A. Mooring a buoy

Introduction

Once a buoy is put into water it needs stay where it is until it is collected. However, in most cases this would not be possible if the buoy was merely placed there without any protection against shifting. Therefore, many buoys are provided with an object called an anchor.

An anchor is basically a heavy object that is connected to a buoy (or a vessel) through a line and placed at the bottom of a river, lake or sea. The main purpose of an anchor is to keep a firm hold of a buoy and to prevent it from moving away from its destined location. Of course, the buoy does not infinitely stay in exactly the same place; it can move around within a certain range depending on the action of wind and tides. Because of their vital importance, anchors have probably been used ever since people set forth into the seas. In the beginning, anchors were not as complex as they are nowadays. In fact, in ancient times people would most often apply "*a large stone, a bag or basket of stones*" or sand. The Egyptians, for example, used a lead-weighted log. The first iron anchors were most likely used by the Greeks, while the first anchors with arms similar to those of modern anchors were applied by the Romans. The typical, but already obsolete, anchor (Figure A-1) consists of a shank, a stock, a crown, and arms, attached near the base of the shank and curving upward to end in flat, triangular flukes. [1] [2]

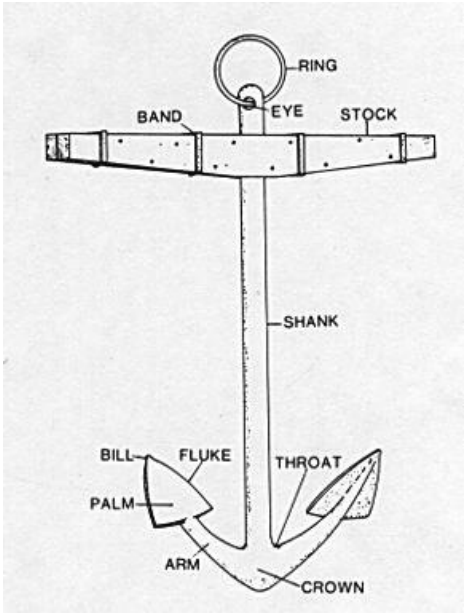

Figure A-1 typical modern anchor [3]

Holding power

The most important parameter of an anchor is its holding power which is defined as *"the value of the maximum pulling force an anchor accepts without dragging in given conditions"* [4]. The holding power of a given anchor is dependent on a few factors. First is deadweight - product of an anchor's mass. In older types of anchors it was the most important factor, and therefore they would often be very heavy. Nowadays anchors can be substantially aided with two additional forces: suction and friction. Suction is the force that appears when with time an anchor digs itself into the soil and covers itself with a considerable amount of material. This provides it with an additional power to hold the buoy. Friction, on the other hand, is present in some anchors that have a special design allowing them to embed themselves into the soil as they are pulled on. Naturally, this significantly increases the holding power as well. In order to determine the approximate holding power of an anchor, three main aspects need to be known: type of soil, type of anchor, and the size of the anchor. As far as the type of soil is concerned, the bottom holding quality of different types of soils can be put into four categories. The first category, appropriately called poor, consist of rocks, dead corals with weed, gravel with shells, and thick weeds. The second category is called medium and is composed of soft sand or mud. The third category, good, refers to most sands or muds. The last and best category, excellent, *"refers to dense sand or mud bottoms"* [4]. In terms of anchor type, the holding capacity is always greater in anchors with a large surface area and often in anchors with a greater weight. The remaining factors are: *"the angulation of the pull of the line, mass of material moved when dragging as a ratio to the mass of the anchor, and the ratio of the scope to the depth"* [5]. Because of the multitude of factors that affect the holding power of an anchor, there is no holding power standard that one can refer to. Therefore, it is hardly possible to compare the holding power for different anchors. Additionally, it is impossible to estimate what will be the actual holding power of an anchor when it is placed in an unknown anchorage. [4] [6] [7] [5]

Types of anchors

Anchors can be categorized in many different ways. One of them is based on the application of an anchor during a journey on a boat and it includes three general categories: the lunch hook (used for short stops), the working anchor (standard anchor), and the storm anchor (used in heavy weather). Obviously, these types of anchors do not apply to a buoy. Anchors can be further defined as burying and non-burying. Moreover, there are many different anchoring

options which can be divided into at least four general categories: gravity, pile, suction, embedment (Figure A-1). [7] [8]

