

### **Study Paper: Failure Modes Of Snow Anchors - Fortini 2001**

1. Failure of carabiner hole in a picket using a carabiner in the hole: 2,033 +/- 333 lbf
2. 2' T-stock, packed snow, vertical orientation, WA state: 1,300 – 1,490 lbf
3. 2' T-stock, packed snow, vertical orientation, UT and CA state: 125 – 270 lbf
4. 2' T-stock, packed snow, horizontal orientation, WA state: 3,315 – 4,000 lbf
5. 2' T-stock, packed snow, horizontal orientation, UT and CA state: 250 lbf
6. Average strengths, packed snow, vertical picket: 186 +/- 48 (n=7)
7. Average strengths, packed snow, horizontal picket: 248 (n=1)

### **Study Paper: On The Use Of Pickets And Flukes As Snow Anchors - Fortini 2002**

1. Mid-clip vertical picket 23% stronger than horizontal picket (n=4 + 3)
2. Failure of carabiner hole in a 2' picket with edge reinforcement: 2,115 lbf
3. Failure of carabiner hole in a 3' picket with no edge reinforcement: 1,060 +/- 42 lbf
4. Average strengths, 2' picket, high density snow, WA state, horizontal mid-clip: 1,755
5. Average strengths, 2' picket, high density snow, WA state, vertical mid-clip: 2,210
6. Two vertical mid-clip pickets, side by side, horizontal separation of 3.5 feet: knot failed at 3,300 lbf
7. 2' picket, high density snow, WA state, 12 - 16" deep, horizontal mid-clip: 1,755 +/- 416 lbf (1,300-1,850)
8. 2' picket, high density snow, WA state, vertical mid-clip: 2,210 +/- 400 lbf (1,730-2,670)
9. **Recommendation** - Mid-clip horizontal picket: bury as deep as possible, wide trench that is backfilled
10. **Recommendation** - Mid-clip vertical picket: bury as deep as possible, sling trench must be as packed as surrounding snow
11. **Recommendation** - Highest strength vertical multi-picket anchor (3 pickets): bury first 2 pickets 2/3 to 3/4 length and last picket full length, tie top of first picket to snow level of second picket, then top of second picket to snow level of third picket.
12. **Recommendation** - Two vertical mid-clip pickets, side by side: separate horizontally 3 times picket depth

### **Study Paper: Predicting Failure Modes Of Snow Anchors - Fortini 2005**

1. Top-clip vertical picket, snow failure range: 75 - 475 lb (n=15)
2. Top-clip vertical picket, picket failure: 750 - 1,500lb (n=2)
3. Mid-clip horizontal picket, biner 12" deep, snow failure: 200 - 1,300 lb (n=6)
4. Mid-clip horizontal picket, biner 12" deep, picket failure: 1,750 - 2,200 lb (n=2)
5. Mid-clip horizontal picket, biner 12" deep, no failure: 1,800 - 4,000 lb (n=4)
6. Mid-clip vertical picket, biner 12" deep, snow failure: 100 - 1,750 lb (n=3)
7. Mid-clip vertical picket, biner 12" deep, picket failure: 1,100 - 3,000 lb (n=5)
8. Mid-clip vertical picket, biner 12" deep, no failure: 1,500 - 2,700 lb (n=4)
9. **Recommendation** - If you can make a snowball, compacting snow will strengthen the snow
10. **Recommendation** - If you can not make a snowball, compacting snow will weaken the snow
11. **Recommendation** - Mid-clip vertical picket: do not use if snow is fluffy or can't make a snowball
12. **Recommendation** - Never assume a top-clip vertical picket will hold more than 500 pounds
13. **Recommendation** - Never assume a mid-clip vertical picket will hold more than 1,500 pounds
14. **Recommendation** - Never assume a top-clip horizontal picket will hold more than 1,500 pounds

### **Study Paper: Failure Modes Of Snow Anchors During Drop Testing - Fortini 2008**

1. Mid-clip vertical picket, picket failure: 2,100 lb (n=1)
2. Mid-clip vertical picket, snow failure: 1,870 lb (n=1)
3. Drop conditions: 31 degree slope, hard packed snow, 215 pound test mass, 26 feet of rope, fall factor of 1
4. Mid-clip horizontal 2' picket, biner 18" deep: drop #1 passed at 640 lb force; drop #2 snow failure; drop #3 carabiner failure at 920 lb force
5. Mid-clip horizontal 3' picket, biner 12" deep: drop #1 picket eye hole failure at 960 lb force, similar slow pull failure normally in the 1,500 to 2,000 pound range
6. Mid-clip vertical Yates picket with cable, biner 12" deep: drop #1 passed at 1,300 lb force; drop #2 snow failure at 1,260 lb force
7. **Recommendation** - Weak fluffy snow (can't make a snowball): Do not use a mid-clip vertical picket; do not disturb the snow in front of the anchor; use a narrow trench for the leash
8. **Recommendation** - Strong wet snow (can make a snowball): compress the snow in front of the anchor; the back filled trench for the leash on a mid-clip vertical picket must be as strong as the surrounding snow
9. **Recommendation** - Drop test strengths about 1/3 to 1/2 of the strength of comparable slow pull results

### **Study Paper: Snow Anchor Testing - Heilman 2009**

1. Snow conditions in the morning were somewhat weak and dry snow that could not be work hardened much
2. Snow conditions in the afternoon was stronger and wetter snow that could be work hardened
3. Top-clip vertical 3' picket, snow not hardened: snow failure at 110 lbf
4. Top-clip vertical Yates picket, snow not hardened: snow failure at 0 lbf
5. Top-clip vertical 2' picket, snow not hardened: snow failure at 0 lbf
6. Top-clip vertical 3' picket, snow moderately hardened: snow failure at 455 lbf
7. Top-clip vertical Yates picket, snow moderately hardened: snow failure at 270 lbf
8. Two top-clip equalized vertical 3' pickets, snow moderately hardened: snow failure at 450 lbf
9. Mid-clip horizontal 2' picket, biner 26" deep, snow hardened, no failure at 1,700 lbf
10. Mid-clip horizontal 3' picket, biner 22" deep, snow hardened, picket web failure at 1,375 lbf
11. Mid-clip horizontal Yates picket, biner 14" deep, snow hardened, snow failure at 755 lbf
12. Mid-clip horizontal 3' picket, biner 14" deep, snow hardened, picket web failure at 850 lbf
13. Mid-clip horizontal 2' picket, biner 14" deep, snow hardened, snow failure at 1,500 lbf
14. Tandem-clip horizontal 3' picket, biner 14" deep, snow hardened, no failure at 1,825 lbf
15. Mid-clip horizontal Yates picket, biner 14" deep, snow hardened, no failure at 850 lbf, picket moved 4 feet
16. Mid-clip horizontal Yates picket, biner 14" deep, snow hardened, picket eye failure at 1,500 lbf