78-14

HYDRAULICS RESEARCH DIVISION

Technical Note

DATE: August 1978 REPORT NO: 78-14

TITLE: Estimate of Torque Required for Anchors Embedded in Lake Bottom Sediment

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REASON FOR REPORT: This calculation has been carried out in response to the request by Mr. H. Savile, Mechanical Engineering, ESS, NWRI, in connection with the proposed underwater installation of a photologger frame.

CORRESPONDENCE FILE NO:

5180

1.0 TYPE OF ANCHOR

The anchor considered for the proposed installation is shown in Figure 1, and it is further described by the manufacturer on sheets appended to this report (Appendix 1).

2.0 THEORY

In general, a torque required to turn anchor at a certain embedment depth below the lake bottom can be computed from the following equation:

$$T = A \times M \times f \tag{1}$$

where: T is the torque [N x m]

A is the surface area of the anchor [m^2]

M is the moment arm [m]

and f is the skin friction [N x m^{-2}]

The term A x M will be derived first. The surface area represents a sum of the area of the anchor helix and that of the anchor rod. For the anchor considered, i.e. with one pitch of the helix, the following equation can be employed:

$$A \times M = \int_{r_o}^{r} 2\pi r^2 \, dr + 2\pi r_o^2 \times d \tag{2}$$

where: r is the radius of the helix [m]

r_o is the radius of the rod [m]

and d is the embedded length [m]

For longer anchors of the helical auger type, the torque can be calculated by means of formulas derived in Appendix 2.

Upon integration Equation (2) takes the form

$$A \times M = \frac{2}{3}\pi \left(r^3 - r_o^3\right) + 2\pi r_o^2 \, d \tag{3}$$

While the term A x M can be established quite accurately, an estimate for f is much less certain due to the complex distribution of normal stresses along the anchor, variable consistency of the sediment, temporary changes of pore water pressures during driving, etc.

The table below summarizes the range of expected values, which should be considered as rough estimates only. A more reliable information can be obtained only from direct field tests (Terzaghi and Peck, 1967).

TABLE 1 Ultimate Values of Skin Friction on Steel Piles in Cohesive Sediments (adapted from Terzaghi and Peck, 1967)

Unconfined Compressive Strength [kNm^{-2}]	Skin Friction, f [kNm^{-2}]
0 - 71.8	0 - 33.5
71.8 - 143.6	33.5 - 47.9
143.6 - 287.3	47.9 - 57.5
> 287.3	57.5

3.0 APPLICATION

According to Figure 1, two different sizes are considered:

Anchor Catalog No.	r [cm]	r_o [cm]	d [cm]
4345-1	5.1	1.9	137
6346-1	15.2	1.9	168

Substituting the appropriate values into Equation (3) yields the following numbers for term A x M.

	Anchor Helix [m^3]	Anchor Rod [m^3]
4345-1	2.62×10^{-4}	3.11×10^{-3}
6346-1	7.33×10^{-3}	3.81×10^{-3}

Using limited geotechnical data available from the vicinity of the proposed installation site, the f values are estimated as follows.

