Coastal Engineering Technical Note

CRANE SURVEY OF SUBMERGED RUBBLE-MOUND COASTAL STRUCTURES

PURPOSE: To describe a technique of obtaining underwater profiles of a rubblemound coastal structure by sounding with a crane-suspended, weighted base.

BACKGROUND: The interface between land and water always presents a problem to the surveyor because data obtained using two techniques have to correspond. Typically, measuring level and rod are used onshore, while echo sounding is used offshore. Under calm conditions, considerable overlap can be obtained when the rod man can wade out to overlap the area surveyed by a shallow-draft survey vessel, particularly when tidal fluctuation can be used. This overlap is extremely useful for adjusting the two surveys to the same datum. As wave heights increase, however, this overlap vanishes and a gap develops where neither technique can be used to provide data.

A rubble-mound structure poses additional problems to echo sounders because its highly reflective and irregular surface scatters the return signal, making sounding by use of a lead-weighted line from small vessels the typical technique. Obviously, rough conditions preclude this option. In addition, unless extremely close spacing is used, soundings from a small lead weight can lead to interpreting isolated armor peaks or voids as indicative of the overall profile. Consequently, accurate surveys of structures on the open coast are highly weather-dependent and time-consuming, causing increased project costs and delays.

Three approaches successfully used to solve this problem on sandy beaches are: (a) use of an elevated, amphibious vehicle (e.g., the Coastal Research Amphibious Buggy (CRAB) as a mechanical rod man); (b) towing a sled equipped with a surface-piercing vertical rod by boat or amphibian; and (c) sounding with a weighted line from a helicopter. The first two are obviously unsuitable for use on a rubble-mound structure, and considering the increased density and number of points required to survey a breakwater, a mobile crane would likely make a more cost-effective platform than a helicopter. Traditionally used by contractors during construction, this technique has not often been used for post-construction assessment. Thus, there is no previously available documentation of the technique.

APPLICATION: This technique has the following potential applications:

a. For rubble-mound structures of stone or concrete armor units in unprotected waters where timely surveys are hampered by a high frequency of rough water or other adverse conditions.

b. Where a mobile crane is (ideally) already at the site or readily available.

c. Where the crane has access to the survey area from the following:

1. The top of the rubble-mound structure itself.

2. A fixed platform adjacent to the structure.

3. A floating platform in the lee of the structure in calm water. (The technique is less applicable from a floating platform in unprotected water. Even when conditions appear calm, low-frequency swell and surge could be present which could cause sufficient displacement of the platform to introduce significant errors.)

EQUIPMENT REQUIRED:

a. Platform. A crane or derrick with sufficient reach to extend to the limits of the survey area at an adequate height is required (see Figure 1).

b. Base. The base is the end of the cable from which elevations are taken when it contacts the breakwater. Smoothing of the true profile will result both from the discrete spacing of the data points and the physical dimensions of the base. The latter effect is, in fact, desirable in order to avoid the potential error caused by use of a small lead-line weight. Thus, vertical resolution is replaced by a horizontal area resolution which is controlled by the size of the base's footprint. Features smaller than the horizontal dimensions of the base will be averaged into the surrounding features, or ignored, according to their particular shapes (see Figure 2). Model studies conducted at the Waterways Experiment Station have indicated the base diameter, D, should be related to an equivalent length, ℓ, of a theoretical cube of armor material, i.e.,

$$\ell = \left(W_a/\gamma_a\right)^{1/3}$$

where ℓ = equivalent length, ft

W_a = average weight of armor units, lb

γ_a = average density of armor unit material, pcf

then,

$$D = C\ell$$

where C = 0.57 for stone and 1.14 for dolosse

Wave-induced motion of the base must be minimized for reliable results, requiring material of sufficient density. Regarding its shape, the base must be capable of maintaining a constant reference or zero point at various angles of repose. A sphere meets this requirement, but other shapes may be satisfactory. Three examples illustrated in Figure 2 are as follows:

1. Solid (Figure 2a). This base is typically spherical and made of steel or lead; however, the weight can become excessive in cases requiring a large footprint. Alternatively, a lifting ring can be attached to a typical size armor unit. Care must be exercised with a heavy base to avoid damage to concrete armor units.

