The Effect of Bending on the Tensile Strength of Statically Loaded Synthetic Ropes

*Mark Pederson, Greg Mozsgai and Danielle Stenvers

Introduction

- General overview of tensile strength reductions of terminated ropes when bending is involved

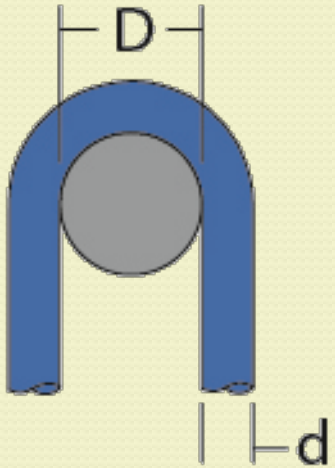
- Static cases examined only
  - No shock, fatigue, creep, etc

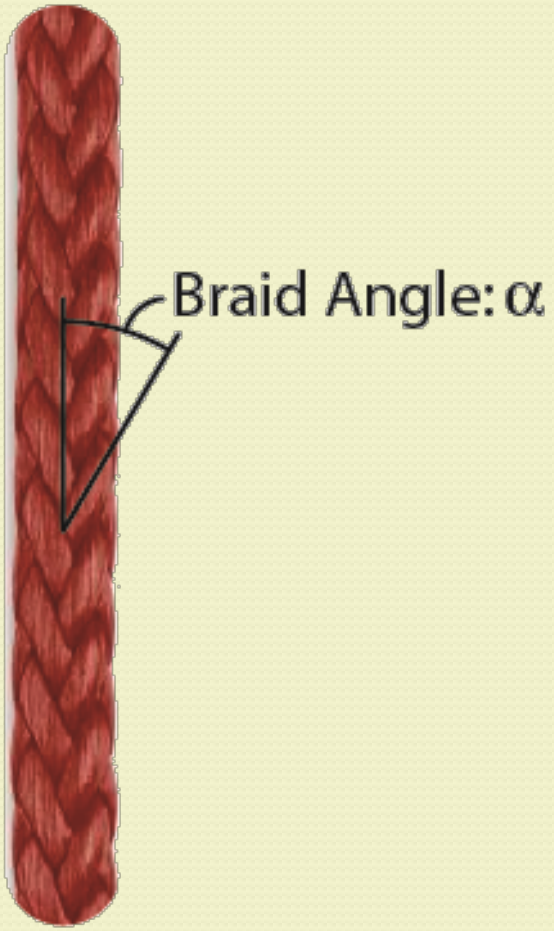
Overview

- Definitions
- Mechanisms
- Rope Connections
  - Single Leg
  - Grommet
  - Cow hitch
  - Eye-to-Eye
- Lifting
- Knots and other hitches
- Conclusions

Definitions

- Diameter
- Minimum Break Strength
- Braid/twist angle
- D/d ratio
- Splices





Mechanisms of Strength Loss

- Unequal loading of strands resulting in tensile failure
- Exacerbated by:
  - High modulus fiber
  - Low twist
  - Looser braid
  - Low D/d

Mechanisms of Strength Loss

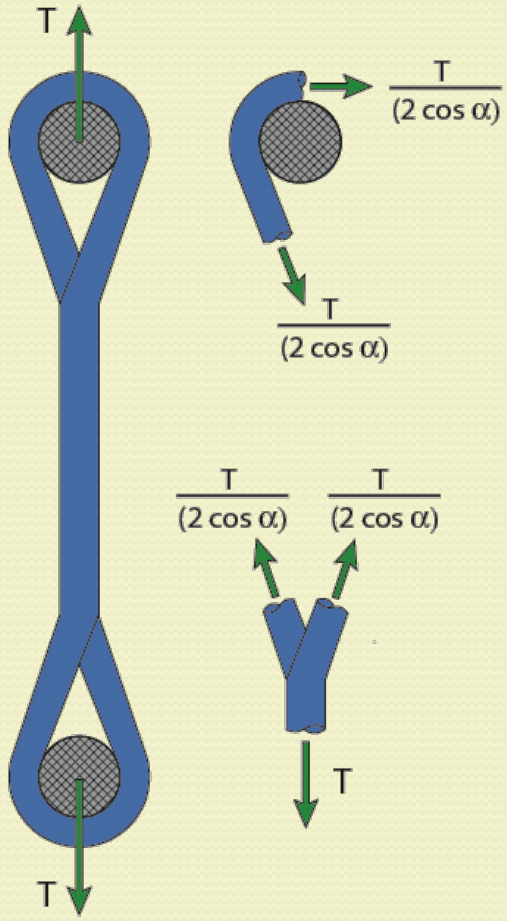
- **“Cutting” or “Pinching” of strands from high contact and strand-on strand pressure**
  - **Fewer strands**
  - **Larger strands**
  - **Tighter braid**

