Small Boat Mooring

Comparative Analysis

Porthdinllaen Seagrass Project

OP 189

Issued to:

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Prepared by		Checked by	Authorised by	Initial Date
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Revision Number	**Issue Date**	**Revision Details**		**Distribution List Index Number**
Rev 1.0	18/12/2017	Draft Report Issued		1,2
Rev 2.0	21/12/2017	Images corrected		1,2
Distribution List Key				
Company		**Responsible Person**		**Distribution List Index Number**
MarineSpace		Gareth Johnson		1
MarineSpace		Rachel Crabtree		2

Background

Orcades Marine Management Consultants Ltd established in 2010, is a leading provider of Marine Project Management, Specialist Marine Risk Management, Innovative and Practical Consultancy Advice, Third Party Verification, Independent Auditing and Assessment to the Shipping and Port Industry, the Marine Renewable Energy Sector, and the Offshore Oil and Gas Industry, accredited to ISO 9001 and OHSAS 14001 for the provision of those services to the industry.

In sectors of the industry such as the development of marine renewable wave energy and tidal energy devices we have extensive experience developing innovative solutions for moorings for the devices. We also introduced a concept for mooring small workboats operating in extreme tidal conditions which now have been universally accepted for this work. We have worked on novel anchoring solutions both small and large scale and we have also carried out consultancy on civil engineering projects which have required input into the mooring design for pontoons and barges. We act for marine warranty insurers and provide a Third Party Verification service to the marine renewable energy industry which requires us to undertake numerical modelling of moored systems and vessels to verify the capacity to withstand environmental and imposed loading. Many of the mooring systems are new and developed for a specific purpose.

Orcades Marine Management Consultants Ltd was contacted by MarineSpace to provide input into an investigation into environmentally friendly mooring adaptations at Porthdinllaen in Wales, with a view to reducing impacts on seagrass beds.

MarineSpace provided three mooring concept options and we have carried out comprehensive background discussions in order to best achieve useful information for the Client within the limited budget. Comparative mooring analysis has been undertaken on the three mooring options based on agreed specifications and parameters.

The final designs can be visualized to show any contact with the seabed, the dynamic loads, and station keeping with moored vessels.

Introduction

Orcades Marine Management Consultants Ltd (OMMC) is supported by Dynamic Systems Analysis Ltd (DSA) to undertake the mooring analysis using ProteusDS software. This report outlines a sensitivity study of a baseline (taken from a representative existing mooring) and three mooring options for generic small boat anchor systems.

Objectives

The objectives of this analysis are relative comparisons:

- grounded mooring length
- surface vessel watch circle
- anchor load behavior

Inputs and setup

Overview

A generic small boat hull was attached to three mooring design concepts and a baseline and subjected to an extreme environmental state consisting of wind, wind driven current, and waves. These mooring options were analysed at multiple water depths.

Environmental conditions

Four water depths were simulated (1.5m, 4.3m, 7.5m, and 10m) with the same sea state applied to each depth. A steady state sensitivity study was completed using only a mean speed of 12m/s. A fully dynamic model was then completed using a wind spectrum that applied gusting, as well as a JONSWAP spectrum wave state. The waves were made up of a significant wave height of 0.7m and a peak period of 3 seconds.

Model properties

Each mooring option used a different combination of mooring components. A comparative summary is described in the table below

Specification	Baseline	**Mooring Options**		
		1.Rubber Roller	2.Sub-surface buoy	3.Sealite Mooring
Total Length of riser	22 metres	15 metres	15 metres	15 metres
Material and composition of riser	22 m Studless short link chain	14m x Polymide Rope 1m x Stiff rubber roller	15 m Studless short link chain	15 m Rubber sheathed nylon
MBL	240 Kn MBL	Approx. 240 Kn MBL	240 Kn MBL	20 te MBL (196 Kn)
Diameter and characteristics of riser	22 mm open link galvanized chain	34 mm polymide 3 or 8 strand	22 mm open link galvanized chain	Internal core 36 mm Outer rubber sheathing approx. 10 mm (total dia 46 mm)
Weight per unit length (in air)	9.8 kg/metre	0.715 kg/metre	9.8 kg/metre	1.2 Kg/metre
Other			A3 polyform* buoy attached at: a) 2 metres for water depths 1.5 m and 7.5 m b) 4 metres for water depths 4.3 and 10 m	

