

A Comprehensive Analysis of Cable Bolt Anchorage Characteristics

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Presentation Outline

1. Introduction.
2. Cable Bolts Test Specimens.
3. Anchorage Capacity per Linear Length of Encapsulation.
4. Effects of Counter-Clockwise Rotation.
5. Encapsulation Safety Factor.
6. Off-Axis Capacity.
7. Effects of Long-Term Creep.
8. Conclusions.



Introduction

Introduction

- Traditional cable bolts incorporated with birdcages and two component polyester resin cartridges have been a tried and proven system.
- With a variety of cable bolts available to the mining industry. Where do these bolts rank in their actual performance?

Cable Bolt Test Specimens



- Indented Cable.
- Bird Caged Cable.
- Plain Cable.

Tests Conducted

Compared Characteristics-

1. Anchorage capacity per linear length of encapsulation.
2. Effects of reverse spinning on installation.
3. Off-axis capacity associated with angle bolting.
4. Effects of long-term creep.



Anchorage Capacity per Linear Length of Encapsulation

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Test Overview



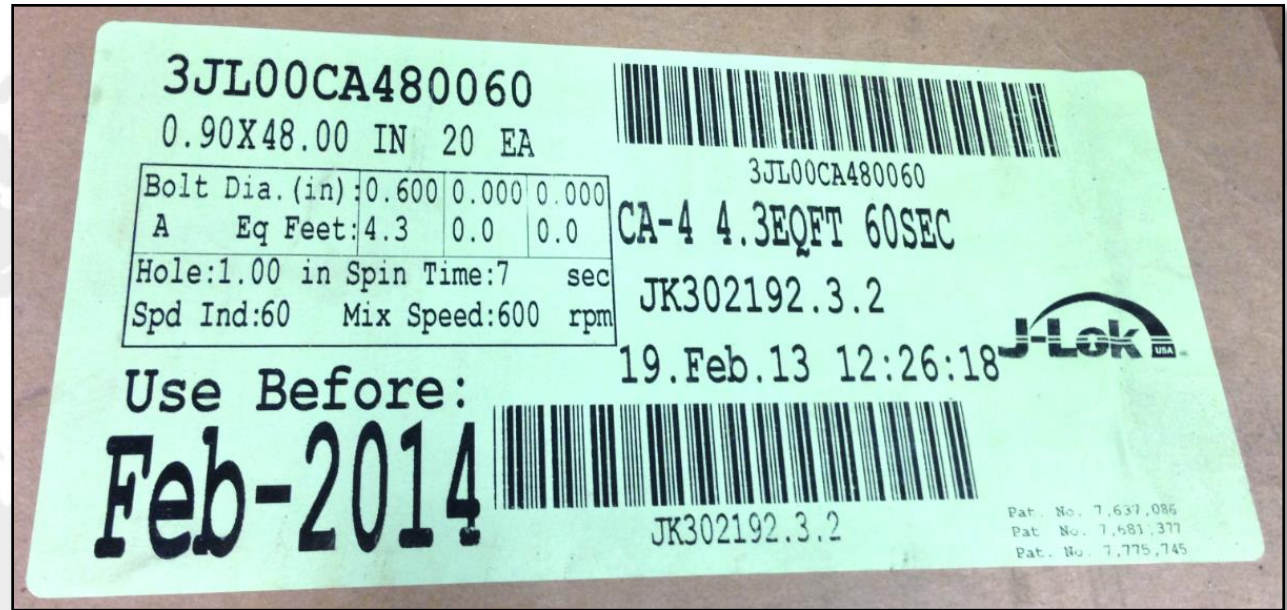
- Tests used to determine the actual anchorage capacity with various lengths of encapsulation.
- Numerous samples tested from 6" to 48".
- Used internally threaded steel bore holes to act as the drill hole.

Bore Tubes (“Drill Hole”)



- 1" ID x 1.75" OD (.375" wall).
- Tapped 27 x 3 metric thread.
- In accordance to ASTM F432 A3.1.2 for Chemical Grouting Materials.

