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Technical Report R-882S

Supplement to TR-882: GUIDE TO THE USE OF PROPELLANT-EMBEDDED ANCHORS IN CORAL AND ROCK SEAFLOORS

By

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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93043

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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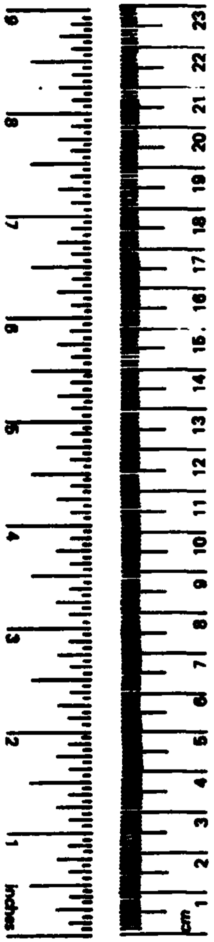
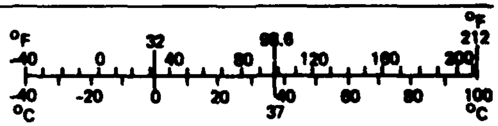
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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This handbook-style report has been prepared to assist the engineer with limited propellant-embedded anchoring experience in estimating holding capacity of this type of anchor in coral and rock seafloors. Site survey requirements are discussed with regard to coral and rock types and sediment cover and their affect on holding capacity. An equation is provided for estimating holding capacity in coral. Limited general guidance is provided for estimating holding capacity in rock.

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1. Propellant-embedded anchors 2. Seafloors I. YF59.556.091.01.204

This handbook-style report has been prepared to assist the engineer with limited propellant-embedded anchoring experience in estimating holding capacity of this type of anchor in coral and rock seafloors. Site survey requirements are discussed with regard to coral and rock types and sediment cover and their affect on holding capacity. An equation is provided for estimating holding capacity in coral. Limited general guidancc is provided for estimating holding capacity in rock.

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A

1.0 INTRODUCTION

Propellant-embedded anchors have become an important asset in the Navy's mooring equipment inventory. They offer potential for anchoring in coral and rock seafloors where conventional anchors will not work or present major logistic problems. Generally satisfactory results have been obtained when the propellant-embedded anchors have been used in coral seafloors. There have been no operational uses of propellant-embedded anchors in rock seafloors, although limited testing has demonstrated the potential of propellant-embedded anchoring in rock seafloors. This supplement to Technical Report R-882 provides guidance on the use of propellant-embedded anchors in coral and rock seafloors. This guidance covers both site survey requirements and holding capacity estimation. The guidance is generally limited to NCEL-developed, plate-like coral flukes and the recently developed experimental conical rock fluke.

1.1 Background

The Navy's interest in direct embedment anchors is concentrated on propellant-embedded anchors, of which four are available for use: the NCEL 10K, 20K, 100K, and the SUPSALV anchors. The anchors appear and function similarly, except that the SUPSALV anchor has a frame that allows it to sit on the seafloor and then be fired electrically from the surface on command. Figure 1-1 shows the NCEL 20K propellant-embedded anchor. On contact with the seafloor the touchdown probe triggers the safe/arm device that in turn initiates the propellant contained in the gun barrel. The burning propellant drives the fluke into the seafloor at high velocity, while reaction is provided by the gun barrel and reaction vessel. As the fluke penetrates the seafloor, it drags successive loops of downhaul cable behind it.

A major advantage of propellant-embedded anchors over other types of direct embedment anchors is their potential for anchoring in coral and rock. The first attempts to anchor in coral with a propellant-embedded anchor were in 1961 (Bradley, 1963). Since then, there has been a steady evolution of propellant-embedded anchor flukes for coral. Figure 1-2 shows the type of coral fluke now being used with the NCEL family of propellant-embedded anchors. It is a plate-like fluke that keys, or partially keys, after penetrating into the surrounding coral mass to achieve resistance to pullout. Wadsworth and Beard (1980) analyzed available data from coral anchor tests and installations to develop a way to estimate the holding capacity of plate-like flukes.

Attempts to test propellant-embedded anchors in rock have been reported by Smith (1971), Taylor and Beard (1973), and Taylor (1976). The fluke designs they used gave mixed results; sometimes capacities were very good, other times no holding capacity was obtained. Wadsworth and Beard (1980) reported on an investigation to determine the optimum shape for a rock fluke. Eight different model-sized shapes were tested. The best performance was obtained by a conical-shaped fluke. Investigations with this fluke shape have continued and tests have been conducted with a conical rock fluke sized for the NCEL 20K anchor. A report on this work is in preparation (Beard and Miller, 1983). The fluke is shown in Figure 1-3. This fluke performed well in sandstone and a vesicular basalt seafloor, but no method has been developed to estimate capacity in other rock types or with other fluke sizes.

1.2 Related Reports

This supplement is based on information contained in a number of reports that provide additional detail on coral and rock anchoring tests and installations.

