal Projected Area (m^2)	1203	1235	1425
Transverse Wind Load, F_{TW} (kN)	655	673	777
Longitudinal Wind Load, F_{LW} (kN)	98	110	142

Due to the relatively sheltered nature of the berth at Ardrossan and the conservative approach adopted above it was not considered necessary to consider current forces at the berths.

BS 6349 recommends that for calculation by hand, the mooring system should be simplified by assuming that the longitudinal forces are resisted by the spring lines and the transverse forces at the bow and stern by the bow and stern breasting lines respectively.

By inspection, it would appear that there are sufficient bollards at Ardrossan to satisfy the design forces associated with the 100m vessel. The proposed mooring arrangement for the vessel is yet to be confirmed and it would be prudent to confirm the capacity of all bollards once it is known. In adverse weather it would appear that additional lines could provide a sufficient factor of safety.

6. RISK REVIEW

CMAL wish to assess the level and likelihood of all operational risks associated with the continued use of the MV Caledonian Isles and MV Hebrides and the potential introduction of the proposed '100m vessel' on the existing ferry berth. These risks are assessed in the table below and in all cases it is assumed that there are no changes to the existing infrastructure on the ferry berth at Ardrossan.

Any mitigation measures recommended or discussed are changes to operational procedures or further survey or investigation works rather than changes to the infrastructure.

In summary, the most significant risks remain those associated with passenger embarkation, the bed level at the nose of the linkspan and the potential additional load on the berth structure.

The risks associated with passenger embarkation at excessive gangway angles can be mitigated by having passengers board via the linkspan as is current practice when the MV Hebrides is in service. This however introduces additional time and health and safety risks due to the increased boarding time and potential conflict between foot passengers and vehicles.

The review of the bathymetric survey has shown that the bed level at the nose of the linkspan may be slightly higher than desirable. The effect of this may be limited to insufficient under keel clearance at LAT. Should the operator consider the reduced clearance to be satisfactory this operational risk may be considered acceptable.

The introduction of the proposed vessel would see an increased risk of damage to the berth structures due to increased berthing loads. Should the vessel skippers consider the approach velocities in table 5.2 to be satisfactory this operational risk may be considered acceptable.

Table 6.1 *Risk review of berth at Ardrossan with existing infrastructure*

Item	*Hazard / Risk*	*Likelihood (Existing Vessels)*	*Likelihood (Proposed Vessels)*	*Mitigation*	*Likelihood (Existing Vessels)*	*Likelihood (Proposed Vessels)*
Bathymetry	Bathymetric survey of the berth suggests that the under keel clearance for the proposed vessel may be less than the desirable limit at LAT. Risk of damage to vessel due to insufficient water depth at lowest tides.	Low	Medium	Consult with CFL Vessels team to confirm suitability of existing bed levels. Procure a new bathymetric survey and ground investigation of berth area to confirm or otherwise the actual sea bed levels and possibility of carrying out dredging if necessary.	Low	Unknown, pending review
Gangway	Passenger embarkation and disembarkation at unacceptable slopes during high tide events. Health and safety risk, especially to elderly and young children during inclement weather.	Medium	High	Carry out operational risk assessment in association with CFL to determine maximum permissible gangway gradient. All embarkation / disembarkation above this limit to be via linkspan. (Boarding via linkspan has its own associated risks - see below)	Low	Low
Gangway	Risk of delays to service if all foot passengers forced to embark and disembark via linkspan. Associated risks of interaction of pedestrians with vehicles.	Medium	High	Review of turnaround time on published timetable to consider additional time required. Careful segregation of pedestrians and vehicular traffic during boarding.	Medium	Medium
Berthing - Structures	Risk of damage to roundhead and berth (and by association the vessel hull) during berthing, especially during inclement weather due to additional load.	Low	Medium	Consultation with vessel skippers to determine all potential regular berthing manoeuvres and to confirm the suitability of berthing velocities considered within this study.	Low	Medium
Berthing	Vessel belting above the level of 3 out of 6 berth fenders at some high tide events. Potential for damage to vessel and fendering.	Low	High	No mitigation without infrastructure change.	Low	High
Mooring - Structures	Capacity of existing mooring bollards is unknown. Potential damage to structure due to excessive forces during inclement weather. (Mooring forces from proposed vessel is up to 29% higher than MV Caledonian Isles).	Low	Low	Carry out site back-analysis and/or site load tests to determine capacity of existing bollards.	Low	Low

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The existing berth at Ardrossan Ferry Terminal could potentially accommodate the proposed '100m vessel' in its current form. There are however items that require clarification and further investigation and improvements would be necessary to some of the infrastructure including provisions for passenger embarkation.