Overview

- Definitions
- Mechanisms
- **Rope Connections**
  - **Single Leg**
  - **Grommet**
  - **Cow hitch**
  - **Eye-to-Eye**
- Lifting
- Knots and other hitches
- Conclusions

Single Leg

- Single leg slings are used to baseline most rope strengths
- Theoretical load distributions
- There is a true loss in bend around pin but each leg around pin only carries ~½ T



Single Leg

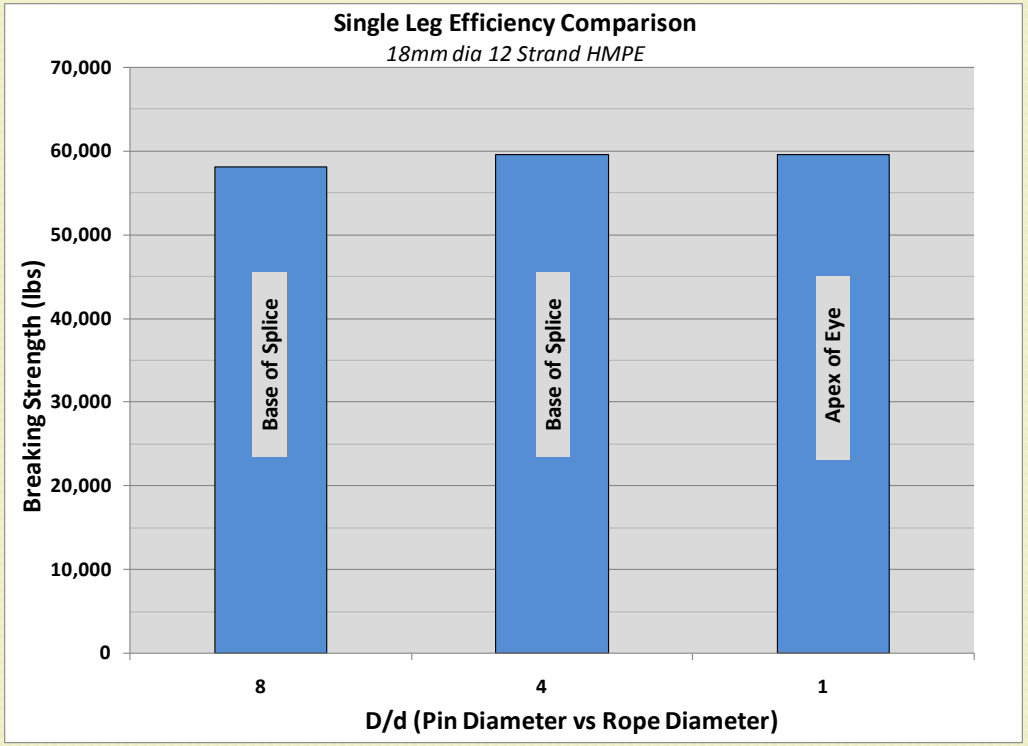
- Failure types
  - Base of splice
    - Closest to a true rope strength
  - Crotch splice
    - Tearing open
  - Back of pin
    - Failure due to tight bend

Single Leg

- **Current practice-minimum testing requirements:**
  - **D/d:**
    - **Cordage Institute (CI 1500)** **2**
    - **ASTM (D4268)** **1.5**
    - **ISO (2307:2010)** **2**
  - **Eye Length:**
    - **Cordage Institute (CI 1500)** **N/A**
    - **ASTM (D4268)** **2x Pin Dia.**
    - **ISO (2307:2010)** **3x Pin Dia.**