Beard, R. M., and J. E. Miller (1983). Results of 20K anchor conical rock fluke tests in sandstone and basalt, Naval Civil Engineering Laboratory, Technical Memorandum M-42-83-__. Port Hueneme, Calif. (to be published)

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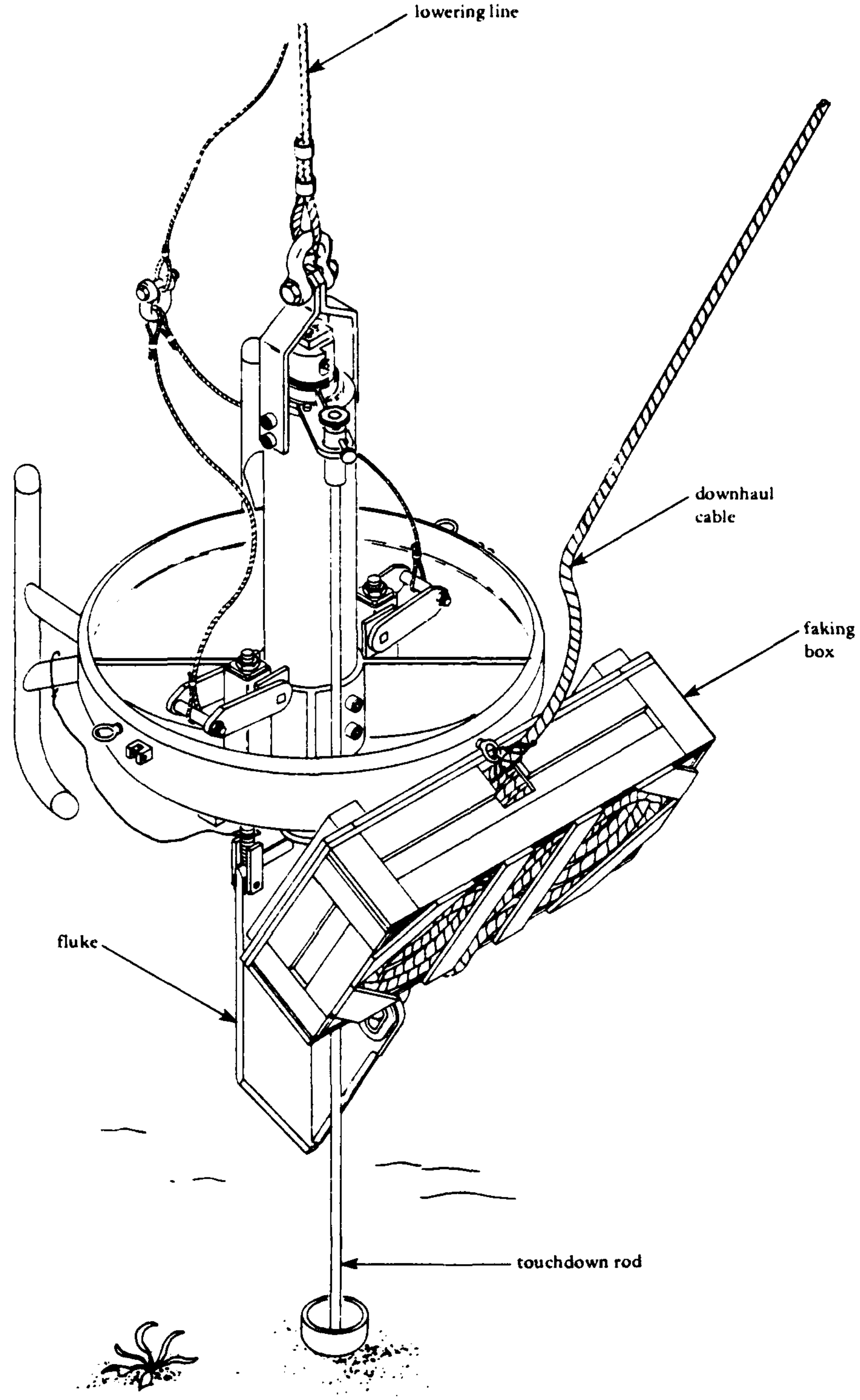

Figure 1-1. NCEL 20K propellant-embedded marine anchor.

