Single Point Yacht Moorings, Working Group 168
by

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EXTENDED ABSTRACT

1. INTRODUCTION

Single point moorings are often provided by port authorities and marina operators as a facility for visitors at locations where there is poor holding ground, deep water, insufficient slips at docks, or where there is a requirement to moor yachts more densely than can be achieved using the yachts' own anchors. In addition, at some locations, anchor damage to sensitive seabed ecology can be minimized by the provision of moorings. Finally, at some locations, visiting yachts are an important contributor to the economy. If these locations are exposed, the difficulties of anchoring or unsafe conditions means that many yachts will not visit unless secure moorings are provided.

2. MOTIVATION AND SCOPE

There is a lack of clear guidance for several aspects of single point yacht moorings. Therefore, PIANC Working Group 168 (WG 168) was formed to provide guidelines for the design, installation and maintenance of these type of moorings to designers and operators. The guidelines focus on a) Design Principles, b) Type of Mooring Systems, c) Components, d) Design, e) Installation and f) Maintenance.

3. SINGLE POINT YACHT MOORINGS

3.1 Design Principles

There are several types of yacht mooring systems but, regardless of type, all must be designed following similar design principles. These include functionality, regulatory, environmental, constructability, operational, inspection/maintenance, and economy. In the context of these guidelines, design principles are the set of fundamental ideas, concepts and rules that need to be satisfied to achieve a balanced design.

The mooring system needs to achieve its most basic function which is to hold the yacht on station. Its design and performance must comply with local, state and national regulations, and it should not harm the environment. Its design should allow it to be built with readily available commercial products, and be installed using standard techniques, equipment and a reasonable experienced marine contractor. The mooring system should be easy and reliable to use by the average user, and it should allow for maintenance to be performed in a cost-effective manner, with minimal downtime and by available staff. Finally, it would be desirable for it to require the lowest initial and life-cycle costs.

3.2 Types of Mooring Systems

Single point yacht moorings, are also often referred to as swing, conventional, or traditional mooring systems. Essentially, there are two types of systems, the catenary system, and the conservation or eco-friendly system. The catenary system is the most widely used and features (from bottom to top): an anchor, a bottom chain and a light chain or rope (collectively called the rode), a buoy and a pennant. The restoring force of the system is derived by the weight of the suspended rode (line) that hangs from the buoy to the anchor forming a catenary shape. For the rode to achieve elasticity, its length must be some multiple of the water depth. This results in a section of the rode (e.g., the bottom chain) to drag on the bottom most of the time, as the yacht swings around the anchor. In ecological sensitive areas with seagrass, benthic fauna, etc. on the bottom, this causes considerable damage to the environment. To overcome this problem, the conservation or eco-friendly mooring system was developed. This system is similar to the catenary system, except that the rode is a synthetic element, a rubber cord,

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that is significantly lighter and shorter than a chain or chain/rope rode, and which provides the restoring force through its elasticity.

3.3 Components

Several anchor types are available for single point moorings. Which anchor would be best will depend on the bottom conditions, mooring system type, loads and cost. Popular anchor types include the pin (cemented or epoxied), helical, manta ray, pyramid, mushroom and concrete block. The pin anchor is adequate for hard bottoms, while all the others are adequate for mud or sand bottoms. Helical anchors are generally used for conservation systems, and concrete blocks for catenary systems.

Catenary rodes consist of chain or chain/rope sections which are connected to each other, and to the anchor and buoy, by means of shackles, swivels and other hardware. Mooring chain is generally hot-dip galvanized carbon steel, grade 30 (BBB or Proof Coil), grade 40 or 43. The link size could be short, mid or long link, with the mid link size offering the best compromise between strength, weight, flexibility and capability to accept like-sized shackles. Stud link chain is not used for permanent yacht moorings as it is relatively heavier and expensive. Generally, rope (synthetic or wire) is not used for catenary moorings, because their relative lighter weight would provide a lesser restoring force. Conservation rodes consist of an elastic element (e.g., a light weight rubber cord) that stretches under load. Because the elastic elements are manufactured in certain lengths, these are typically combined with synthetic ropes to provide the necessary rode length. Conservation rodes are connected to the anchor and buoys with the same hardware as catenary rodes.

Buoys provide the main functions of marking the mooring location, its identification, and holding the rode at the surface. The buoy must have enough buoyancy to support the weight of the rode at all offset positions of the moored yacht. Because catenary systems feature relatively heavier rodes than conservation systems, buoys for these are larger, generally, 12 to 30-inch diameter foam-filled polyethylene shells. Buoys for conservation moorings are generally 6-inch diameter polyethylene tube spar buoys with some concrete ballast, however, spherical foam-filled buoys can also be used. The recommended way to tie the yacht to the mooring is with the pennant to the rode under the buoy. Pennants are generally short synthetic lines, with lengths about 3 times the distance from the water surface to the yacht's chock on the foredeck, and made of nylon or dacron, 3-strand or braided.