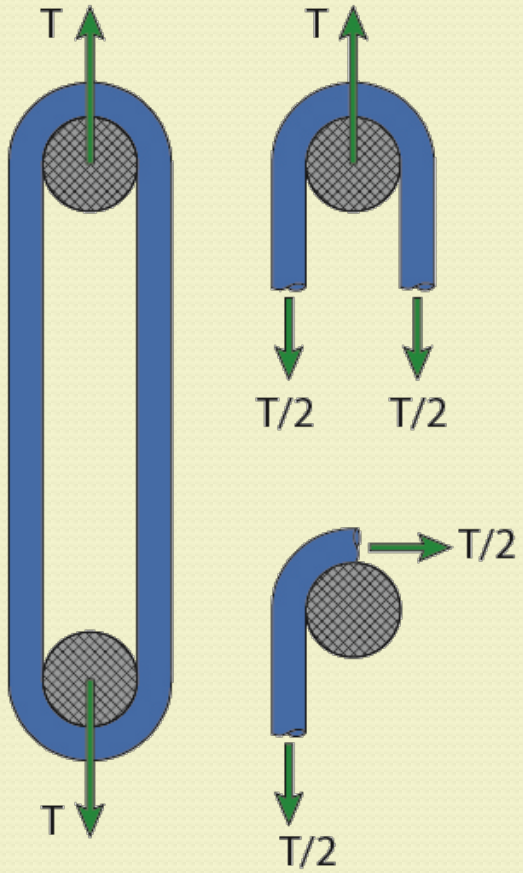
Single Leg

- **Recommendations:**
  - **Min D/d = 2**
- **D/d = 1 did not show significant strength loss, however break occurred at the back of the eye (on the pin)**



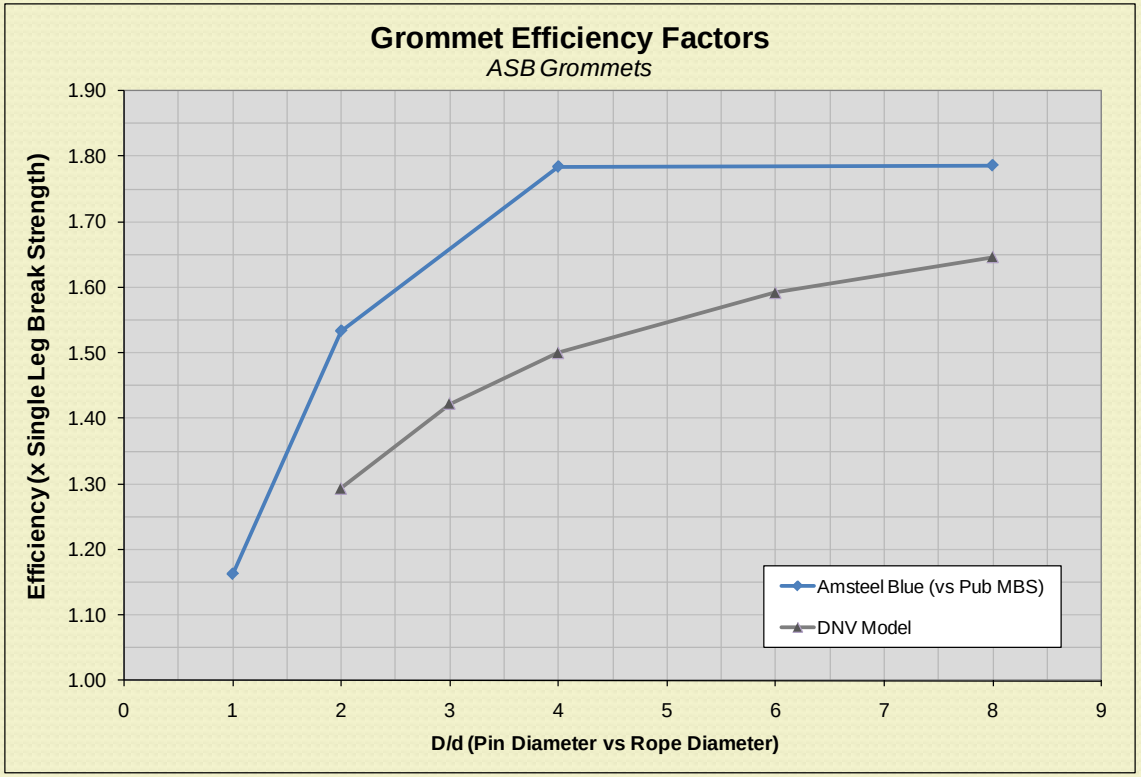
Grommet

- Grommet configuration highlights bending losses
- Grommet strength is actually <2x rope strength
- Current industry recommendations range from 1.6-1.8x rope strength