7.1.1 Marshalling

The introduction of the proposed 100m vessel would potentially introduce an additional 26 cars per crossing. The proposed vessel has capacity for 136 cars as opposed to the MV Caledonian Isles which can carry 110. Although the existing marshalling area cannot quite accommodate the desirable 150% vessel capacity it has capacity for 190 cars and should therefore be sufficient.

Should there be a need to provide the full 150% capacity it may be possible to reduce the capacity of the long stay car park adjacent to the marshalling yard. This car park is extremely busy during the summer months however and this may not be an economical proposition.

7.1.2 Bathymetry and Length of Pier

The existing bathymetry at the site generally appears adequate for the proposed vessel and its 3.6m draught. The one area however that requires further consultation is the current sea bed level adjacent to the front of the linkspan. The proposed vessel has a bulbous bow and the current level may not provide sufficient depth at extremely low tides approaching LAT. It is possible that this area would require localised dredging followed by regular monitoring of the sea bed level.

7.1.3 Linkspan

Based on the vessel drawings and the site survey it should be possible for the proposed vessel to berth bow-in or stern-in on the linkspan at Ardrossan.

The centreline of the proposed '100m vessel' would be approximately 0.8m seaward of the centreline of the linkspan. The current proposed bow ramp configuration would allow the entire ramp to be landed upon the linkspan. The proposed stern ramp configuration would work and would allow a 4.5m wide section of vehicle ramp to be deployed.

The survey carried out confirming the range of vertical movements that the Ardrossan linkspan can actually perform suggests that the vessel ramp hinge could be approximately 0.8m above the lower limit of the linkspan. The existing linkspan should therefore be able to accommodate the proposed vessel ramp when the ship is fully laden at LAT.

7.1.4 Passenger Access

The introduction of the proposed vessel would render the existing passenger access system redundant in its current location.

The secondary gangway used on site at present is only 12m in length and is insufficient for embarkation of the current vessels at higher tides. The passenger door on the proposed vessel is up to 1.3m higher than that on the MV Caledonian Isles and up to 0.95m higher than that on the MV Hebrides. The number of crossings that would require all foot passengers to embark and disembark using the linkspan would there increase significantly. Given the potential increase in both vehicular traffic and foot passengers this may cause significant increases in turnaround time, especially during peak times.

7.1.5 Berthing

The fenders on the berth at Ardrossan are generally in a poor condition with many face shields observed as split or missing and several elements split or deformed.

Provisions for berthing on the roundhead and berth may well be adequate although the approach velocity of the vessel and preferred berthing sequence requires further clarification. The vertical extent of the MV fenders is generally sufficient to accommodate the proposed vessels although the belting would be above three of the berth fenders at HAT.

7.1.6 Mooring

Provisions for mooring on the berth at Ardrossan appear to be adequate. It would however be necessary to confirm the capacity of all existing bollards prior to conducting any further mooring analysis.

7.2 Recommendations

7.2.1 Marshalling

A review of present and proposed future marshalling requirements should be undertaken in conjunction with the site operators, CFL. Should the current capacity be considered insufficient an option study could be undertaken to look at potential methods of increasing the marshalling capacity of the terminal.

The car park adjacent to the existing marshalling area would be the obvious location for any increase however this may not be desirable.

7.2.2 Bathymetry and Length of Pier

Although there should be sufficient depth to allow the proposed vessel to berth it is uncertain whether there is sufficient under keel clearance at the linkspan to satisfy the operator. This should be referred to CFL's vessels team for confirmation of any localised dredging that may be required.

Furthermore, it would be prudent to consult with CFL site staff to identify any potential rope handling issues that the additional vessel length may create. A review of their proposed mooring arrangements would also identify any potential problems in relation to bollard positions.

7.2.3 Linkspan

The existing linkspan at Ardrossan would appear adequate, both vertically and horizontally, to accommodate the alignment of the proposed vessel. At the time of writing this report however the vessel design was not complete and remained subject to change. The information within this report should be confirmed and referred to CFL and the vessel designers for comment.

Upon finalising the vessel design the alignment should be checked and furthermore it may be prudent to carry out a swept path analysis to confirm the alignment.

7.2.4 Passenger Access

A number of clarifications are required regarding the existing fixed passenger access system. Should the proposed vessel come into service it would be necessary to move the structure to cater for the new passenger door position. The passenger door on the proposed vessel is up to 1.3m higher than the existing vessels and it should be confirmed that the system has the capability to service this door position.