J-LOK Resin



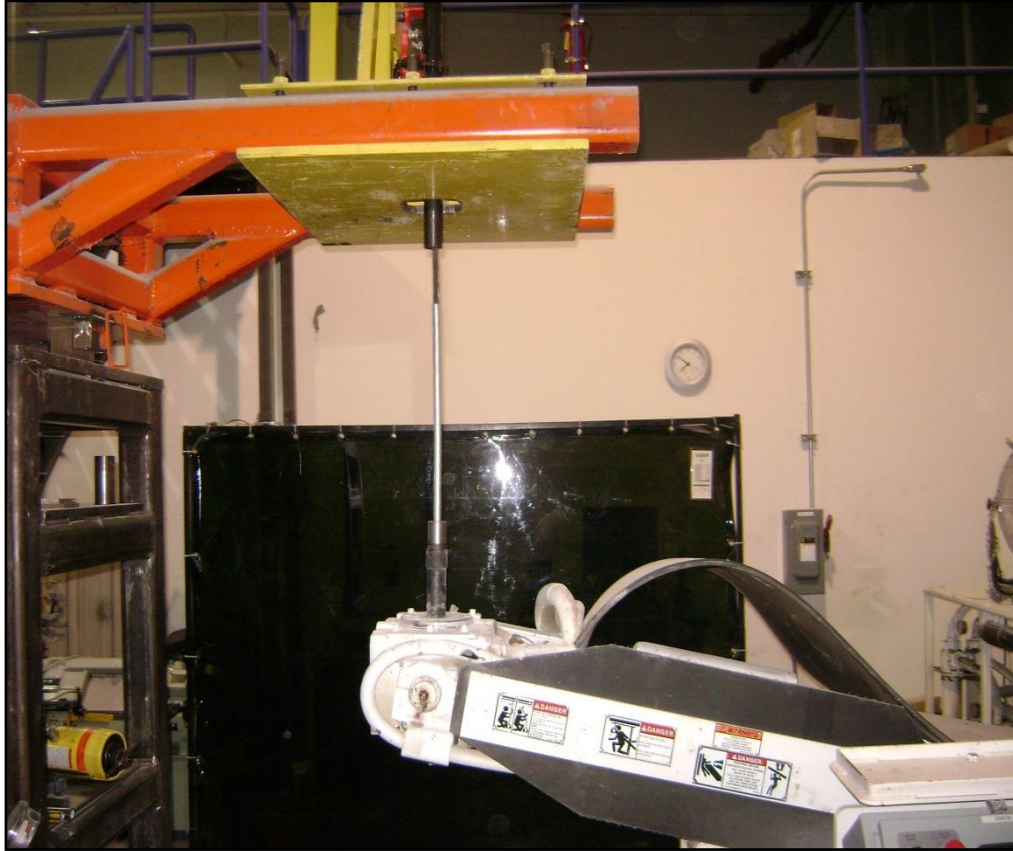
- 60 Second J-LOK Resin.
- 7 second spin @ 600 rpm.

Cable Preparation



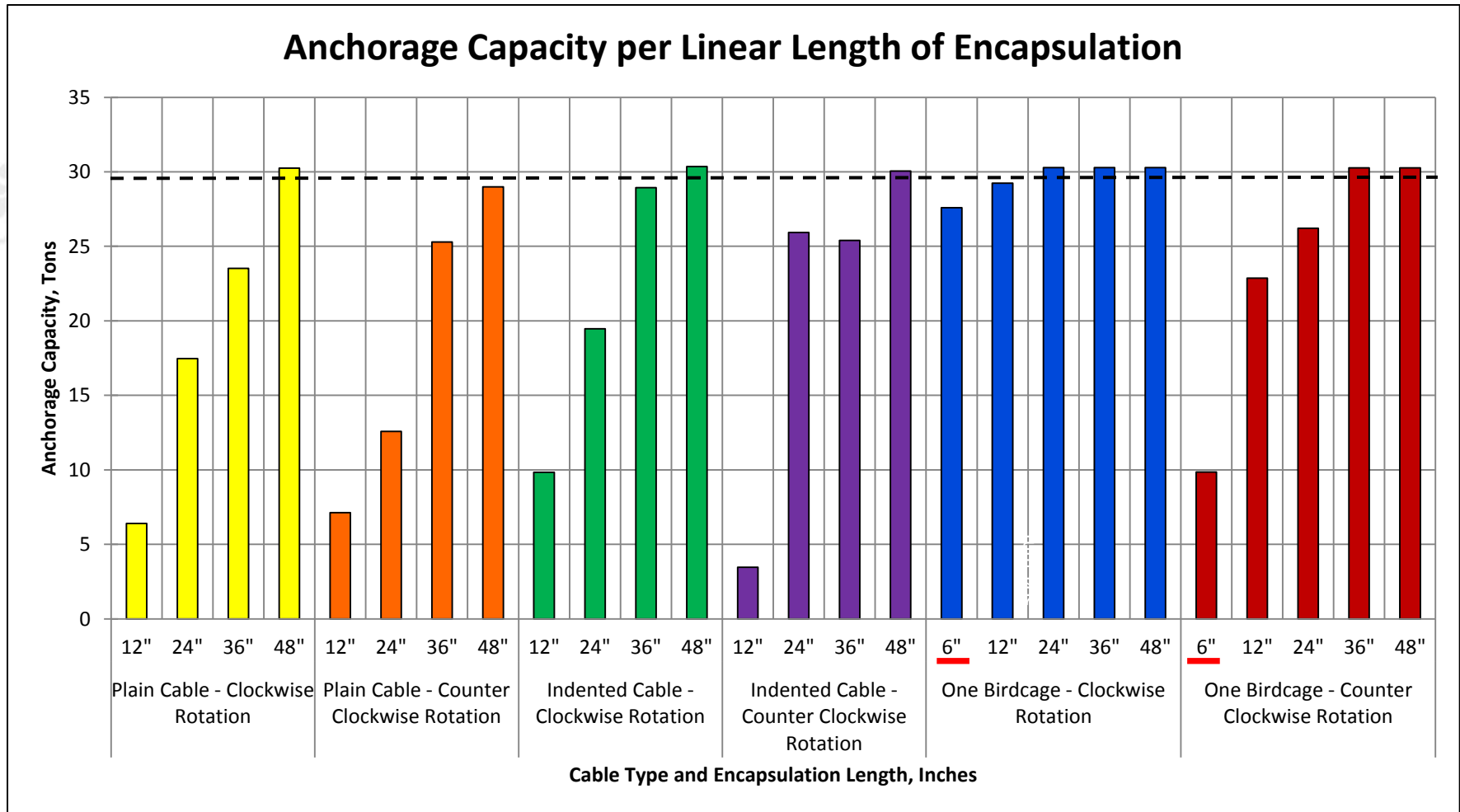
- Cable length – 36” + encapsulation length.
- Samples free of oil, dirt, & rust.
- Packer added to compress resin above encapsulation zone.