Grommet

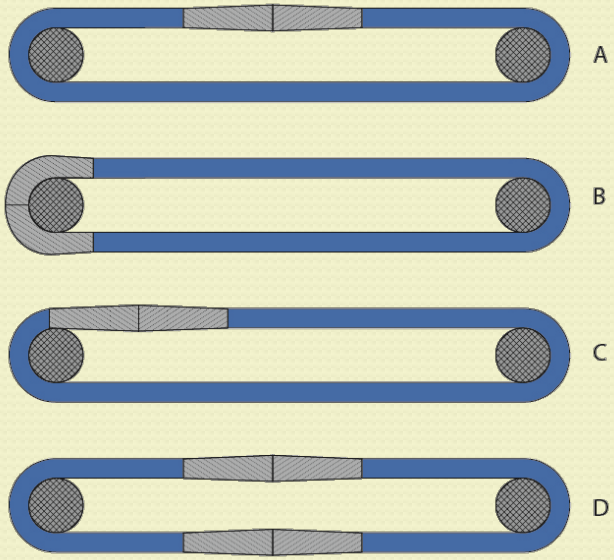
- D/d → Grommet Strength
  - 1/1 1.15
  - 4/1 1.78
- Trendline is similar for both 12strand HMPE and PET



Grommet: Other Considerations

- Splice Placement:
  - Splice area centered on the pin allows the legs to more evenly adjust upon loading.
  - Two splices do not produce a more efficient sling.

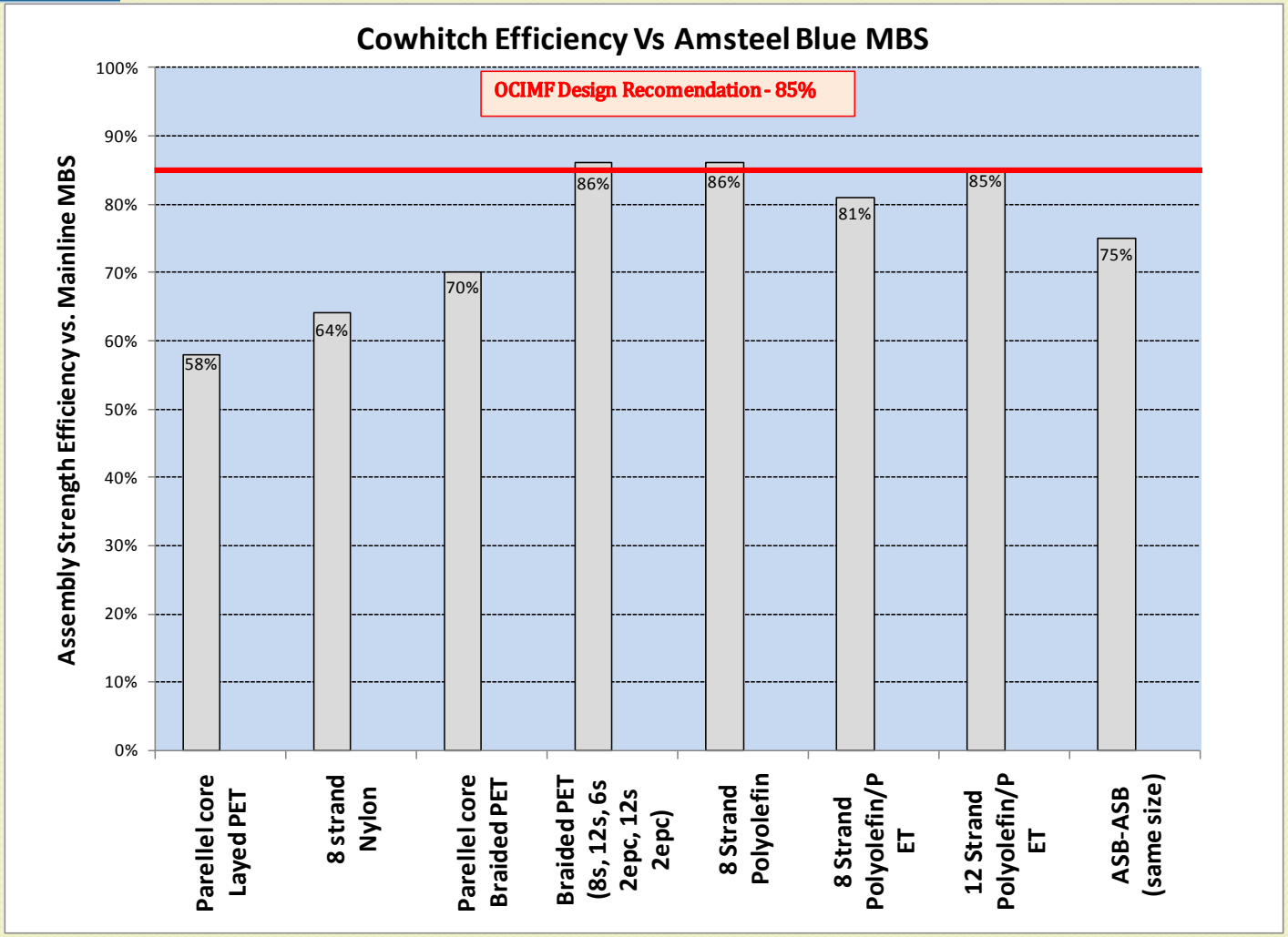
- A 1.6-1.8x
- B 1.7-1.9x
- C 1.7x
- D 1.75x