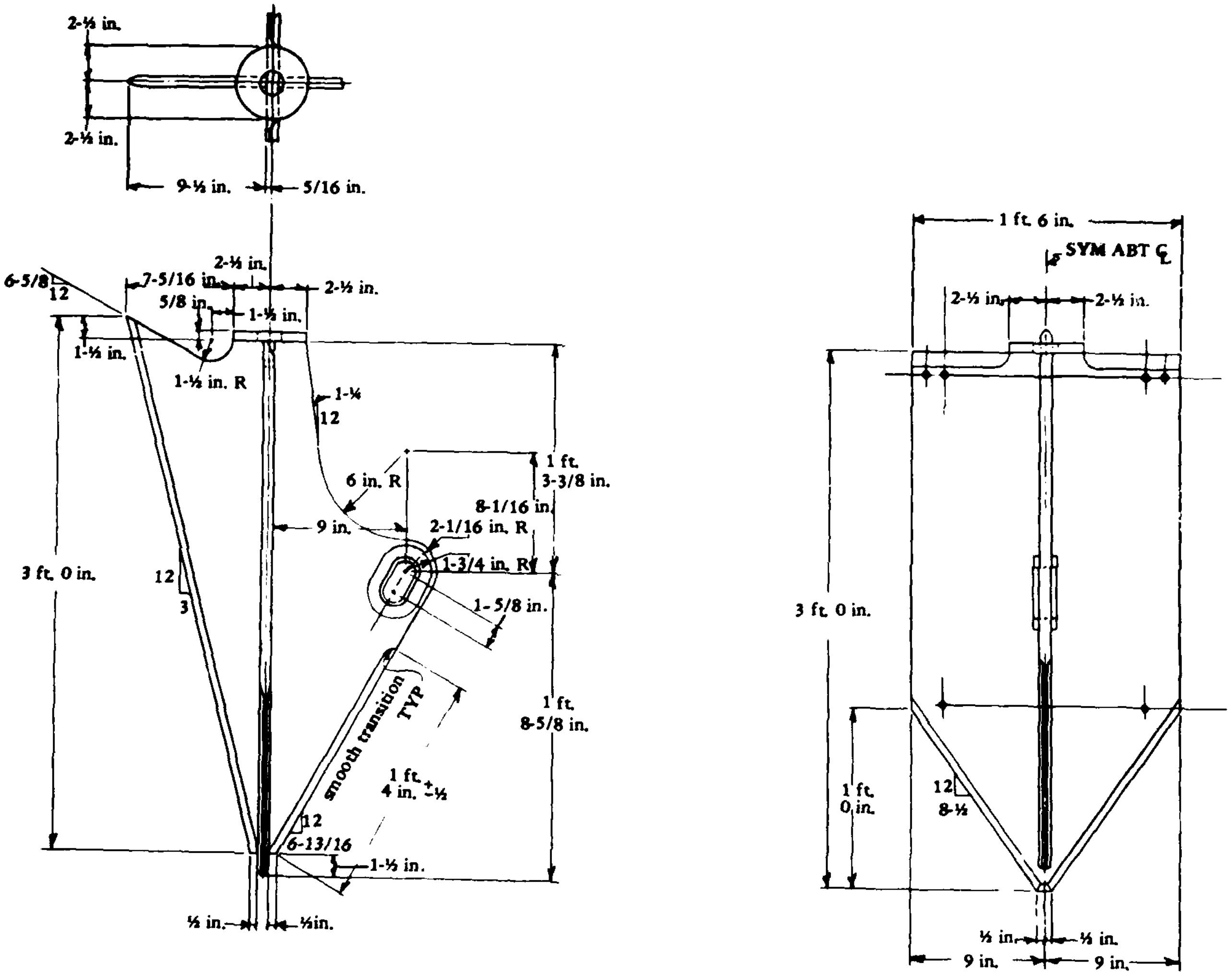

Figure 1-2. CEL 20K coral anchor fluke.

