Appendix G

ACTIVE STABILIZATION DESIGN

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Client	RMR Aggregates, Inc.	Date 8/10/2023	
Project	Mid Continent Mine	Designed By	KRF
Subject	Active Slope Stabilization	Checked By	AC

Technical Summary

Scope

Preliminary design of active stabilization of the west face of the Mid Continent Mine utilizing tensioned tiebacks. Anchored slope design was performed for upper limestone thicknesses of 5 feet.

Design References

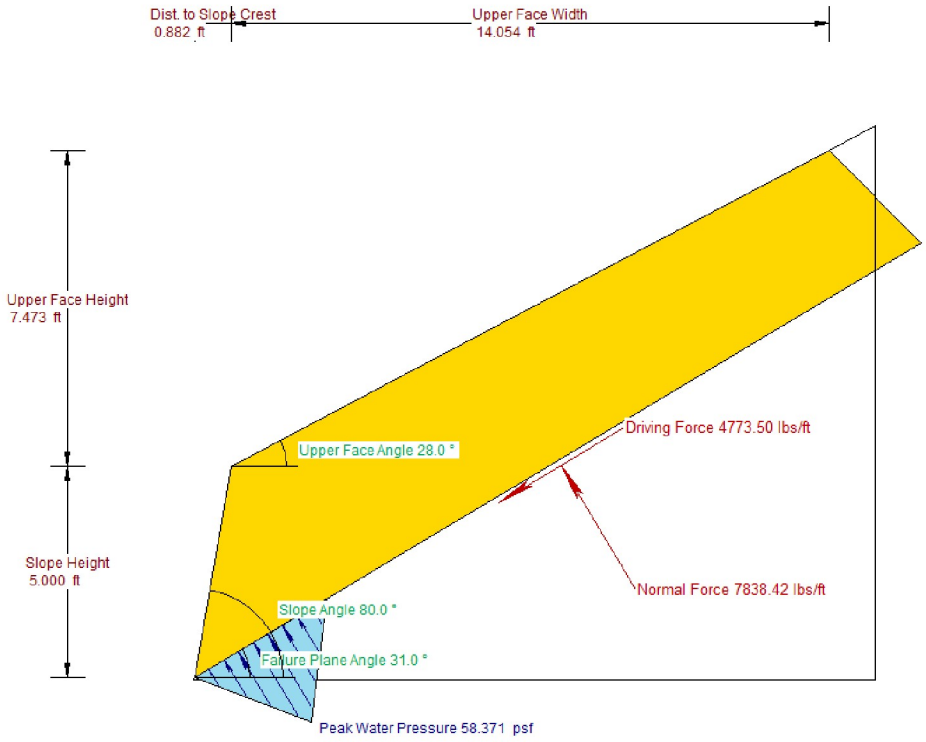
- Rock Slope Engineering 4th edition, Wyllie and Mah, 2005
- PTI DC35.1-14, Recommendations for prestressed rock and soil anchors, 2014.

Design Assumptions

1. Rock parameters were assumed from a back analysis of the west wall ground disturbance performed in RocPlane.
2. Existing west face slope angles were determined from a slope angle heat map from onXmaps.

Slope Stability support

RocPlane model for the existing face:



Calculated driving force, RocPlane: $F_{dr.exis} := 4773.5 \cdot plf$

Calculated existing normal force, RocPlane: $F_{norm.exis} := 7838.42 \cdot plf$

Calculated existing water force, RocPlane: $F_{water} := 106.02 \cdot plf$

Upper face angle, KUE: $\sigma_{up} := 28 \cdot deg$

Failure plane angle, KUE: $\sigma_{fp} := 31 \cdot deg$

Total height, RocPlane: $H := 28 \cdot ft$

Upper face width, RocPlane: $w_{up} := 33.88 \cdot ft$

tension crack length, RocPlane: $t_{cr} := 2.18 \cdot ft$

Joint cohesion, KUE: $c := 50 \cdot psf$

Joint friction angle, KUE: $\phi_{jt} := 25 \cdot deg$

Anchor inclination: $\phi_{st} := 45 \cdot deg$

Upper face length: $L_{up} := \frac{w_{up}}{\cos(\sigma_{up})} = 38.37\,ft$

Required tieback load: $T_{max} := 1 \cdot klf$ Iterative to achieve FS

per slope length

Area of sliding plane per linear foot: $A := \frac{(H - t_{cr})}{\sin(\sigma_{fp})} = 50.13\,ft$