Installation with Test Lab Bolter

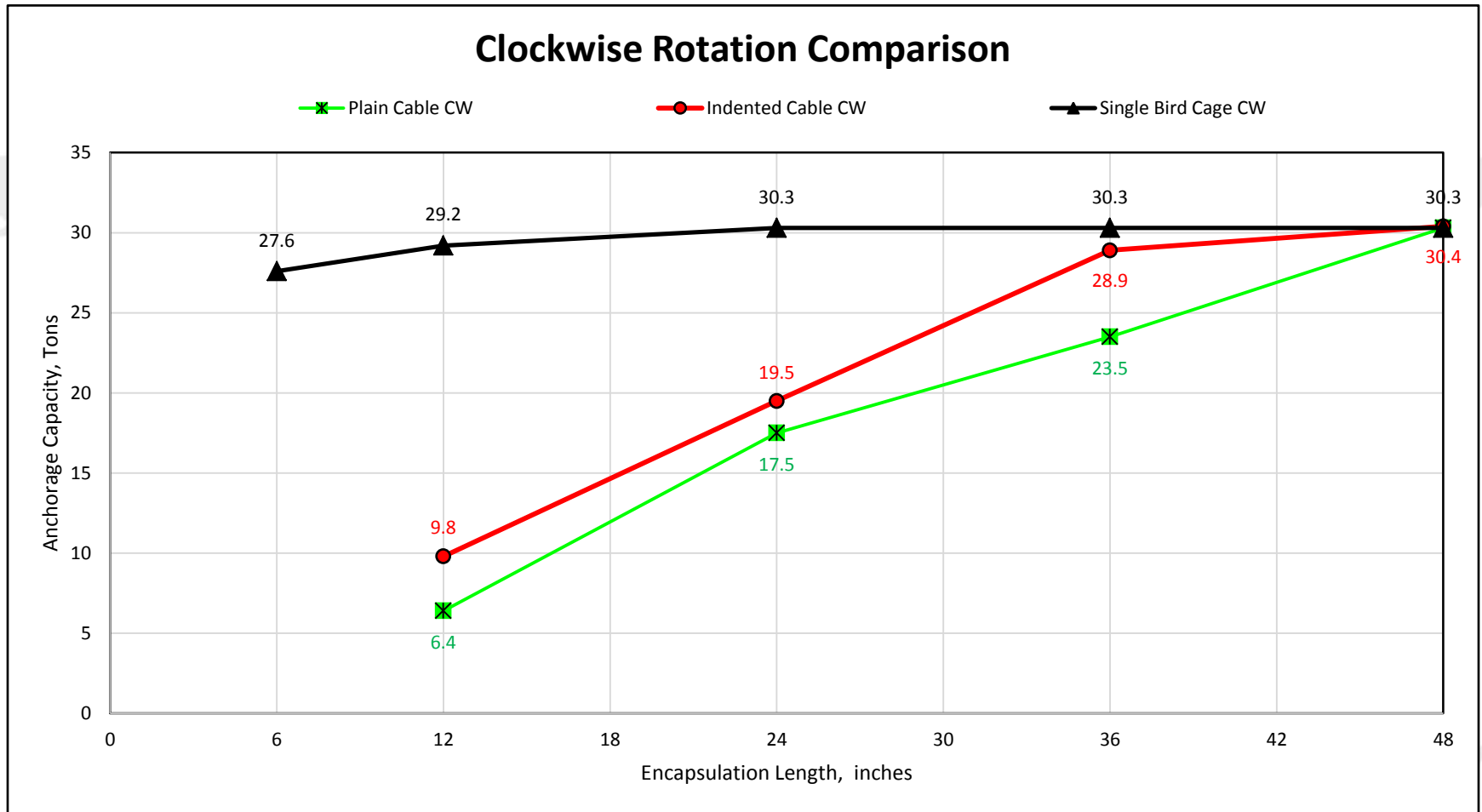


- J-LOK cartridge inserted in bore tube.
- Bolt inserted to back of borehole then spun.
- 2 minute hold time to limit variables.