Cow Hitch

- Common configuration with mooring lines and pendants
- OCIMF guideline of 85% efficiency based on
  - same-size ropes
  - Lower modulus materials (nylon, polyester)
- Strength efficiency considerations:
  - Materials
  - Construction
  - Rope sizes

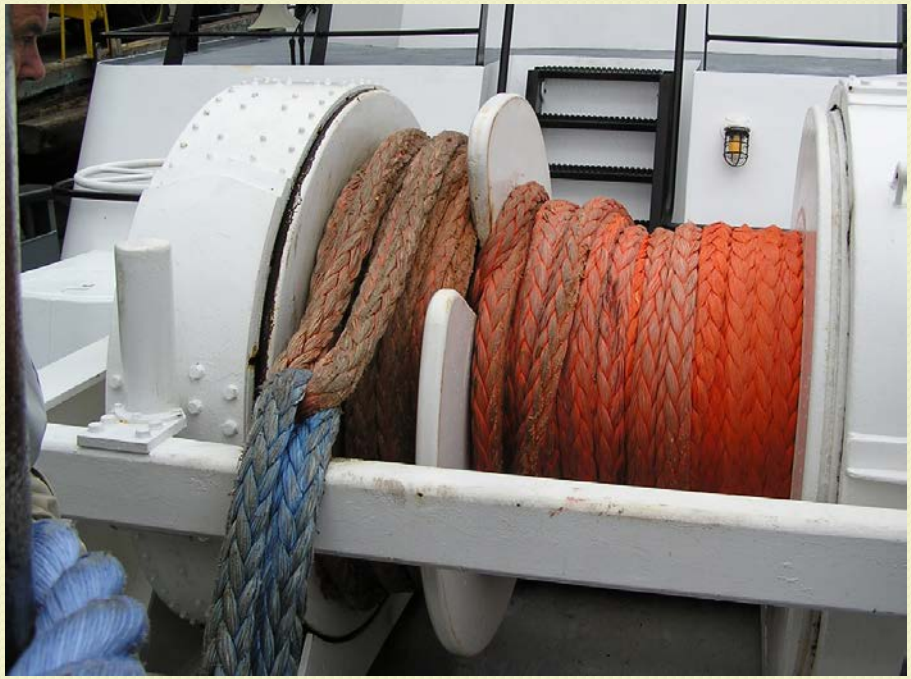
Cow Hitch


Cowhitch Efficiency Vs Amsteel Blue MBS
OCIMF Design Recomendation - 85%
Assembly Strength Efficiency vs. Mainline MBS
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
58%
64%
70%
86%
86%
81%
85%
75%
Parellel core Layed PET
8 strand Nylon
Parellel core Braided PET
Braided PET (8s, 12s, 6s 2epc, 12s 2epc)
8 Strand Polyolefin
8 Strand Polyolefin/PET
12 Strand Polyolefin/PET
ASB-ASB (same size)