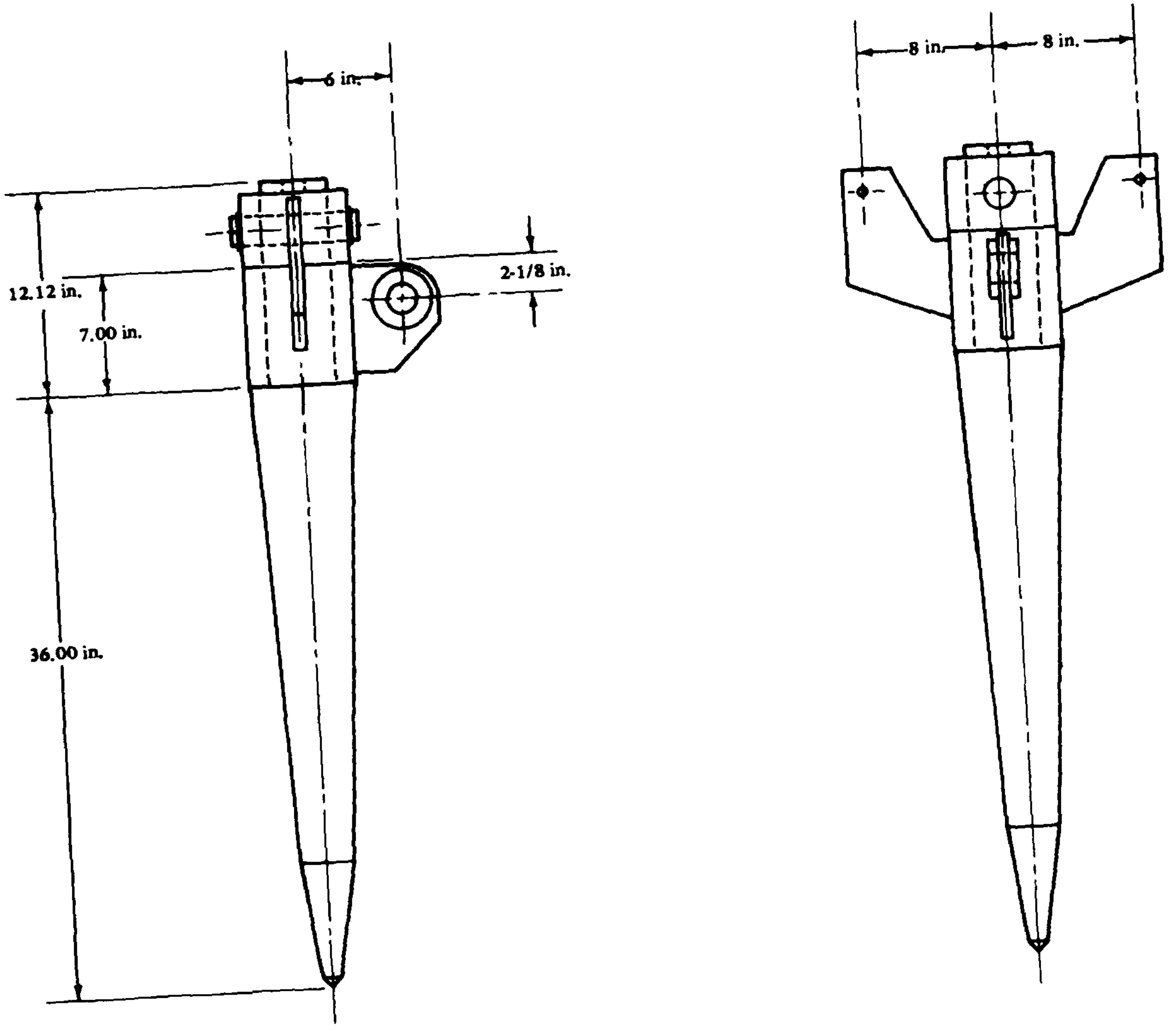

Figure 1-3. CEL 20K embedment anchor experimental rock fluke.

2.0 SITE SURVEY

Site survey requirements for coral have evolved from experience in testing and installing many NCEL 10K, 20K, 100K, and SUPSALV coral anchors (Smith, 1971; True and Taylor, 1976; Wadsworth and Taylor, 1976; Taylor, 1976; True, 1977; and Miller, 1982). There is little experience in surveying rock sites for propellant-embedded anchorage; only two sites have been visited and only eight tests performed (all with the NCEL 20K anchor) (Beard and Miller, 1983). However, survey requirements for coral and rock sites are similar. Specific coral and rock properties are not required as they are not used in holding capacity predictions. The general nature of the coral or rock and the depth of sediment overburden are helpful. Seafloor topography is valuable in selecting suitable anchorage areas or points.

2.1 Coral Type

No change in holding capacity has been noted due to changes coral type. Penetration is reduced as coral strength increases, b holding capacities tend to remain constant.

2.2 Rock Type

Limited information (Wadsworth and Beard, 1980) is available on the effect of rock type on holding capacity. Model test results (Wadsworth and Beard, 1980) indicate that holding capacity declines in the following order of rock types: granite, basalt, limestone, shale, and sandstone. Tests with an NCEL 20K anchor conical fluke (Beard and Miller, 1983) showed adequate performance in a vesicular basalt and a sandstone. The tests ended in mechanical failure of connective hardware at loads between 180 and 310 kN (40 and 70 kips).

2.3 Sediment Overburden

Penetrating through a sediment cover attenuates the energy of a fluke, resulting in lower coral or rock penetration and presumably lower holding capacity. Sparse results are available to provide a means of estimating the influence of specific types or depths of sediment cover. Most tests have been conducted on formations void of sediment cover. At Diego Garcia Island, up to 3 meters (10 feet) of coralline sands and oozes did not seem to affect holding capacity of the NCEL 100K or the SUPSALV coral anchors as judged by applied proof loads. Smaller anchors, which penetrate about half as far as the 100K anchor, presumably would not be affected by sediment cover of similar materials perhaps up to 1.5 meters (5 feet) thick. The effect of overburden on the conical rock fluke is unknown. Tentative guidance is to limit sediment cover to 3 meters (10 feet) or less of clay or 1.5 meters (5 feet) or less of sand.

2.4 Topography

Holding capacity in coral and rock is affected indirectly by topography. Sloping surfaces may cause the fluke to ricochet. Attempting to penetrate on top of an outcrop or near the edge of a ledge might cause the coral or rock to spall with little or no penetration achieved. In general, surfaces sloping more than 20 degrees should be avoided. Areas with vertical or near vertical rock faces taller than one fluke length should also be avoided when possible to increase chances of obtaining a good anchorage.

3.0 HOLDING CAPACITY IN CORAL

Holding capacity in coral is defined as the load required to pull an anchor fluke out of the seafloor in a matter of minutes. It is thought that holding capacity is obtained by plate-like flukes in coral when an increasing load causes the fluke to key, or partially key, into the coral formation. All reported holding capacity data have resulted from short duration static pulls; no other type of holding capacity data are available (Beard and Wadsworth, 1980). Because the mechanism of failure is not understood, mechanistic models to predict holding capacity have not been developed. The approach used to develop a predictive equation has been empirical (Wadsworth and Beard, 1980). In their work known projectile (fluke) parameters and target (coral) properties were studied to determine their effect on holding capacity.