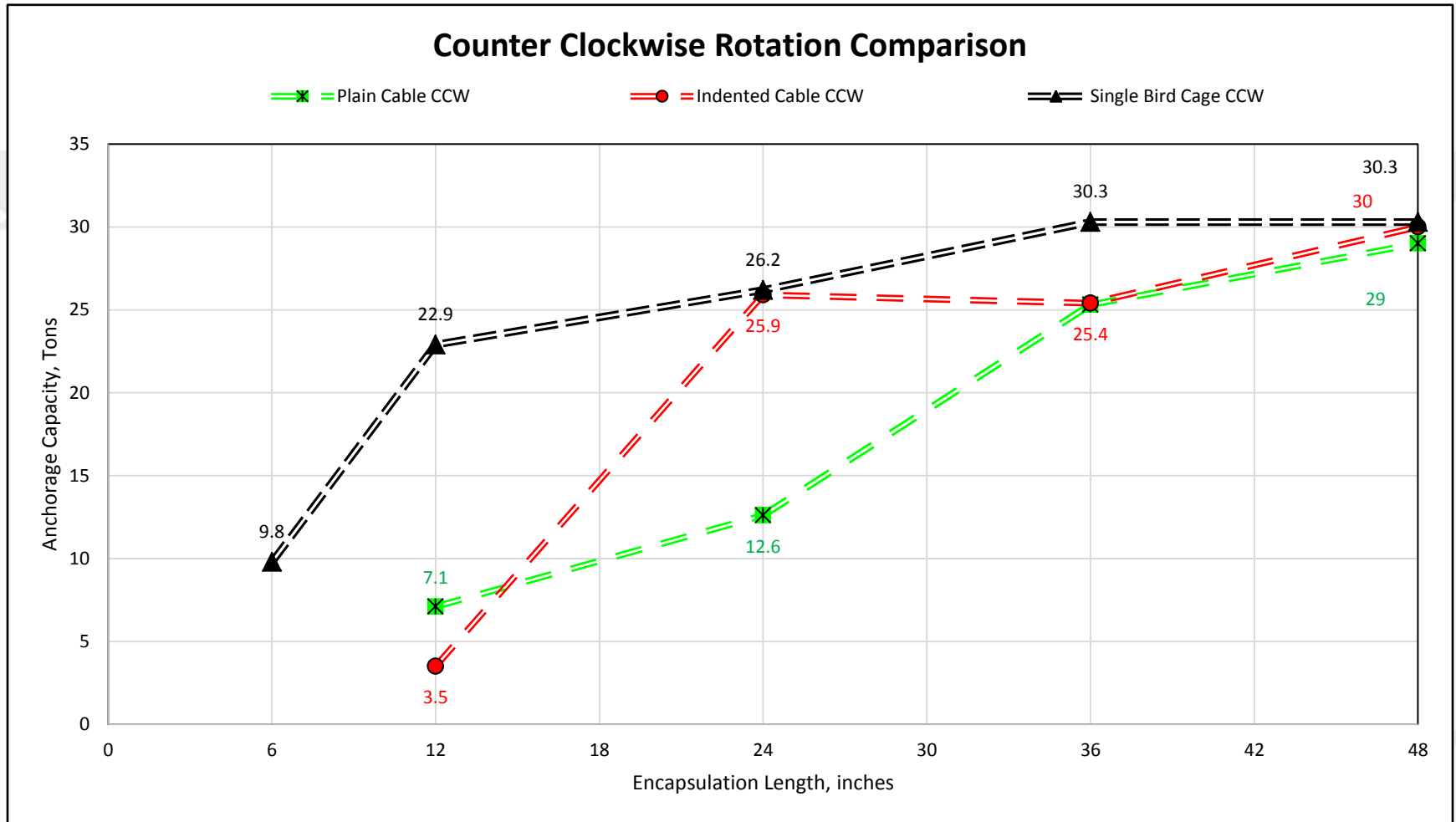
Anchorage Capacity per Linear Length of Encapsulation Results




Clockwise Rotation Comparison



Counter-Clockwise Rotation Comparison



Anchorage Capacity per Linear Length of Encapsulation

Sample Type	Rotation Direction	Encapsulation Length, in.	Average Peak Capacity, tons	Percentage of ASTM Minimum Break Strength ¹ , %
<u>Plain Cable</u>	<u>Clockwise</u>	12"	6.4	22%
		24"	17.5	60%
		36"	23.5	80%
		48"	30.3	103%
	Counter- Clockwise	12"	7.1	24%
		24"	12.6	43%
		36"	25.3	86%
		48"	29.0	99%
<u>Indented Cable</u>	<u>Clockwise</u>	12"	9.8	34%
		24"	19.5	66%
		36"	28.9	99%
		48"	30.4	104%
	Counter-Clockwise	12"	3.5	12%
		24"	25.9	89%
		36"	25.4	87%
		48"	30.0	103%
<u>One Birdcage</u>	<u>Clockwise</u>	6"	27.6	94% 
		12"	29.2	100%
		24"	30.3	103%
		36"	30.3	103%
		48"	30.3	103%
	Counter- Clockwise	6"	9.8	34%
		12"	22.9	78%
		24"	26.2	89%
		36"	30.3	103%
		48"	30.3	103%

¹ ASTM minimum break strength is 58,600 lbf for 0.6 in. (15 mm) cable as per ASTM F432-95.



Encapsulation Safety Factor

Encapsulation Safety Factor

- Applies a safety factor to the anchorage of each respective cable.

- $$SF_{re} = \frac{\text{Obtained Load}}{\text{Designed Load}} \quad (1)$$

- $$SF_{re} = \frac{(\text{Obtained Load} + ((c-p) * l))}{\text{Designed Load}} \quad (2)$$

(When $SF_{re} > 1$ before 48" of encapsulation.)

c - The encapsulation length of the sample.