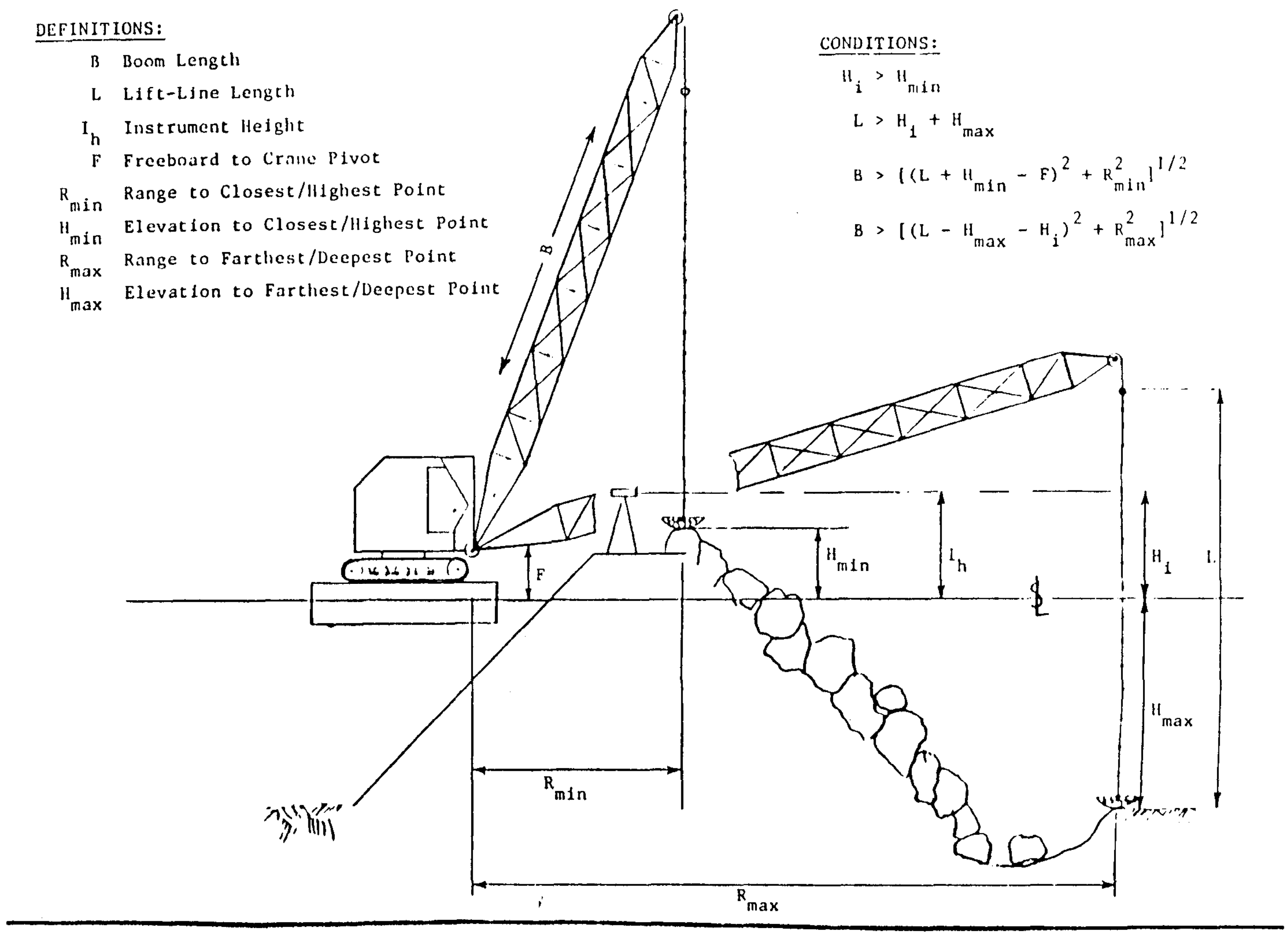
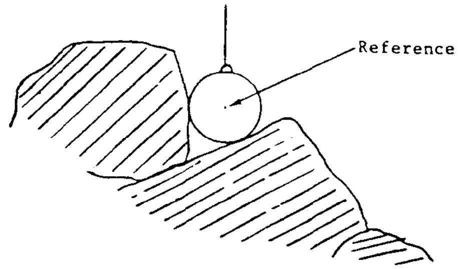
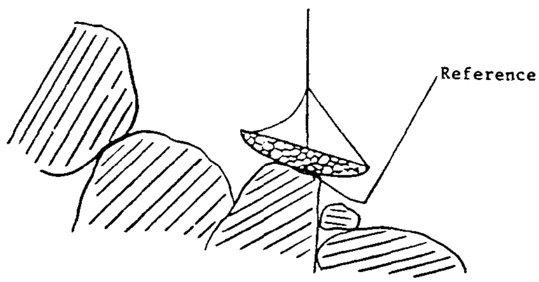


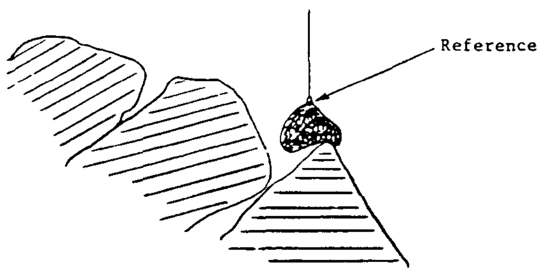
Figure 1. Requirements of crane-mounted surveying rig.



a. Solid.



b. Open mesh.



c. Flexible.