Wadsworth and Beard (1980) reported the analysis of available embedment anchor tests and installations in coral seafloors. The results analyzed came from tests with anchor sizes that ranged from model scale to the SUPSALV propellant-embedded anchor. As would be expected, the fluke mass and impact velocity were the dominating factors controlling holding capacity. Of the 86 test installations, there were only 19 tests where the anchor flukes were pulled out, and for only 6 of those 19 tests were the target properties known. This severely limited the data base to be used for analysis. While coral properties intuitively seem important, the paucity of data precluded using any coral properties in the analysis. Consequently, the mass and velocity of the projectiles were the only parameters included in the analysis. They were combined into a kinetic energy term and an empirical equation for estimating holding capacity in coral from the kinetic energy of the projectile.

The equation is:

$$F_c = 0.024 \left(\frac{m\,v^2}{2}\right)^{0.684} \tag{3-1}$$

where F_c = holding capacity (kN)

m = projectile (fluke and piston) mass (kg)

v = projectile velocity (m/sec)

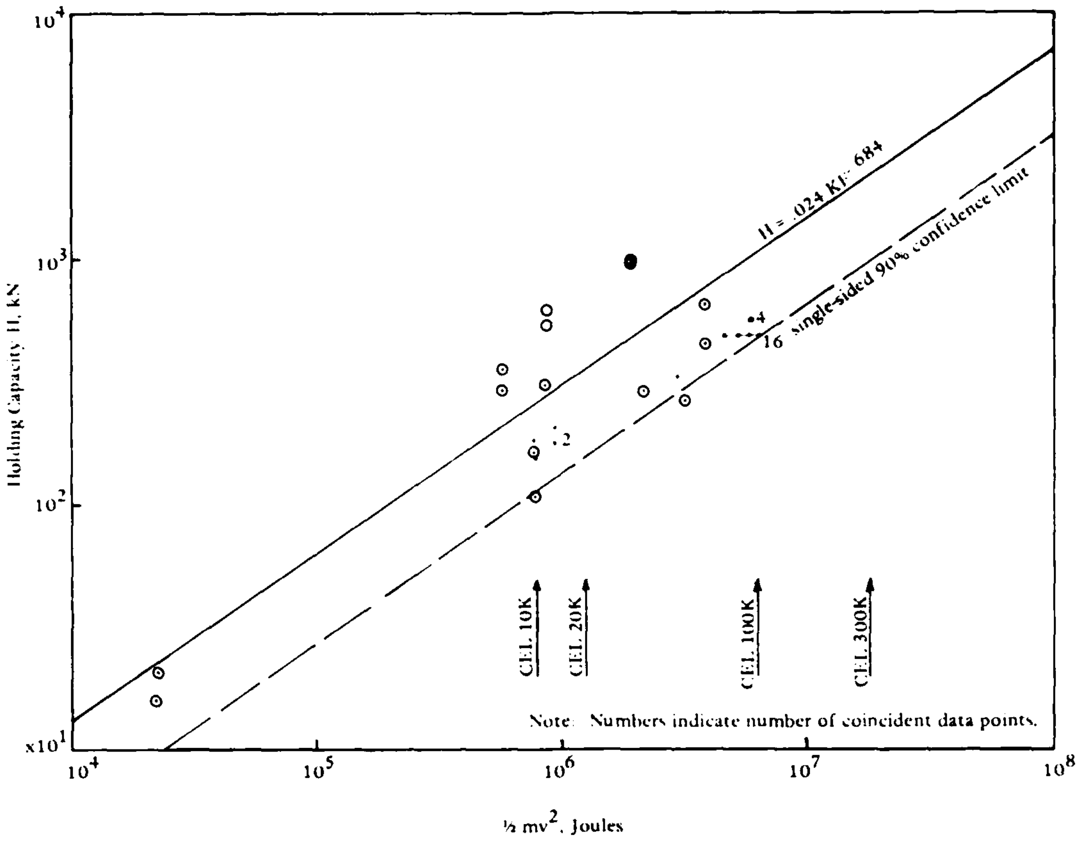

Figure 3-1. Results of pullout tests in coral plotted versus fluke kinetic energy (after Wadsworth and Beard, 1980).

A data plot that yielded this empirical equation is shown in Figure 3.1. Because this equation was developed from a narrow data base, its use must be restricted to the range of parameters used in the development. The equation only applies to NCEL plate-like coral flukes. Projectile velocities should be within 100 to 150 m/sec (330 to 500 ft/sec). Projectile mass should be between 8 and 800 kg (0.5 and 55 slugs).

In lieu of a proof load to or above design capacity, suitable factors of safety need to be applied to holding capacities calculated with Equation 3-1. From a statistical view of the data base, applying a factor of safety of 2 gives 90% confidence that a fluke will not be pulled out.

For the NCEL family of propellant-embedded anchors, Table 3-1 gives estimates of their holding capacity in coral seafloors. These are estimated average pullout loads.

Table 3-1. Estimated Average Holding Capacities of NCEL Propellant-Embedded Anchors in Coral Seafloors

Anchor	Projectile Mass, kg (slugs)	Velocity, m/sec (ft/sec)	Holding Capacity, kN (kips)
NCEL 10K	52 (3.5)	125 (410)	160 (37)
NCEL 20K	130 (9.1)	130 (425)	325 (73)
NCEL 100K	725 (49)	130 (425)	1,045 (235)
SUPSALV 100K	725 (49)	130 (425)	1,050 (235)

4.0 HOLDING CAPACITY IN ROCK

Holding capacity in rock is defined as the load required to pull an anchor fluke out of the seafloor in a few minutes. It is thought that holding capacity is achieved by the conical rock fluke through bonding of comminuted rock to the fluke surface by heat generated during penetration and high compressive stresses between the rock and the fluke. Experience with the conical-shaped fluke fired from a NCEL anchor in the ocean is limited to eight firings with the 20K anchor, the first two of which did not remain embedded for reasons that have since been corrected. Other than these tests, only the results of 28 tests with 20-cm-long (8-inch-long) conical fluke models are available.