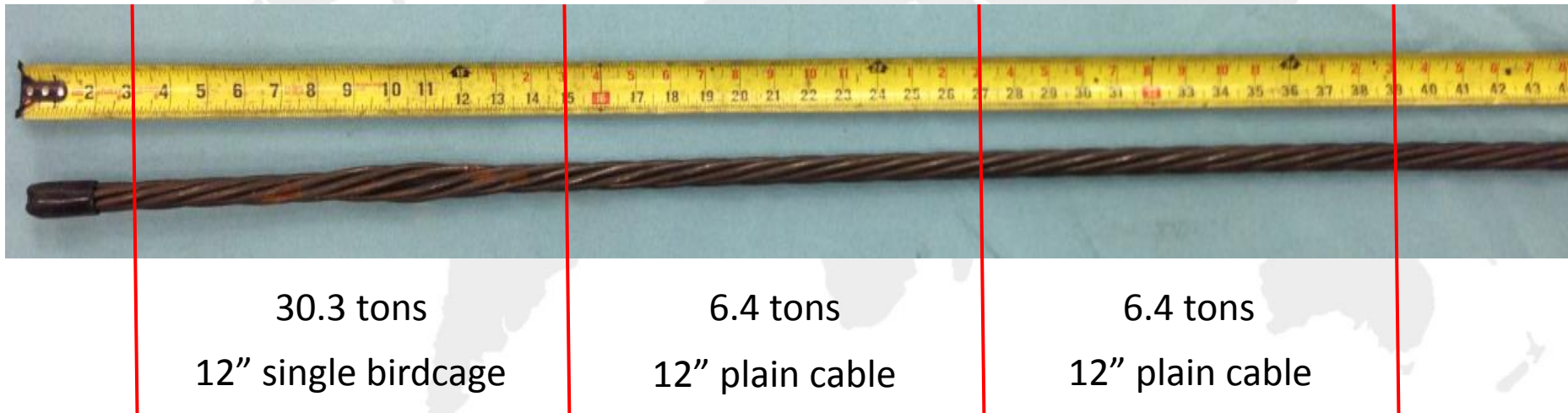
p - The encapsulation length when the SF_{re} is equal to one.

l - The load capacity per inch of encapsulation calculated from a 12" cable sample.

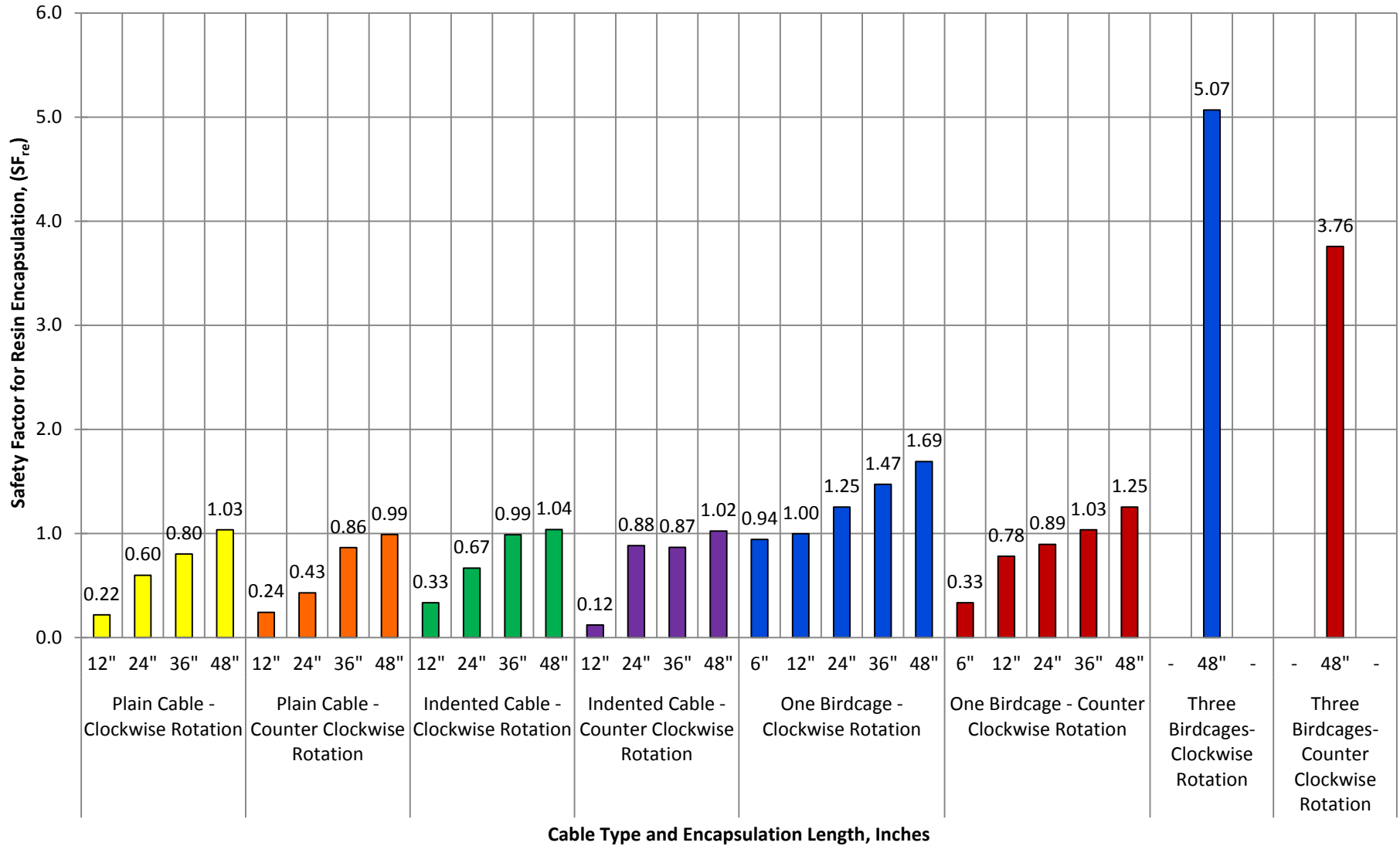
Resin Anchorage Safety Factor Calculation