*Attached at position from sinker - A3 Polyform Buoy: Diameter (Width) 460mm (DIA) Height 575mm Rope Hole Diameter 28mm, Weight 3.10 kg, Gross Buoyancy 52.0 kg

Each option and their respective materials are listed in the following sections.

Surface vessel

The same surface vessel hull shape was used throughout each mooring option. A generic small boat hull was used that had a length of 12m and displacement of 8000kg. An image if the hull shape can be seen in **Figure 1**.

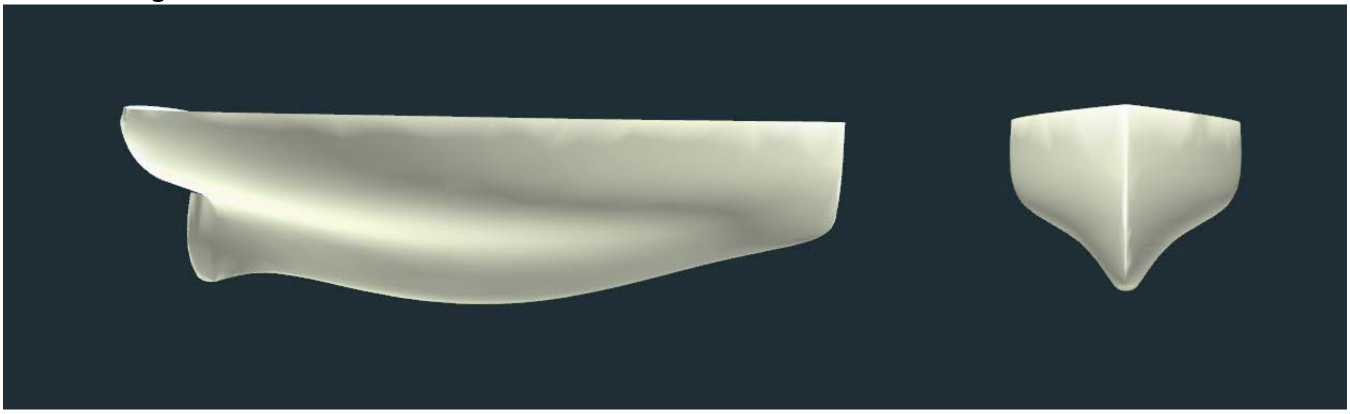

Figure 1: Surface vessel hull shape

Baseline chain mooring option

The baseline mooring was made up of a 22m length of 22mm chain. This is a representation of the existing mooring systems typically used and serves as a reference to compare the alternative concepts to. An image of this mooring can be seen in **Figure 2** and the mooring material properties are reported in **Table 1**.