Holding capacities from the model tests varied widely as a function of rock type, and often the flukes were curled (Figure 4-1). Holding capacities achieved in the NCEL 20K anchor tests are of limited use in developing a holding capacity equation, as none of the flukes were pulled out. As a consequence, it has not been possible to develop a holding capacity equation. Model test results were erratic because of damaged flukes; this appears not to be the case with the 20K anchor conical fluke.

Figure 4-1. Example of curled model size conical rock fluke.

There were several problems in the first two tests. First, a collar at the top of the projectile designed to limit penetration may have caused the projectile to bounce when the collar struck the rock. Second, there was inadequate standoff distance allowed between the projectile tip and the seafloor at the initiation of propellant burn. As a consequence the projectile was prevented from reaching maximum velocity. This happened because the projectile tip contacted the seafloor before the piston pushing the projectile had cleared the gun barrel. Third, the energy of the propellant used was below specification, thereby further limiting projectile velocity. These problems were overcome by removing the collar, increasing the standoff distance, and changing to a more dependable propellant. Subsequently, two tests have been performed in sandstone and four tests in a vesicular basalt with good success (Table 4-1). The results of these tests are the only guide to expected performance of the conical rock fluke. Performance was good in both rock types. It is not known how these results will extrapolate to other rock types or to the NCEL 10K, NCEL 100K, or the SUPSALV anchors.

5.0 SUMMARY

Propellant-embedded anchors have become an important asset in the Navy's mooring equipment inventory. Their use in coral seafloors is fairly common and their performance has been satisfactory. There have been no operational uses in rock seafloors, although their potential has been demonstrated by a limited number of tests.

It is apparent that guidance for using propellant-embedded anchors in coral and rock seafloors is unrefined. Major areas of uncertainty are the effect of coral properties on holding capacity in coral, the effect of rock type and properties on penetration and holding capacity in rock, and the structural adequacy of the experimental conical rock fluke. Efforts to overcome these uncertainties will begin with research on anchoring in rock, as this area requires the most advancement. Initially this would involve study on penetration into rock and the relationship of penetration to holding capacity. Later, efforts would be directed toward development of an improved method for predicting holding capacity in coral with an emphasis on inclusion of coral properties.

Table 4-1. Results of NCEL 20K Anchor Tests in Rock With a Conical Rock Fluke

Rock Type	Compressive Strength, mPa (psi)	Fluke Velocity, m/sec (ft/sec)	Fluke Mass, kg (slugs)	Penetration m (ft)	Peak Load, kN (kips)	Comments
Sandstone	~ 14 (2,000)	102 (335)	178 (12)	0.9 (3)	200 (45)	Could not extract; wire failed
Sandstone	~14 (2,000)	102 (335)	178 (12)	1.1 (3.6)	190 (42)	Could not extract
Basalt	~20 (3,000)	105 (345)	178 (12)	0.9 (3)	--	Could not place load frame over fluke
Basalt	~20 (3,000)	105 (345)	178 (12)	0.9 (3)	290 (65)	Could not extract; wire failed
Basalt	~20 (3,000)	105 (345)	178 (12)	0.9 (3)	290 (65)	Could not extract; wire failed
Basalt	~20 (3,000)	105 (345)	178 (12)	0.9 (3)	330 (75)	Could not extract; wire failed