PROPOSED METHOD OF INSTALLING PHOTOLOGGER ON GLACIAL TILL

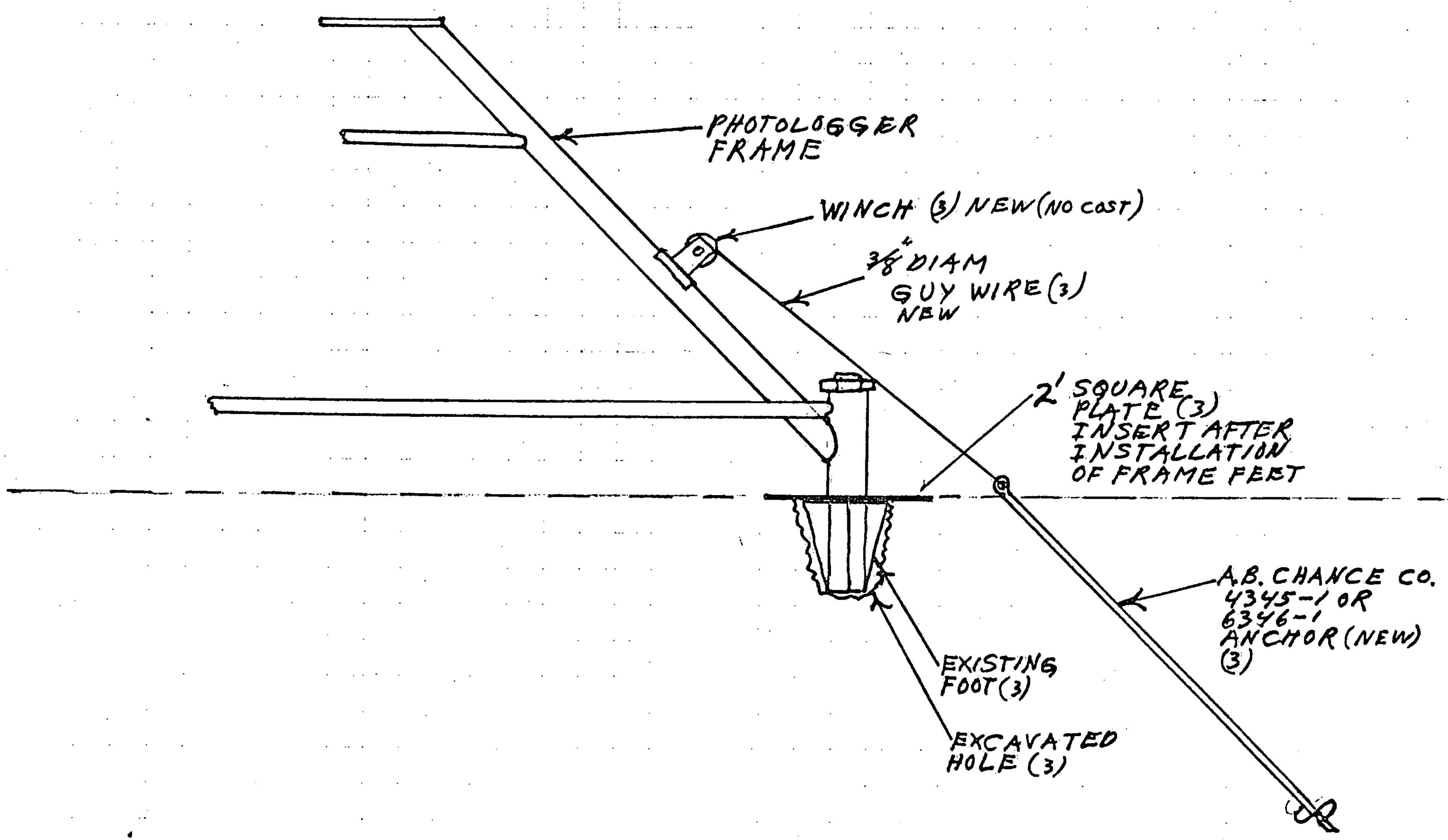


Figure 1

The Standard Penetration Test carried out in the silty till deposit, which is the sediment in question, gave an N-value of 134 blows per 8 cm of penetration (the Trow Group, 1975).

Therefore, the consistency of the sediment is "hard", corresponding to the unconfined compressive strength much in the excess of 380 kNm^{-2} (Terzaghi and Peck, 1967, Table 45.2).

This value thus further corresponds to the maximum value for f given in Table 1. Since remoulding occurs during anchoring, a remoulded value for compressive strength and hence a lower value for f applies to the rod, say one half of the maximum value. Then a very crude estimate for the torque is obtained.