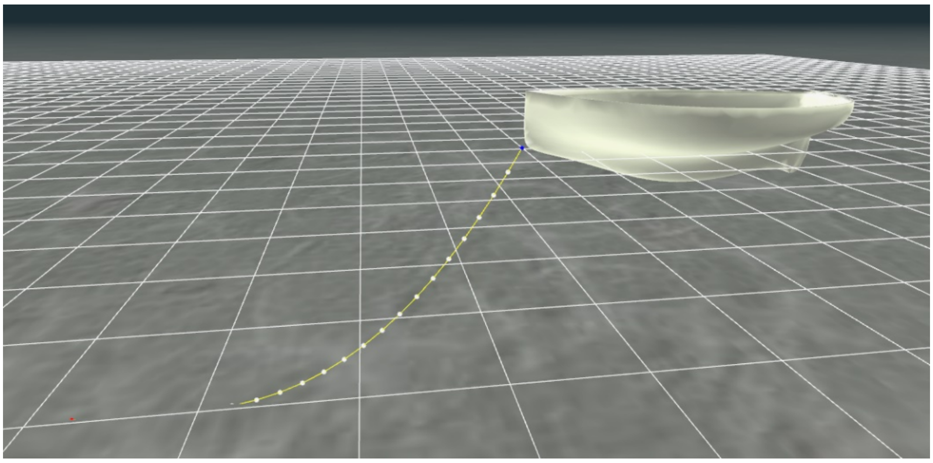
Figure 2: Illustration of baseline mooring

Material	Length (m)	Diameter (m)	Mass (kg/m)	Spec. Gravity
Studless chain	22	0.022	9.78	7.8

Table 1: Baseline option mooring properties

Rubber roller mooring option

The rubber roller mooring option was made up of a 1m length of a rubber roller and 14m of Nylon. An image of this mooring can be seen in **Figure 3** and the mooring material properties are reported in **Table 2**.

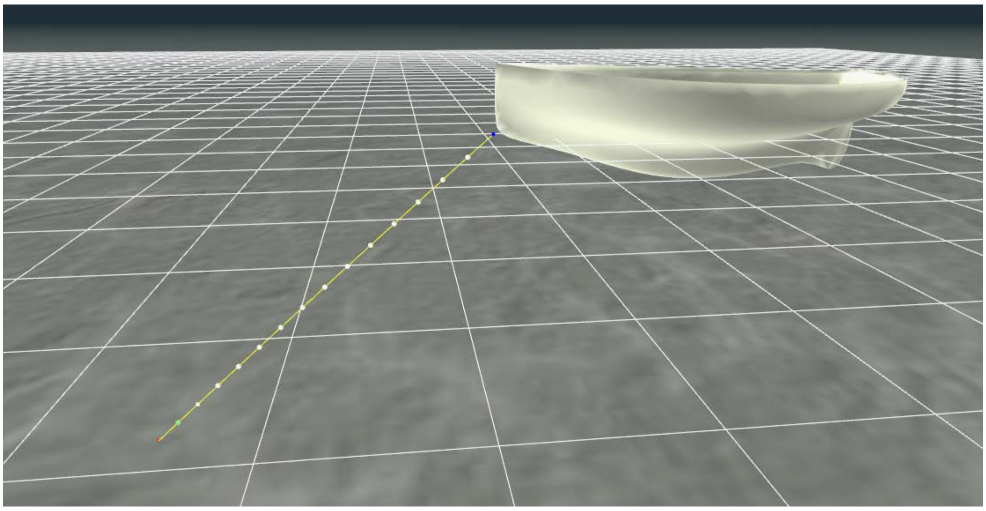
Figure 3: Illustration of Rubber roller option

Material	Length (m)	Diameter (m)	Mass (kg/m)	Spec. Gravity
Rubber roller	1	0.076	4.15	0.91
Nylon (polymide)	14	0.032	0.53	0.66

Table 2: Rubber roller option mooring properties

Sub-surface buoy mooring option

The sub-surface mooring option was made up of a 15m length of 22m chain. A buoy was placed at 2m above the anchor for the 1.5m and 4.3m depths and at 4m above the anchor for the 7.5m and 10m depths. An image of this mooring can be seen in **Figure 4** and the mooring material properties are reported in **Table 3** and **Table 4**.