- 36" single birdcage with clockwise rotation:

$$SF_{re} = \frac{43.1 \text{ tons}}{29.3 \text{ tons}} = 1.47$$



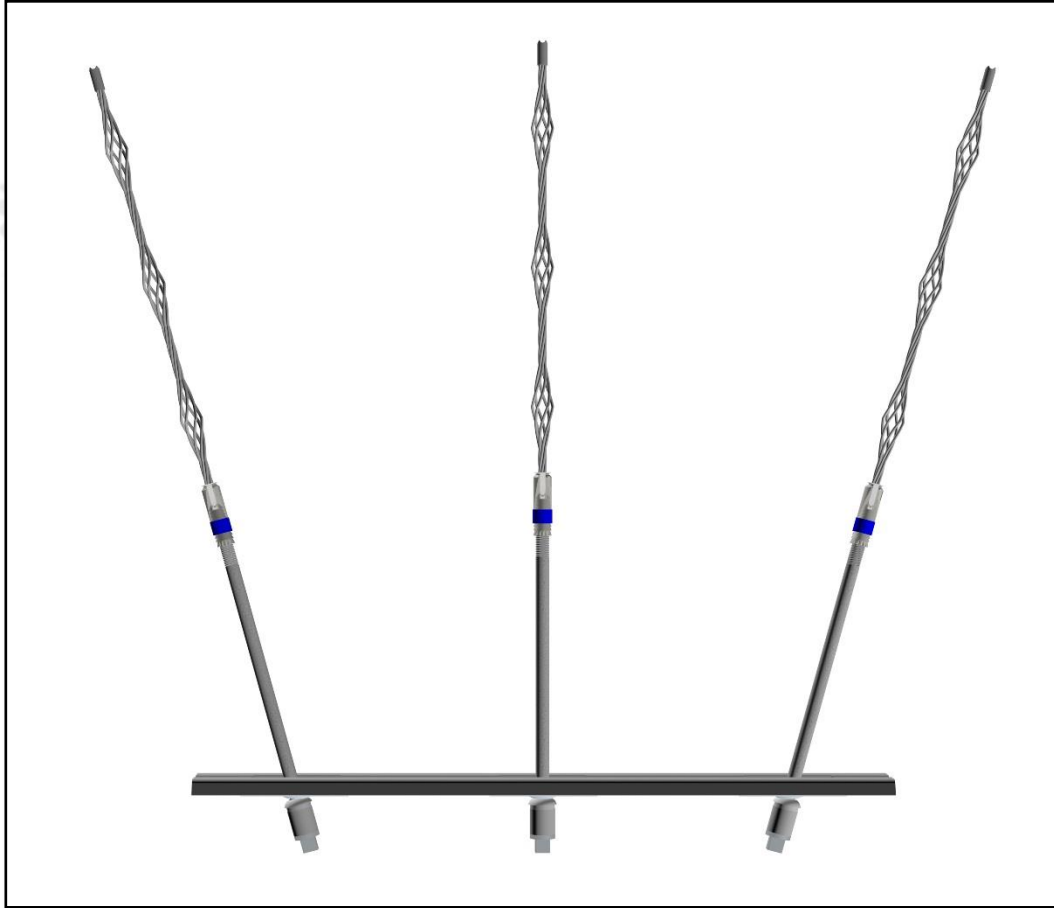
Safety Factor for Resin Encapsulation





Angle Bolt Capacity

Angle Bolt Capacity



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- To determine effects on the capacity of a cable bolt when installed on an angle.
- Plain and indented cable samples tested.

Angle Bolt Capacity Results



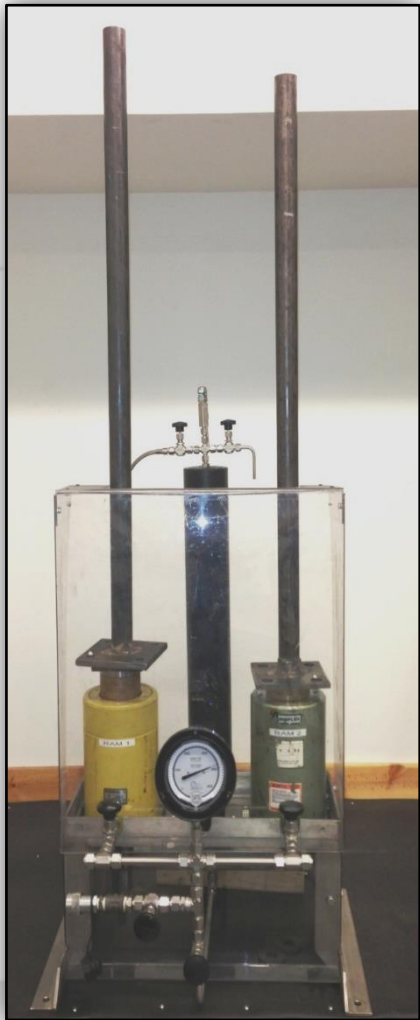
Angle Bolt Capacity Results			
Test Cable	Offset Angle, degrees	Average Peak Load, lbf	Percentage of ASTM Minimum Break Strength ²
Plain	45°	55,000	94%
	30°	60,500	103%
Indented	45°	45,500	78%
	30°	59,500	102%

²ASTM minimum break strength of 0.6 in. (15 mm) cable is 29.3 tons, per ASTM F432-95.