4345-1 $\quad T = 2.62 \times 10^{-4} \times f + 3.11 \times 10^{-3} \times \frac{f}{2}$

$= \underline{\underline{0.105 \text{ kN - m } (77.4 \text{ lb.-ft.})}}$

6346-1 $\quad T = 7.33 \times 10^{-3} \times f + 3.81 \times 10^{-3} \times \frac{f}{2}$

$= \underline{\underline{0.531 \text{ kN - m } (391.7 \text{ lb.-ft.})}}$

N.B. Both results correspond to "probe values" given by the manufacturer for this type of sediment (see Appendix 1).

REFERENCES

Terzaghi, K. and Peck, R. B., 1967. "Soil Mechanics in Engineering Practice". J. Wiley & Sons, pp. 347 and 533.

The Trow Group, 1975. "Foundation Investigation". Proposed Offshore Research Platform, 1 Kilometer off Confederation Park, Lake Ontario, Hamilton, p.

APPENDIX 1

Information on Anchors
Supplied by Manufacturer

A new analysis of soil mechanics, as it effects holding power, reduces the selection and rating of anchors from guesswork to a near-exact science.

For many years, "holding power" data, which served as a guide for selecting anchors, lacked specific information on soils and soil conditions. The physical strength of most anchors had been established with reasonable accuracy, although their effectiveness varied considerably in different types of soils and under different conditions affecting the soils such as drainage, seasonable weather changes, etc. Most of the original soil ratings were listed under such general classifications as "sand," "clay," "hard pan," and "swamp," with no consideration for the condition of these soils and no definite descriptions to explain the meaning.

After years of hit-and-miss solution to anchor rating and selection problems, the test-proven Chance Soil Classification Data revolutionized old theories of soil classification in relation to anchor holding strength. Initially, however, there were certain shortcomings because (1) it was necessary to take earth samples from anchor depth in order to classify the earth and (2) variances, percentage-wise, of granular particles, clay, and moisture content were not easily defined. A by-product of these shortcomings in many instances was a difference of personal opinions in regard to earth classification — and sometimes the best guess led to anchor failure!

Soil Test Probe being used to determine class of soil

Soil Test Probe Developed

With the design and development of the Chance Soil Test Probe, a mechanical instrument which makes it possible to study the subsoil from the surface, the problems of taking earth samples and guessing at soil classes have been mostly solved.

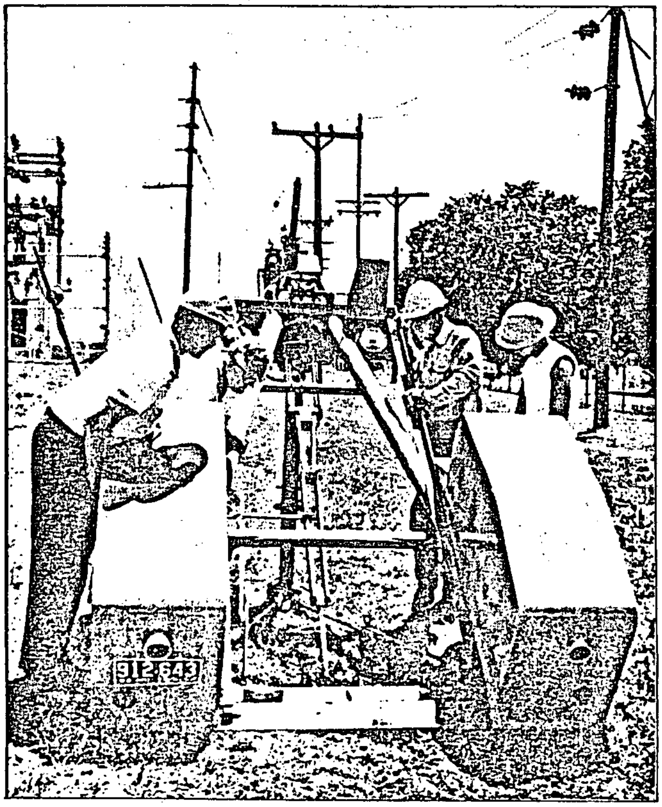
The Soil Test Probe is screwed into the ground and, as it displaces the earth, probe readings are taken in inch-pounds as measured on the torque gauge built into the handle.