A wide range of hardware is available to facilitate the connection of all mooring components. These include shackles, swivels, rings, bridle plates, etc. Shackles shall be screw-pin type, and swivels eye-to-eye, both hot-dip galvanized, drop-forged, carbon steel.

3.4 Design

The loads that act on a single point yacht mooring are originated by the interaction of wind, waves and currents with the yacht, and to a lesser degree by the interaction of waves and currents with the mooring (i.e., the rode and the buoy). For simplicity, the latter are generally neglected.

Consequently, a good knowledge of the wind, wave and current conditions at the project site is fundamental for the design of moorings. Because waves and currents may be transformed as they arrive to and travel through the mooring location, and the length of the rode would depend on the water depth, knowledge of the bathymetry, water levels and coastal features is also fundamental. Furthermore, because some anchors work better on certain bottoms, the knowledge of bottom characteristics is important to determine which anchor would work best and how to install it. Finally, knowledge of the yacht types to be moored and their parameters is important because larger yachts would experience larger loads, and the loads and response of sailing yachts are different than that of motor yachts.

Several methodologies, technologies and tools are available to define the site conditions, and these range greatly in complexity and cost. These include surveys, statistics, empirical formulas, modeling, and field experiments. Designers shall exercise professional judgement in the selection of these, and their use must be consistent with the level of detail that is required and the degree of uncertainty that is acceptable for the stage of the design under consideration.

The calculation of mooring line tensions and angles, and general parameters of a catenary mooring system is complex and is performed with a numerical solver. For a conservation mooring system, however, the calculation is relatively simpler and is performed based on trigonometric relationships and knowledge of the load-stretch relationship of the rode. Regardless of the system, some quick and preliminary parameters of the mooring system can be calculated considering that the total load due to wind, current and waves is equal to the horizontal tension of the mooring line at the buoy, and equal to the total horizontal tension at the anchor. Furthermore, for catenary systems, the vertical tension of the mooring line at the buoy is equal to the weight of the suspended rode.

3.5 Installation

The ease or difficulty of installing a mooring system is basically represented by the ease or difficulty of installing its anchor. Among all anchor types the easiest to install is the concrete block. Given their large weights, barge cranes are typically required for the installation. No additional specialized equipment is required, as well as specialized contractors. All other anchors would require diver assistance, rotary power tools, vessel mounted hydraulic auger drives, or hydraulic or pneumatic jack hammers.

Pins used in hard bottoms are typically 316 stainless steel rods cemented or epoxied into a hole drilled into the bottom to the appropriate depth. The pin can be fixed with cement or with underwater epoxy. Helical anchors are installed with hydraulic torque motors, by divers or by spud vessels. Manta ray anchors are installed by divers using hydraulic hand-held jack hammers that drives a steel rod placed into the foot of the vertically oriented anchor. When the desired depth is reached, the drive rod is removed and the anchor assembly is pulled upward, which turns the foot 90 degrees and sets the anchor.

3.6 Maintenance

Mooring systems will suffer wear and damage and should be inspected regularly, in particular, systems installed in the marine environment. Mooring systems are submerged and wear and damage cannot not be detected unless the system is removed, or inspected in-situ by a diver or remote operated vehicle (ROV). Maintenance should include an inspection of all components at periods that could vary between one and three years. The frequency of the inspections will depend on local conditions. If a mooring is exposed to harsh conditions it will naturally wear more rapidly. Normal wear is not, however, the only cause of damage of mooring components. Corrosion and abrasion can also be responsible for loss of metal. Therefore, unless the wear patterns of mooring systems at the project site are well known, moorings need to be carefully monitored until a wear pattern can be established. In addition to the regular inspections, inspections before/after a storm may be necessary.

The mooring components shall be inspected by a qualified and independent inspector who will submit an inspection report including a list and photos and/or video of the mooring components, description of site conditions, measurements, condition assessment, and recommendations. Particular attention should be given to shackles and swivels. Worn components should be replaced and the buoy and rode should be scraped clean of marine growth as this could be sharp or abrasive and lead to wear and damage.

Generally, anchors are not subjected to wear and damage. However, anchors may drift from their original locations. If an anchor drifted, the type/weight of the anchor and bottom conditions must be reassessed and the anchor replaced. Anchor eyes and shafts may wear due to corrosion or abrasion. If the loss of metal exceeds 20% of the original size then the anchor must be replaced or repaired. Chains where links are worn 20% from their original dimension, or deformed, must be replaced. Shackles and swivels worn 20%, or deformed must be replaced. Pennants with obvious chafing, stretching, or un-laying must also be replaced.

The elastic elements in conservation moorings can be expected to last between 7 and 10 years and should be replaced following manufacturers recommendations. Chain, however, may require replacement more frequently as well as sections of the rode made of synthetic rope. Measures to extend the life of the mooring include removing the rode and buoy, or sinking the rode, when the mooring is not in use (e.g., during the winter at certain locations when the yachts are taken to dry storage). Measures to save maintenance time include replacing an entire mooring with a new or recently refurbished one, while the old mooring can then be thoroughly inspected, cleaned, and repaired back on land.