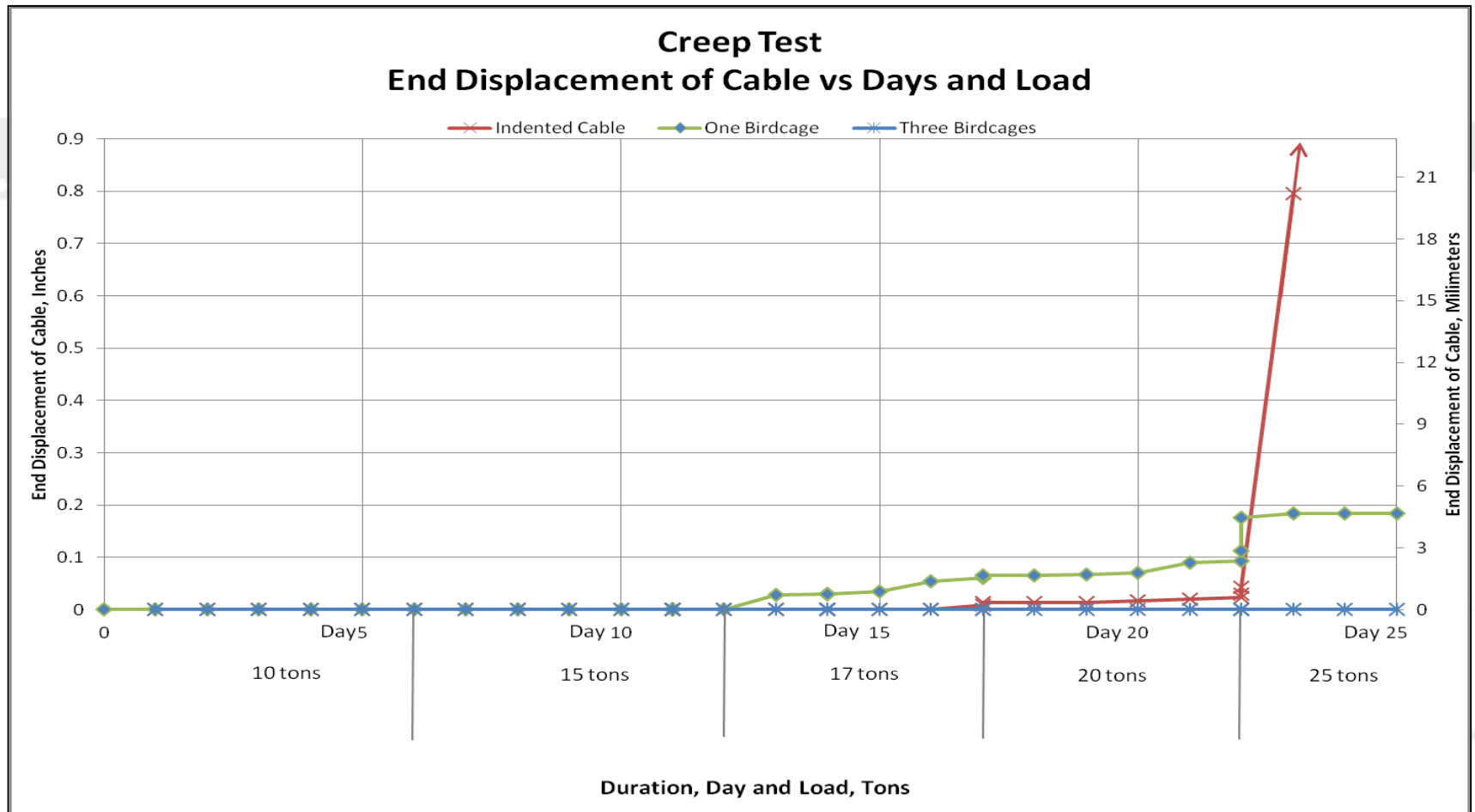
Effects of Long-Term Creep

Effects of Long-Term Creep



- Creep Tester-
 - Designed to maintain a constant load as a function of time.
 - Recorded end displacement over time and load.
- Test Samples-
 - Indented cable.
 - Plain cable with one bird cage.
 - Plain cable with three bird cages.