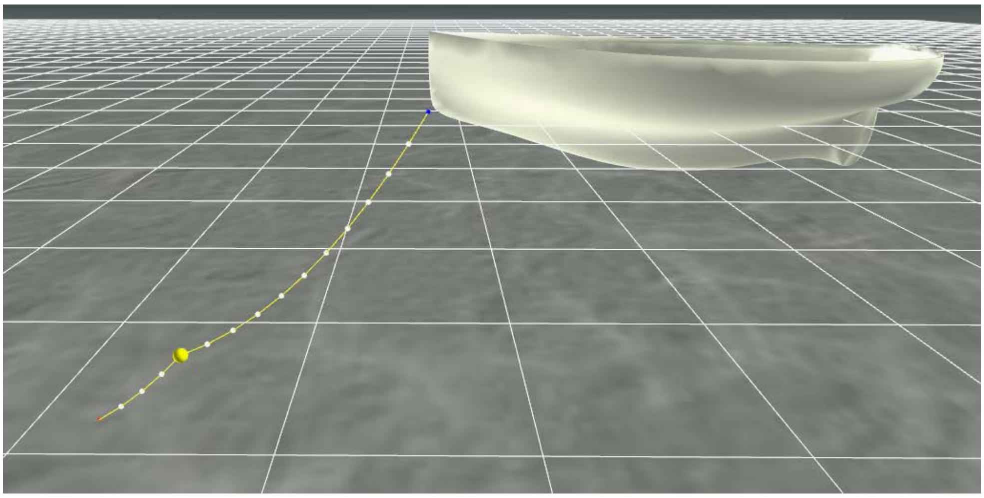

Figure 4: Illustration of Sub-surface buoy option

Material	Length (m)	Diameter (m)	Mass (kg/m)	Spec. Gravity
Studless chain	15	0.022	9.78	7.8

Table 3: Sub-surface option mooring properties

Material	Diameter (m)	Net buoyancy (N)	Drag coeff.
Buoy	0.46	467	0.5

Table 4: Sub-surface option buoy properties

Sealite rope mooring option

The Sealite mooring option was made up of a 15m length of Sealite rope. An image of this mooring can be seen in **Figure 5** and the mooring material properties are reported in **Table 5**.

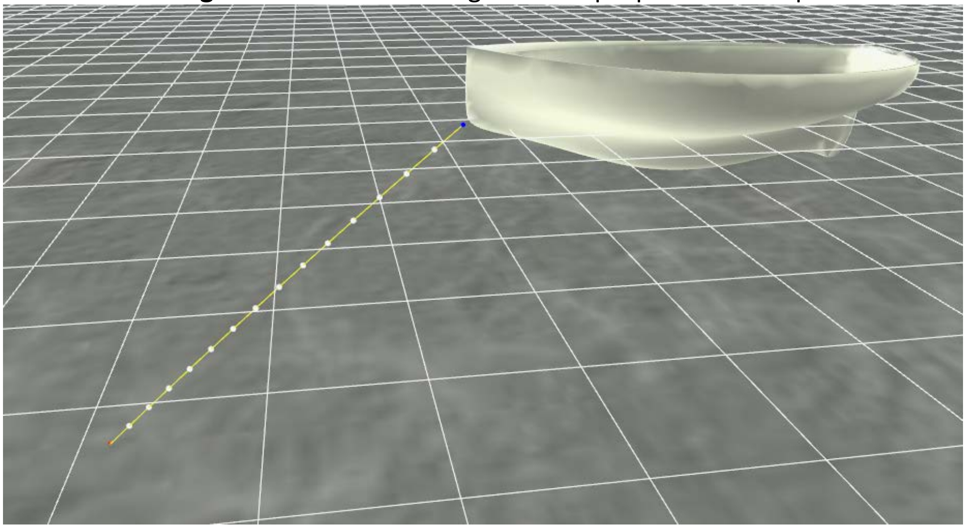

Figure 5: Illustration of Sealite option

Material	Length (m)	Diameter (m)	Mass (kg/m)	Spec. Gravity
Sealite rope	15	0.046	1.2	0.72

Table 5: Sealite rope option mooring properties

Results and discussion

Overview

A constant wind was applied to each mooring option to gain an understanding of the steady state displacement, or watch circle, in these environmental conditions. Once a steady state analysis was completed, dynamic waves were introduced.