Figure 2. Typical base types.

2. <u>Open frame (Figure 2b</u>. A spherical or hemispherical steel basket will increase the footprint while minimizing surface area exposed to wave forces. Weight can be controlled by adding lead, steel, or rock to the basket to suit the existing wave conditions. An open frame made of reinforcing steel is most practical for stone armor units and is generally recommended. Again, care must be exercised with a heavy base to avoid damage to concrete armor units.

3. <u>Flexible (Figure 2c)</u>. Essentially a bag of fabric or steel mesh filled with lead, steel, or stone weights, the flexible base provides additional smoothing of the profile by conforming to individual peaks. It can also indicate voids without falling into them. This type of base is less likely to snag in very irregular surfaces such as dolosse, but some accuracy is lost due to its random deformation.

c. Lift Line. The evaluation of the reference point of the base is taken, in practice, as an offset measured from a point on the lift line. If an optical level is used to determine elevations, the lift line must be graduated in some manner so its length can be read. Any scheme of painted marks, wooden or plastic shapes affixed to the line, etc., will suffice, as long as a point on the line is readily visible and distinguishable.

The lift "line" above the base can also be a solid rod. In both cases, the markings must extend a length greater than the maximum water depth plus instrument height (see Figure 1).

METHODOLOGY: Depending upon the positioning method selected, standard surveying instruments required are transit and level or a total station.

The final data required is the three-dimensional position of the reference of the base when it rests on the breakwater. The procedure is to place the base on the breakwater, determining by the slack in the lift line when it has made contact, carefully take up the slack, and measure the position and elevation of the lift line.

If the position of the crane is known or determinable (e.g., by placing the crane on a known station on the breakwater), the position of the upper end of the boom is obtained by simple geometry, knowing boom length and vertical and horizontal angle. Base elevation can be read by sighting the lift line intersection through an optical level.

Flagging or otherwise marking a specific point on the lift line allows triangulation if two transits are used, with base elevation available from vertical angle measurement or a separate level reading. This eliminates the need to locate the crane itself.

Two transits can be replaced by one total station and a reflector. It the reflector is placed on the boom (typically at the boom tip) an optical level is still required to determine vertical elevation. Placing the reflector on the lift line itself reduces the survey equipment needed to one instrument--the total station. Since alignment of a standard prism might be a problem on a cable free to rotate, the reflector should be visible to the instrument operator at any angle. A cylinder covered with reflectors, affixed to the top of the lift line, and a prism on a swivel controlled by a tag line back to the crane are two option.

Density of points measured will depend on the required resolution of the survey. However, in general, along any one section line, points should be spaced at intervals no greater than twice the equivalent length, ℓ. Determination of the exact point where the base makes contact with the structure and causes a slacking of the lift line will be more difficult under rough conditions due to wave-induced motion of the lift line.

Estimates of accuracy range from 0.1 ft with a rigid base under moderate conditions to 0.5 ft with a flexible base under rough conditions.

Each profile section should extend beyond the toe of a structure. This will provide valuable data on the bottom topography (particularly scour problems) near the structure.

PERSONNEL REQUIREMENTS: While a crane operator is required in all cases, the number of people required to position the base depends on the technique selected. With a total station and line-mounted reflector, a single instrument man can sight and fix the prism, and thus the base. If an electronic data logger is not supplied, an additional person to record data would save considerable time.

Using a level to read lift-line elevations adds a second instrument man, and a third is required if lift-line position is obtained by triangulation using two transits.

If the lift line position is obtained from a known base position and boom geometry, the crane operator, or preferably an assistant, needs to record boom vertical angle and turntable horizontal angle.

Survey time will vary with technique and ease of crane mobility, but once the crane is on a station, fixing of individual data points should be on the order of 20 per hour or faster.

HAZARDS: As with any lifting operation, care should be taken that the load is never positioned over any personnel. Because of the existence of voids and overhangs in the structure, particularly with concrete armor units, the possibility of fouling or hanging the base in the structure should be considered. When fouled, the base (a relatively low-cost component) should be considered expendable, rather than risking dislodging armor units or deploying divers in an attempt to retrieve it. A break-away connection between the lift line and the base (e.g., a lightweight shackle or a loop of light line) would allow the base to be safely lifted, but would release if it became fouled in the structure.

ADDITIONAL INFORMATION: For further information contact Mr. David McGehee of the U.S. Army Engineer Waterways Experiment Station at (601)634-2084 or FTS 542-2084.

REFERENCES:

Carver, R. D., "Stability of Stone and Dolosse Armored Rubble-mound Breakwater Trunks Subjected to Breaking Waves with No Overtopping," Technical Report CERC-83-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1983.

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