The Chance Soil Classification Data now combine the probe readings from the Soil Test Probe so that users of this instrument may translate their readings into the appropriate soil class. In addition, the data table for a particular anchor shows the probe value for each soil class, and the related holding strength of the anchor at that class and value. For more information on the Soil Test Probe, see page 1A-2.

Effects of Anchor Tests

Using Chance designed and constructed hydraulic powered anchor test machines, it has been possible to obtain load-creep (stress-strain) data for various sizes and types of anchors in many different earth types.

These nationwide tests have provided utilities with valuable data in regard to comparative anchor holding strengths. In addition, they have resulted in an expansion of the Chance Soil Classification Data. Soils which hold alike, though they are of different texture, are described; and there are now eight different classes ranging from solid bedrock to water-covered swamp.



Hydraulic Anchor Test Unit conducting pull test

SOIL CLASSIFICATION DATA

CLASS	DESCRIPTION OF SOIL	PROBE VALUE
1	Solid Bed Rock	------
2	Dense Clay; Compact Gravel; Dense Fine Sand; Laminated Rock; Slate; Schist; Sandstone	Over 600 in.-lbs.
3	Shale; Broken Bed Rock; Hardpan; Compact, Clay-Gravel Mixtures	500-600 in.-lbs.
4	Gravel, Compact Gravel and Sand; Claypan	400-500 in.-lbs.
5	Medium-Firm Clay; Loose Sand and Gravel; Compact Coarse Sand	300-400 in.-lbs.
6*	Soft-Plastic Clay; Loose Coarse Sand; Clayey Silt; Compact Fine Sand	200-300 in.-lbs.
7	Fill; Loose Fine Sand; Wet Clays; Silt	100-200 in.-lbs.
8**	Swamp; Marsh; Saturated Silt; Humus	Under 100 in.- lbs.

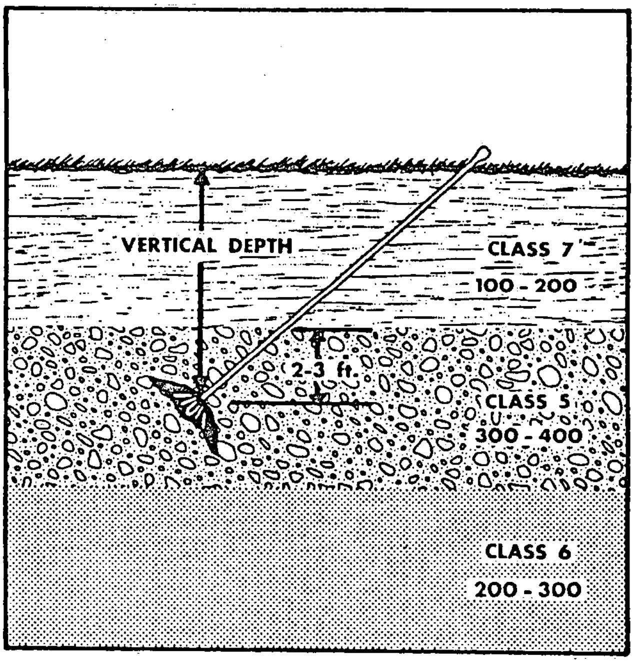
*Class 7 is a marginal soil band and an appropriate factor of safety must be considered.

**Class 8 is a soil description only. It is necessary to install anchors deep enough, by the use of extensions, to penetrate a Class 5, 6 or 7 soil underlying the Class 8 soil.