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NAF PWO, Atsugi Japan
NALF OINC, San Diego, CA
NARF Code 100, Cherry Point, NC; Equipment Engineering Division (Code 61000), Pensacola, FL
NAS Dir. Util. Div., Bermuda; PWD - Engr Div, Oak Harbor, WA; PWD Maint. Div., New Orleans, Belle Chasse LA; PWD, Code 1821H (Pfankuch) Miramar, SD CA; PWD, Willow Grove PA; PWO Belle Chasse, LA; PWO Key West FL; PWO Whiting Fld, Milton FL; PWO, Glenview IL; ROICC Key West FL; SCE Norfolk, VA; SCE, Barbers Point HI
NATL BUREAU OF STANDARDS Kovacs, Washington, D.C.
NATL RESEARCH COUNCIL Naval Studies Board, Washington DC
NAVACT PWO, London UK
NAVAEROSPREGMEDCEN SCE, Pensacola FL
NAVAIRDEVCEN Code 813, Warminster PA
NAVCHAPGRU CO Williamsburg VA
NAVCOASTSYSCEN Code 719, Panama City, FL; Code 772 (C B Koesy) Panama City FL; CO, Panama City FL; Code 715 (J Quirk) Panama City, FL; Code 715 (J. Mittleman) Panama City, FL; Library Panama City, FL
NAVCOMMAREAMSTRSTA SCE, Wahiawa HI; SCE Unit 1 Naples Italy
NAVCOMMSTA Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWO, Exmouth, Australia
NAVCONSTRACEN Code 00U15, Port Hueneme CA; Curriculum/Instr. Stds Offr, Gulfport MS
NAVEDTRAPRODEVCEN Technical Library, Pensacola, FL
NAVELEXSYSCOM Code PME 124-61, Washington, DC; PME 124-612, Wash DC
NAVEODTECHCEN Code 605, Indian Head MD
NAVFAC PWO, Centerville Bch, Ferndale CA
NAVFACENGCOM Code 03T (Essoglou) Alexandria, VA; Code 043 Alexandria, VA; Code 044 Alexandria, VA; Code 0453 (D. Potter) Alexandria, VA; Code 0453C, Alexandria, VA; Code 0454B Alexandria, Va; Code 04A1 Alexandria, VA; Code 04B3 Alexandria, VA; Code 06, Alexandria VA; Code 044B) Alexandria, VA; Code 100 Alexandria, VA; Code 1002B (J. Leimanis) Alexandria, VA; Code 1113, Alexandria, VA; Morrison Yap, Caroline Is.
NAVFACENGCOM - CHES DIV. Code 405 Wash, DC; Code 407 (D Scheesele) Washington, DC; Code FPO-1C Washington DC; Code FPO-1E, Wash, DC; FPO-1 Washington, DC; FPO-1EA5 Washington DC; FPO-1P/1P3 Washington, DC
NAVFACENGCOM - LANT DIV. Eur. BR Deputy Dir, Naples Italy; RDT&ELO 102A, Norfolk, VA
NAVFACENGCOM - NORTH DIV. (Boretsky) Philadelphia, PA; CO; Code 04 Philadelphia, PA; Code 09P Philadelphia PA; Code 1028, RDT&ELO, Philadelphia PA; ROICC, Contracts, Crane IN
NAVFACENGCOM - PAC DIV. CODE 09P PEARL HARBOR HI; Code 2011 Pearl Harbor, HI; Code 402, RDT&E, Pearl Harbor, HI; Commander, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV. Code 90, RDT&ELO, Charleston SC
NAVFACENGCOM - WEST DIV. AROICC, Contracts, Twentynine Palms CA; Code 04B San Bruno, CA; O9P/20 San Bruno, CA; RDT&ELO Code 2011 San Bruno, CA
NAVFACENGCOM CONTRACT AROICC, Point Mugu CA; Dir, Eng. Div., Exmouth, Australia; Eng Div dir, Southwest Pac, Manila, PI; OICC, Southwest Pac, Manila, PI; OICC/ROICC, Balboa Panama Canal; ROICC AF Guam; ROICC, Diego Garcia Island; ROICC, Keflavik, Iceland; ROICC, NAS, Corpus Christi, TX; ROICC, Pacific, San Bruno CA
NAVFORCARIB Commander (N42), Puerto Rico
NAVOCEANO Library Bay St. Louis, MS
NAVOCEANSYSCEN Code 4473 Bayside Library, San Diego, CA; Code 4473B (Tech Lib) San Diego, CA; Code 52 (H. Talkington) San Diego CA; Code 5204 (J. Stachiw), San Diego, CA; Code 5214 (H. Wheeler), San Diego CA; Code 5221 (R.Jones) San Diego Ca; Code 5311 (Bachman) San Diego, CA; Hawaii Lab (R Yumori) Kailua, HI; Hi Lab Tech Lib Kailua HI
NAVPETRES Director, Washington DC
NAVPGSCOL C. Morers Monterey CA; Code 61WL (O. Wilson) Monterey CA; E. Thornton, Monterey CA
NAVPHIBASE CO, ACB 2 Norfolk, VA; COMNAVBEACHGRU TWO Norfolk VA; Code S3T, Norfolk VA; Dir, Amphib. Warfare Brd Staff, Norfolk, VA; Harbor Clearance Unit Two, Little Creek, VA; SCE Coronado, SD,CA
NAVREGMEDCEN Chief of Police, Camp Pendleton CA; SCE (D. Kaye); SCE, Guam
NAVREGMEDCEN SCE, Yokosuka, Japan
NAVSCOLCECOFF C35 Port Hueneme, CA
NAVSCSOL PWO, Athens GA
NAVSEASYSCOM Code C132 (Mr. J. Peters) Washington, DC; Code OOC-D, Washington, DC; Code PMS 395 A 3, Washington, DC; Code PMS 395 A2, Washington, DC; Code SEA OOC Washington, DC; PMS-395 A1, Washington, DC; PMS395-A3, Washington, DC; SEA 04E (L. Kess) Washington, DC
NAVSECGRUACT PWO, Adak AK
NAVSHIPREPFAC Library, Guam; SCE Subic Bay