Notwithstanding the above it may be necessary to undertake a structural appraisal of the berth to confirm the adequacy of the new position.

7.2.5 Berthing

The fender assessment within this study assumes that the fenders are maintained in a good condition. At the time of the site visit a number of defects were observed however it was apparent that fender replacement works were ongoing.

Although a berthing was observed as part of this study it would be prudent to consult with the ship's skippers to clarify preferred berthing methods and the approach velocities that could be expected at Ardrossan. This would allow the adequacy of the fenders to be determined with greater confidence and any necessary replacement fenders to be identified and designed. For example, although three of the main berth fenders are below the level of the belting at HAT the extremely shallow berthing angle adopted suggests that the remaining fenders may be sufficient.

Further to the detailed assessment of the fenders it may be necessary to carry out a more detailed structural analysis of the pier to determine the exact forces being imposed by the proposed vessels and to confirm that the structural capacity of the existing pier is acceptable

7.2.6 Mooring

If no further existing information exists it would be necessary to perform some form of site testing to quantify the capacity of all existing bollards prior to conducting any further mooring analysis.

Once the capacity of all bollards is known we would recommend carrying out an Optimoor mooring analysis of the berth. This would be carried out in consultation with CFL and the ship's skippers.

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Appendix A - Record Drawings

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Appendix B – Study Drawings

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Appendix C – Fender Calculations

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Appendix D - Photographs

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Photo 1 – The ferry berth at Ardrossan

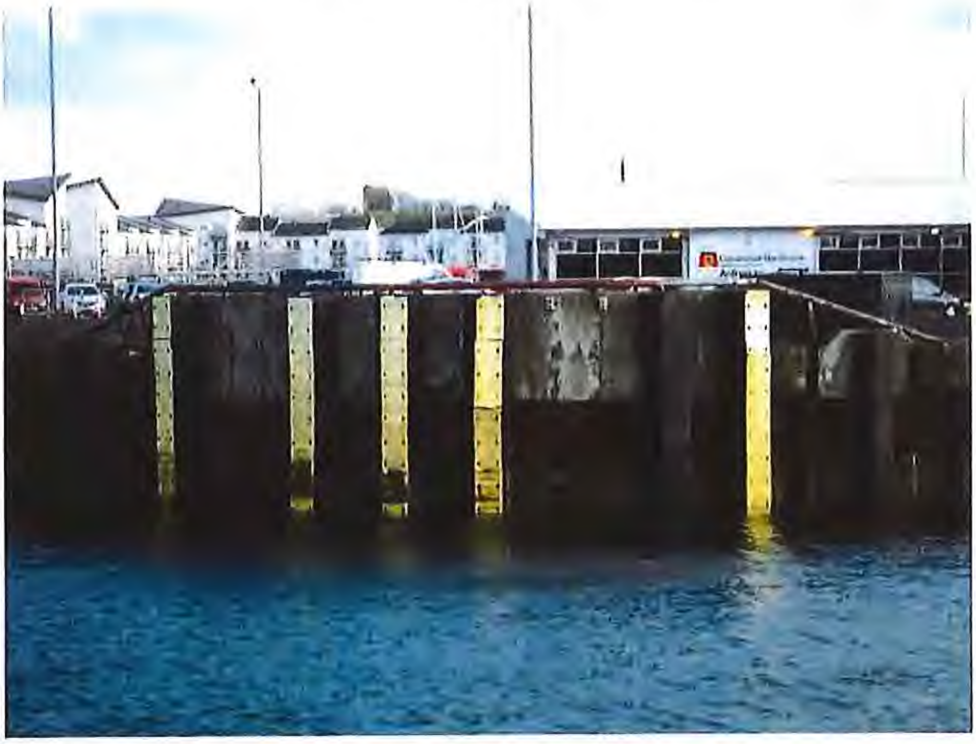

Photo 2 – The roundhead at Ardrossan

Photo 3 – The entrance to the marshalling yard at Ardrossan

Photo 4 – The marshalling yard at Ardrossan

Photo 5 – The long stay car park adjacent to the marshalling yard

Photo 6 – The linkspan approach at Ardrossan

Photo 7 – The linkspan at Ardrossan

Photo 8 – The existing passenger access system at Ardrossan

Photo 9 – The passenger access system lifting frame base

Photo 10 – The secondary gangway latched to the MV Hebrides

Photo 11 – MV Hebrides bow-in on the linkspan at Ardrossan

Photo 12 – General view along the ferry berth at Ardrossan

Photo 13 – General view along the ferry berth at Ardrossan

Photo 14 – Typical mooring bollard at Ardrossan