ANCHOR DEPTH IS IMPORTANT

A year-round study of soil properties defines the proper depth for an anchor setting. Whereas it was formerly believed that an increase in anchor depth automatically assured greater holding power, it is now established that holding power will increase with depth only if a stronger earth will be penetrated. Oftentimes a deeper setting will place an anchor in a weaker strata and holding power will be reduced.

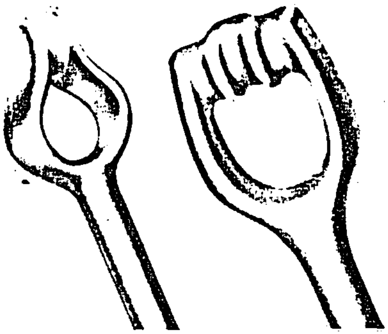
Soil-anchor holding strengths published in this bulletin are based on a minimum penetration of 3 ft. into the particular soil classification band by the anchor. A standard anchor installation will, of course, include a *minimum* vertical cover of 5 ft. to ensure it is not located in the active frost zone.

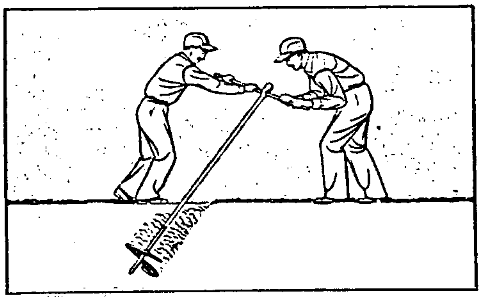


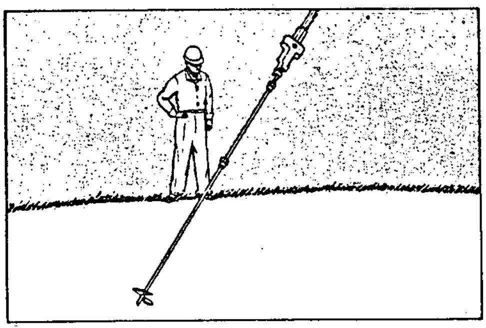
TO DETERMINE VERTICAL DEPTH OF ANCHOR BELOW GROUND

(A) If Anchor Rod installed at 45° Angle, multiply length of anchor rod penetration by .707.
(B) If Anchor Rod installed at 60° Angle to horizontal, multiply length of anchor rod penetration by .866.

CHANCE NO-WRENCH SCREW ANCHOR







• For Hand or Machine Installation

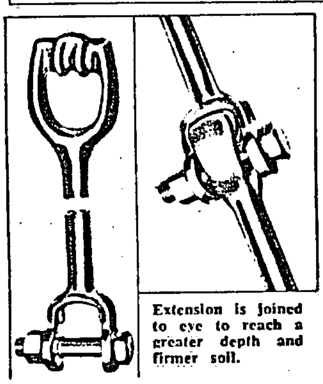
The Chance No-Wrench Screw Anchor may be installed by hand or by machine. The "King-size" Thimbleye® or Tripleye® on the rod has a large opening to admit a turning bar for screwing the anchor down. The eye will also fit into an adatper available from most hole boring machine manufacturers so that the anchor may be power installed. This one piece Screw Anchor consists of a drop forged, alloy steel Thimbleye or Tripleye rod, electric welded to a high strength structural steel blade (helix). The Rod is galvanized. The Helix and a part of the rod is dipped in rust-resistant black asphalt paint.

• Pitch Controlled – Small Hub

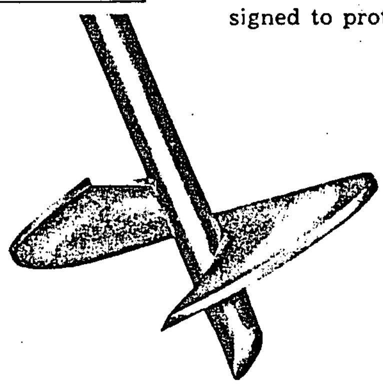
Every anchor helix is "pitch controlled" for fastest installation and greatest holding power. The method of manufacture also permits a small hub that minimizes friction, making installation easier. This small hub also reduces earth disturbance during installation and thus increases the holding power of the anchor.