NAVSHIPYD Bremerton, WA (Carr Inlet Acoustic Range); Code 202.4, Long Beach CA; Code 380, Portsmouth, VA; Code 410, Mare Is., Vallejo CA; Code 440 Portsmouth NH; Code 440, Puget Sound, Bremerton WA; Tech Library, Vallejo, CA
NAVSTA Dir Engr Div, PWD, Mayport FL; CO Roosevelt Roads P.R. Puerto Rico; Code 4, 12 Marine Corps Dist, Treasure Is., San Francisco CA; Engr. Dir., Rota Spain; Long Beach, CA; Maint. Div. Dir/Code 531, Rodman Panama Canal; PWD (LTJG.P.M. Motolenich), Puerto Rico; PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam; SCE, Subic Bay, R.P.; Security Offr, San Francisco, CA
NAVSUPPFAC PWD - Maint. Control Div, Thurmont, MD
NAVSURFWPNCEN G-52 (Duncan) Dahlgren, VA
NAVTECHTRACEN SCE, Pensacola FL
NAVWPNCEN Code 2636 China Lake; Code 3803 China Lake, CA
NAVWPNSTA Code 092, Colts Neck NJ
NAVWPNSTA PW Office Yorktown, VA
NAVWPNSTA PWD - Maint. Control Div., Concord, CA; PWD - Supr Gen Engr, Seal Beach, CA; PWO, Charleston, SC; PWO, Seal Beach CA
NAVWPNSUPPCEN Code 09 Crane IN
NCTC Const. Elec. School, Port Hueneme, CA
NCBC Code 10 Davisville, RI; Code 15, Port Hueneme CA; Code 155, Port Hueneme CA; Code 156, Port Hueneme, CA
NCBU 411 OIC, Norfolk VA
NCR 20, Code R70; 20, Commander; 30th Det, OIC, Diego Garcia I
NMCB 74, CO; FIVE, Operations Dept; Forty, CO; THREE, Operations Off.
NOAA (Dr. T. Mc Guinness) Rockville, MD; Library Rockville, MD
NORDA Code 410 Bay St. Louis, MS; Code 440 (Ocean Rsch Off) Bay St. Louis MS; Code 500, (Ocean Prog Off-Ferer) Bay St. Louis, MS
NRL Code 5800 Washington, DC; Code 5843 (F. Rosenthal) Washington, DC; Code 8441 (R.A. Skop), Washington DC
NROTC J.W. Stephenson, UC, Berkeley, CA
NSC Code 44 (Security Officer) Oakland, CA; Code 54.1 Norfolk, VA
NSD SCE, Subic Bay, R.P.
NTC OICC, CBU-401, Great Lakes IL
NUCLEAR REGULATORY COMMISSION T.C. Johnson, Washington, DC
NUSC Code 131 New London, CT; Code 332, B-80 (J. Wilcox) New London, CT; Code EA123 (R.S. Munn), New London CT; Code EA131 (G. De la Cruz), New London CT
OFFICE SECRETARY OF DEFENSE ASD (MRA&L) Code CSS/CC Washington, DC; OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC
ONR CO (Code 701) Pasadena, CA; Central Regional Office, Boston, MA; Code 481, Bay St. Louis, MS; Code 485 (Silva) Arlington, VA; Code 700F Arlington VA
PHIBCB 1 P&E, San Diego, CA; 1, CO San Diego, CA; 1, CSWC D Wellington, San Diego, CA
PMTC Code 3144, (E. Good) Point Mugu, CA; Code 3331 (S. Opatowsky) Point Mugu, CA; EOD Mobile Unit, Point Mugu, CA; Pat. Counsel, Point Mugu CA
PWC CO Norfolk, VA; CO, (Code 10), Oakland, CA; CO, Great Lakes IL; CO, Pearl Harbor HI; Code 10, Great Lakes, IL; Code 120, Oakland CA; Code 120C, (Library) San Diego, CA; Code 128, Guam; Code 154, Great Lakes, IL; Code 200, Great Lakes IL; Code 424, Norfolk, VA; CO (Code 613), San Diego, CA; Code 400, Great Lakes, IL; Code 400, Pearl Harbor, HI; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code 505A Oakland, CA; Code 600A Norfolk, VA; Code 700, Great Lakes, IL; Code 700, San Diego, CA
SPCC PWO (Code 120) Mechanicsburg PA
SUPANX PWO, Williamsburg VA
UCT ONE OIC, Norfolk, VA
US DEPT OF INTERIOR Bur of Land Mgmnt Code 583, Washington DC
US GEOLOGICAL SURVEY Off. Marine Geology, Piteleki, Reston VA
US NAVAL FORCES Korea (ENJ-P&O)
USCG (G-MP-3/USP/82) Washington Dc; (Smith), Washington, DC; G-EOE-2/61 (Espinshade), Washington, DC; G-EOE-4 (T Dowd), Washington, DC; Gulf Strike Team, Bay St. Louis, MS; Lant Strike Team Elizabeth City, NC; Pac Strike Team, Hamilton AFB, CA
USCG R&D CENTER CO Groton, CT; D. Motherway, Groton CT; S Rosenberg, Groton, CT; Tech. Dir, Groton, CT
USDA Forest Service Reg 3 (R. Brown) Albuquerque, NM; Forest Service, San Dimas, CA
USNA Civil Engr Dept (R. Erchyl) Annapolis MD; Ocean Sys. Eng Dept (Dr. Monney) Annapolis, MD; ENGRNG Div, PWD, Annapolis MD
WATER & POWER RESOURCES SERVICE (Smoak) Denver, CO