Eye-to-Eye

- Common configuration for tug and mooring line connections (mainline to pendant , HMPE to HMPE)
- Connection efficiency per rope size ratio:
  - 1 : 1 90%
  - 1.6 : 1 100%*

*(based on the smaller rope's strength)

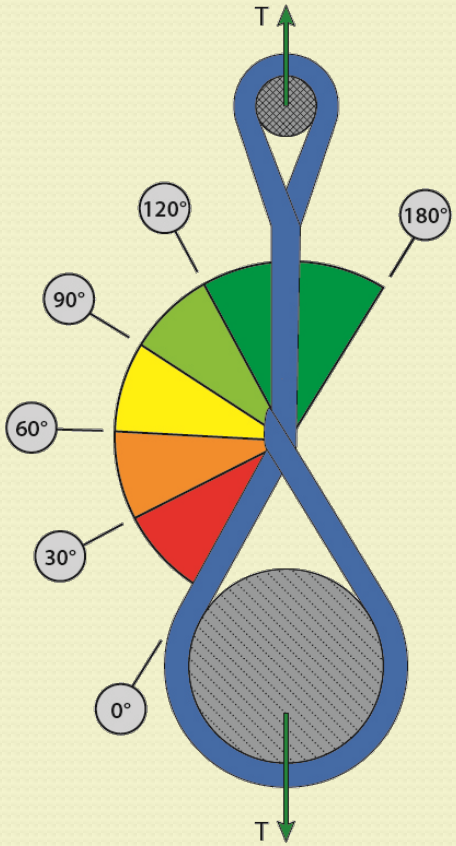


Overview

- Definitions
- Mechanisms
- Rope Connections
  - Single Leg
  - Grommet
  - Cow hitch
  - Eye-to-Eye
- **Lifting**
- Knots and other hitches
- Conclusions

Choker Hitch

- **Current recommendations:**
  - **ASME B30.9 80% (PET roundslings)**
  - **Flory/Richards* 60% (HMPE slings)**
- **Test Results*:**
  - **12-strand, HMPE fiber**
  - **Ranged from 60% - 75%**
    (varied by manufacturer)
- **Choke Angle is critical**
  - **Chocker strength**



* Flory/Richards choker testing presented at the Cordage Inst. meeting May 2010

Overview

- Definitions
- Mechanisms
- Rope Connections
  - Single Leg
  - Grommet
  - Cow hitch
  - Eye-to-Eye
- Lifting
- **Knots and other hitches**
- Conclusions

Other Knots, Bends & Hitches

- Knots involve tight bends on itself, lowering the rope strength
- Traditional rule of thumb has been 50%
- Factors affecting strength:
  - Fiber
  - Construction
  - Type of knot