• Thimbleye® or Tripleye®

Most users will prefer the Thimbleye on the 4", 6" and 8" anchors as it prevents crews from overloading the anchors, but either type is available in these sizes. Only the Tripleye is furnished on the 10" and larger anchors. Both eyes have the EEI thimble groove, designed to protect the guy strand during slack pulling or under load.



Extension is joined to eye to reach a greater depth and firmer soil.



• Rod Extensions for Deeper Installations

Anchor Rod Extensions are used to increase the depth to which No-Wrench Screw Anchors can be installed. The extension is joined to the eye of the anchor rod by placing the clevis over the eye and fastening the bolt as shown in the small photo at left.

APPLICATION & ORDERING INFORMATION

Catalog No.		Anchor Size Dia.	Area Sq. In.	Rod. Dia. and Length	No. in Bdl.	Approx. Wt. Per 100	Soil-Anchor Holding Strength—Lbs. *			
Thimbleye	Tripleye						300-400 In.-Lbs. (Class 5)	200-300 In.-Lbs. (Class 6)	100-200 In.-Lbs. (Class 7)	← Soil Test Probe Value ← Soil Class
4345-1	4345	4"	12½	¾" x 54"	1	805	4500	3000	1500	Note: See Page 1-3 for Soil Class Description and Relationship to Soil Test Probe Values.
6346-1	6346	6"	28	¾" x 66"	1	1087	6500	5000	2500	
816-1	816	8"	50	1" x 66"	1	1910	11000	9000	6000	
	10146	10"	78	1¼" x 66"	1	3030	13000	10000	7000	
	10148	10"	78	1¼" x 96"	1	4107	13000	10000	7000	
	12536	11 5/16"	100	1¼" x 96"	1	4490	15000	13000	10000	
	12537	13½"	143	1¼" x 96"	1	4805	17000	15000	12000	
	15148	15"	176	1¼" x 96"	1	5780	20000	17000	14000	

* Based on Machine Installation. If hand installed, holding power will be reduced 10% to 20%.

ROD EXTENSIONS

Catalog No.	Description	Rod Dia.	Rod Length	Wt. Per 100
402	Rod Ext. (Fits Tripleye Only)	1¼"	71"	2800 lbs.

18200

APPENDIX 2

CALCULATION OF TORQUE FOR AUGER-TYPE ANCHORS

The length L of a cylindrical helix is, in the parametrical form

$$L = \int_0^t \left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2\right]^{1/2} dt \tag{4}$$

where

$$x = r \cos t$$
$$y = r \sin t \tag{5a-c}$$
$$z = b\,t$$

$$b = \frac{p}{2\pi}$$

where p is the pitch of the helix.

Substituting (5a-c) into (4) gives

$$L = (r^2 + b^2)^{1/2}\ t \tag{6}$$

The term A x M is then obtained by integration from r_o to r

$$A \times M = 2t \int_{r_o}^{r} (r^2 + b^2)^{1/2}\ dr$$

Substituting $r^2+b^2=u$

$du=2r\ dr$

$$A \times M = t \int_{u_o}^{u} u^{1/2}\, d_u = \frac{2}{3} t\, u^{3/2} \Big|_{u_o}^{u}$$

$$= \frac{2}{3} t\ (r^2 + b^2)^{3/2} \Big|_{r_o}^{r} \tag{7}$$

$$= \frac{2}{3} t \left[(r^2 + b^2)^{3/2} - (r_o^2 + b^2)^{3/2}\right]$$

Equation (7) is then multiplied by f to obtain T required to turn the anchor.