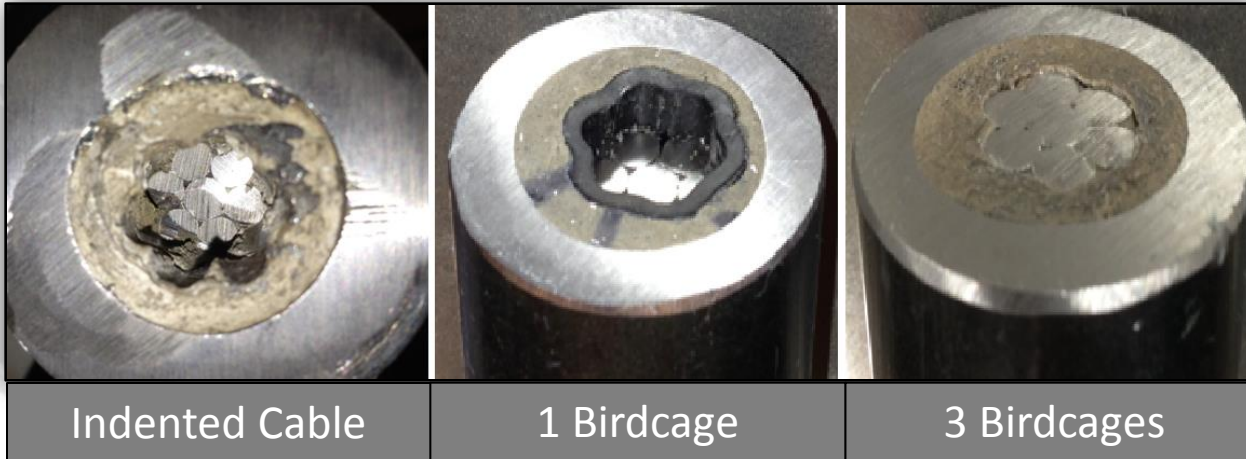
Long-Term Creep Test Results



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Effects of Long Term Creep



Sample	Indented Cable	One Birdcage	Three Birdcages
Total Movement	> 0.80"	0.19"	0.01"



Conclusions

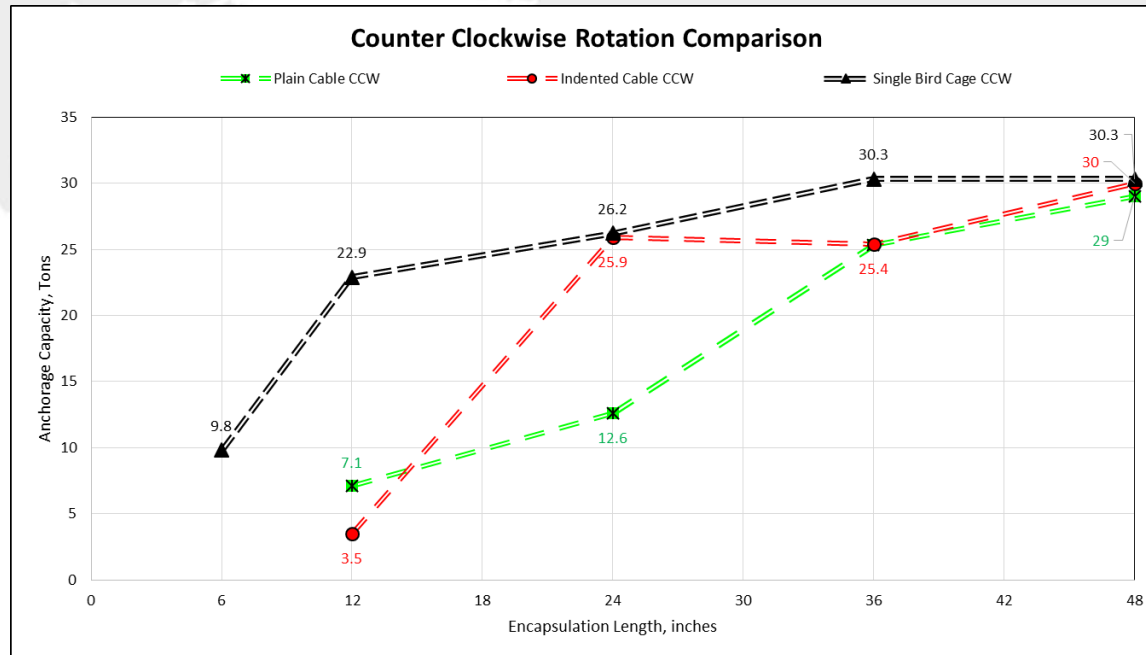
Conclusions

- Determined that cable bolts incorporated with birdcages are a tested & proven system.
 - i. As little as 6" of resin can break the cable.
 - ii. Indented and plain cable need 36" and 48" respectively.
 - iii. Bird cages help centralize the cable.



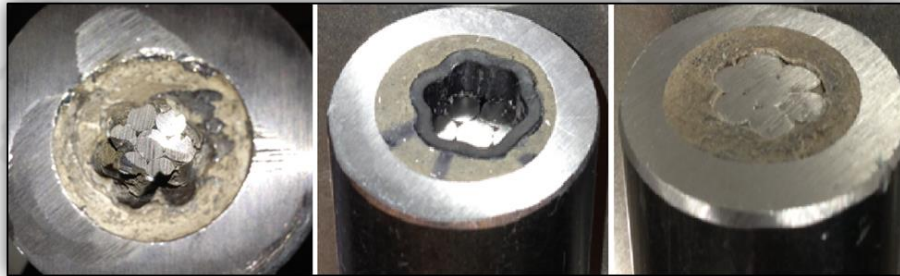
Conclusions

- Counter-clockwise rotation can provide inconsistent results in the cable anchorage capacity.



Conclusions

- There is a potential for creep on plain and indented cable samples when loaded over a long period of time.



Conclusions

- ASTM F432-10 currently requires short encapsulation tests for thread-deformed reinforcing bar.
- No such tests exist for cable bolts.
- **Highly** recommend the industry development of a specification for encapsulation tests of grouted cable bolts.

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