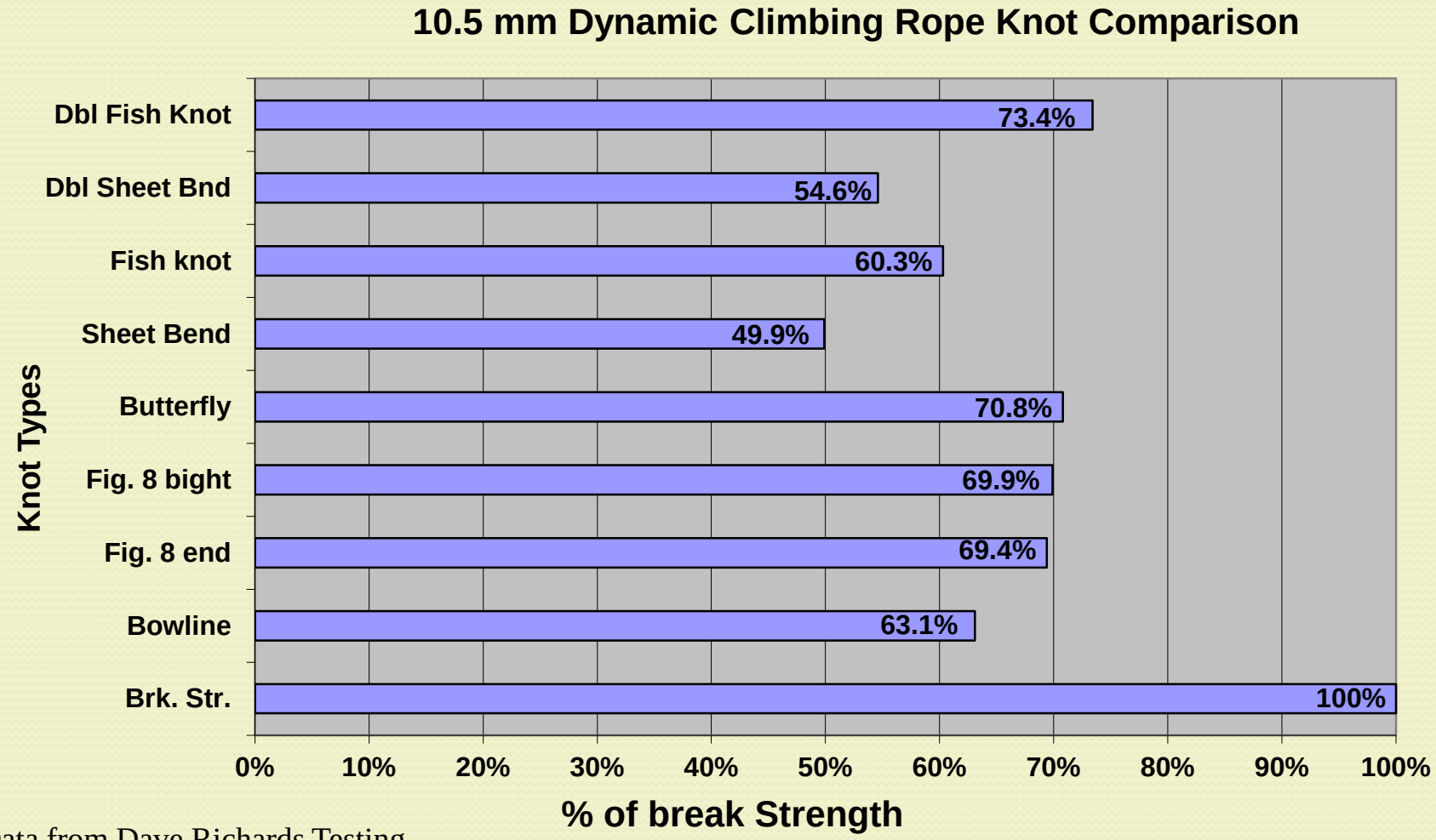
Other Knots, Bends & Hitches

Fiber	Construction	Knot/Hitch	Retained Strength
HMPE	12-strand	Bowline	35%
Technora	12-strand	Bowline	25%
Nylon	Jacketed	Bowline	57%
Nylon	3-strand	Bowline	55%
Nylon/Polyester	Kernmantle	Bowline	63-67%
Polypropylene	3-strand	Bowline	53-60%
Polyester	Jacketed	Square-knot	45-65%

Low modulus fibers: 50% guideline OK

High modulus fibers: Knots are not recommended

Other Knots, Bends & Hitches



*Data from Dave Richards Testing

Overview

- Definitions
- Mechanisms
- Rope Connections
  - Single Leg
  - Grommet
  - Cow hitch
  - Eye-to-Eye
- Lifting
- Knots and other hitches
- **Conclusions**

Conclusions

- Termination ordinarily is the weakest part of the rope
  - Rope should be designed into a system taking into account strength loss due to bending
- Strength losses associated with bending vary with:
  - Configuration (grommet, knot, hitch, etc)
  - Eye size
  - Pin size
  - Fiber Type

Acknowledgments

- Thanks to:
  - John Flory – Tension Technology International
  - Dave Richards – Holloway Houston Inc
  - Kris Volpenhein – Samson
  - Frank Choltco-Devlin – Samson

Questions?