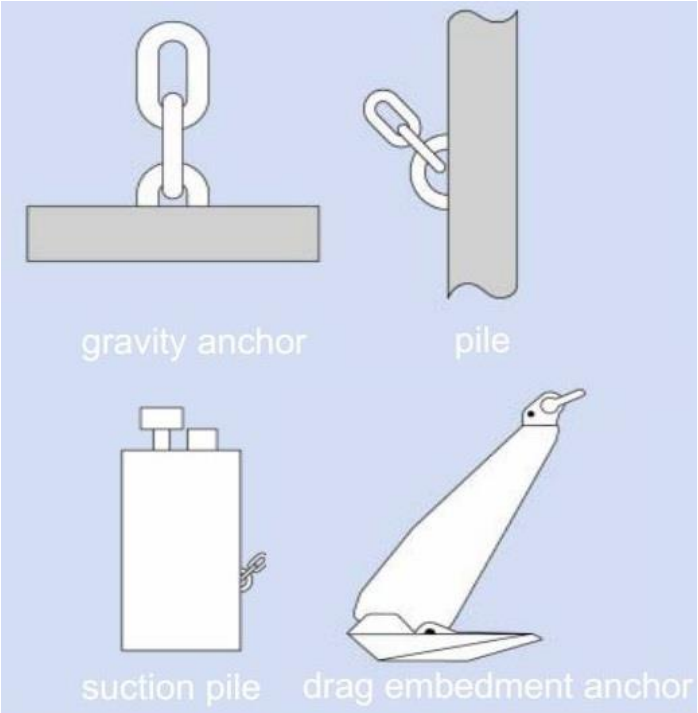

Figure A-2 types of anchors [7]

Most modern anchors of the drag embedment type come in two categories:

- Flat anchors (Figure A-3) – have two flat flukes and an articulated shank, [4]
- plough anchors - have a single plough-shaped fluke that can be convex, flat or concave; the shank is either rigidly linked (Figure A-5) or articulated to the fluke (Figure A-4). [4]

Figure A-3 flat anchor [4]

Figure A-4 articulated plough anchor [4]

Figure A-5 rigid plough anchor [4]

Holding power of a drag embedment anchor

Optimum holding power depends on few conditions [4]:

- "*the fluke(s) must be completely and symmetrically buried in the bottom*" (Figure A-6)
- "*if present, the articulation must be in the "open" position*"
- "*the tension on the pulling eye of the shank must be parallel to the seabed*"
- "*an anchor should neither swing out of the bottom nor turnover on its side when the pulling force increases, even when it drags*"
- "*anchor must re-align itself to a new heading*"

Figure A-6 properly burried anchors

Anchor line

An anchor by itself would not be of much use if it was not somehow connected to the buoy. It is therefore equipped with a thin, long and flexible line that is usually made from one of three materials: chain, rope or polypropylene line. The benefit of using a chain is that it *"does not usually break and is difficult to cut"* [6]. However, the chain does have some disadvantages. It is *"heavy, difficult to transport, and can cause considerable structural damage to the bottom and sedimentation as it swings with the current"* [6]. Rope has the advantages of being light compared to chain and it is easy to transport. Additionally, it is not as destructive as chain. Nevertheless, it has the significant flaw – it can rot and break easily. The last option, polypropylene line, is *"light, durable, and easily replaced if cut or lost"* [6]. Whichever option is selected, an anchor line must be strong enough so that it does not break. A safety factor must be involved in determining the final thickness and type of the line. In most cases this means that the anchor line must withstand from 1,5 to 3 times the predicted strength requirements. The figure below (Figure A-7) presents one of many ways of connecting an

anchor to a buoy. This particular method is intended for smaller and lighter buoys with a mass up to ~ 50kg. [6] [9]

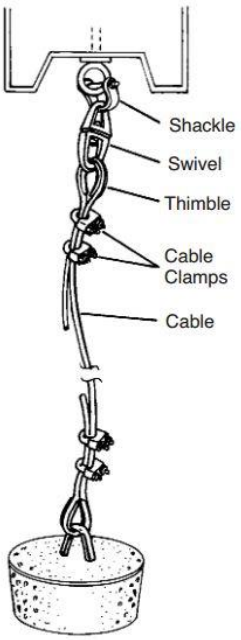

Figure A-7 connection of an anchor line [9]

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