Steady state response

Once the boat hull is settled at its steady state position, each mooring option was checked for the displacement of the boat hull as well as length of mooring contacting the bottom. These results are shown in **Table 6** and **Table 7**. The baseline chain mooring was only assessed in 10m water depth.

Water depth	**1.5m**	**10m**
Baseline	-	23m
Rubber roller	21m	17m
Sub-surface buoy	20.5m	17m
Sealite	21m	17m

Table 6: Surface vessel watch circle

Water depth	**1.5m**	**10m**
Baseline	-	7m
Rubber roller	0m	0m
Sub-surface buoy	7m	0m
Sealite	0m	0m

Table 7: Grounded mooring length

At a water depth of 1.5m, the synthetic material mooring options were pulled taut. This creates a mooring that does not contact the seabed. However, there is minimal compliance in the system to absorb wave induced boat motions.

At a water depth of 10m, each of the new mooring options continued to show a taut mooring, including the sub-surface buoy option. This resulted in zero grounded mooring length. When compared to the baseline case, with a 7m length of grounded chain, the reduction in mooring line length resulted in a reduction in grounded mooring line length.

Dynamic loading response

Snap loads were common throughout the dynamic response in extreme wave conditions. This occurs when there is a slack event followed by a relatively high tension spike. Snap loads can lead to anchor uplift as well as mooring failure from very large line loads. Primarily this can be seen in the relatively high anchor reaction loads at the 1.5m water depth in Table 8. As the water depth increased, the reaction loads also increased, but a mean tension was often sustained. For the sub-surface mooring option, the 4.3m and 7.5m cases showed relatively small anchor reaction loads. This was due to the mid span float adding compliance to the system as well as the weight of the chain in the water column applying a constant tension. Both of these features help to alleviate snap loads.

Water depth	1.5m	4.3m	7.5m	10m
Baseline	-	-	-	2kN
Rubber roller	23kN	8kN	10kN	14kN
Sub-surface buoy	240kN	3kN	3kN	18kN
Sealite	56kN	9kN	15kN	15kN

Table 8: Peak anchor reaction load

When comparing these three new mooring options with the baseline case, the anchor reaction loads are significantly higher. The additional chain length in the baseline case introduces compliance with inertia and weight of the chain to absorb high accelerations caused by the waves.

Conclusions

A comparison of the behavior between the three proposed mooring options with the behaviour of a baseline case all under the same steady state and dynamic environmental loading was completed. It was shown that mooring options made up of synthetic buoyant ropes have tendency to be pulled taut even at the most shallow water depths (1.5m). The watch circle of the surface vessel is maximized at roughly 21m away from the anchor point for all cases.

The sub-surface mooring option showed grounded length at the 1.5m water depth. As the water depth was increased to 10m, the synthetic options remained taut and the sub-surface buoy option also became pulled tight enough to remove most of the compliance.

When observing the baseline mooring option that was made up of 22m of 22mm chain, the additional length and mass from the chain was sufficient in preventing the system from going taut even at 10m water depth. However, significant lengths of chain was in contact with the seabed.

As dynamic waves were applied to the model, the reaction loads observed at the anchor point demonstrated the configurations that behaviour. Snap loads were observed through each of the mooring options, particularly at the 1.5m depth.

However, the sub-surface mooring option showed potential for being viable solution. In the 4.3m and 7.5m depth cases, the sub-surface option showed minimal reaction loads as well as a reduced grounded length when compared to the baseline case. Careful design of the mooring components, buoy size, and anchor type should be considered for a successful design at shallow water depths.

It is important to note that this study was a comparative sensitivity analysis intended to understand the relative behaviour of each mooring option. Additional design analysis of the mooring options should be completed before deployment of any of the anchor systems