Total resisting force, Wyllie & Mah:

$$F_{res} := c \cdot A + \left[T_{max} \cdot \sin\left(\left(\sigma_{fp} + \phi_{st}\right)\right) + F_{norm.exis} - F_{water}\right] \cdot \tan\left(\phi_{jt}\right) = 6.56 \cdot klf$$

Total driving force, Wyllie & Mah: $F_{driving} := F_{dr.exis} - T_{max} \cdot \cos\left(\sigma_{fp} + \phi_{st}\right) = 4.53 \cdot klf$

Factor of safety: $FS := \frac{F_{res}}{F_{driving}} = 1.45$

Pattern vertical spacing: $V_{sp} := 10 \cdot ft$

Pattern Horizontal spacing: $H_{sp} := 30 \cdot ft$

Required resisting force per anchor column: $T_{req} := T_{max} \cdot H_{sp} = 30 \cdot kip$

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Project	Mid Continent Mine	Designed By	KRF
Subject	Active Slope Stabilization	Checked By	AC

Technical Summary

Scope

Preliminary design of active stabilization of the west face of the Mid Continent Mine utilizing tensioned tiebacks. Anchored slope design was performed for upper limestone thicknesses of 10 feet.

Design References

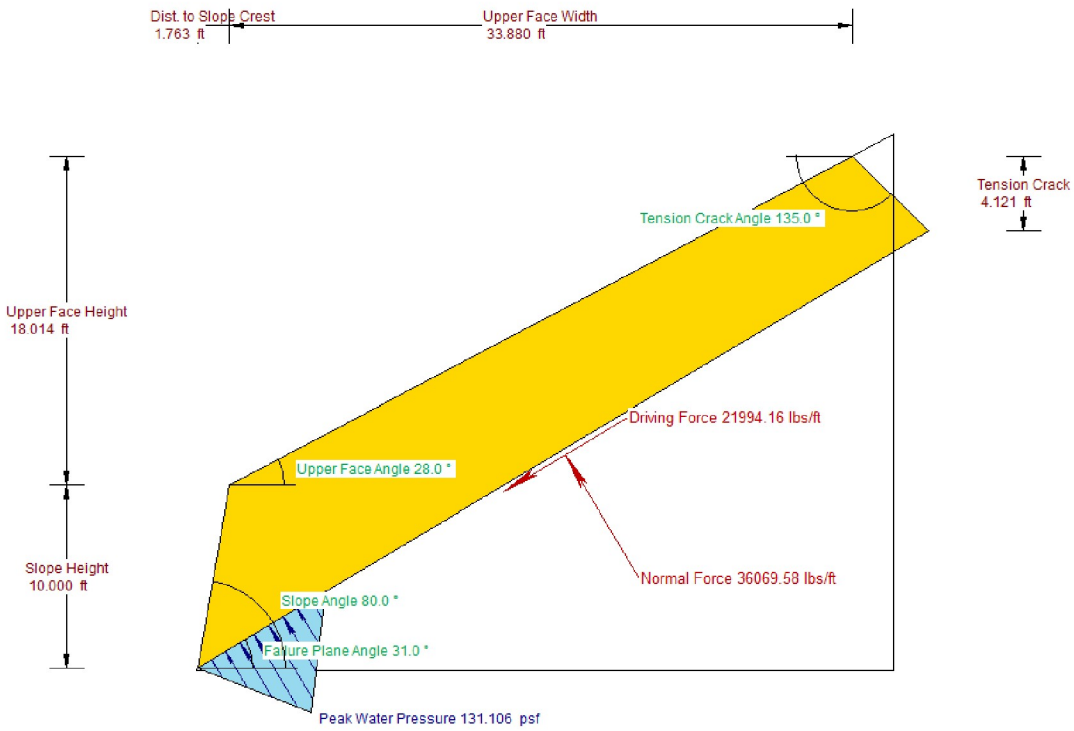
- Rock Slope Engineering 4th edition, Wyllie and Mah, 2005
- PTI DC35.1-14, Recommendations for prestressed rock and soil anchors, 2014.

Design Assumptions

1. Rock parameters were assumed from a back analysis of the west wall ground disturbance performed in RocPlane.
2. Existing west face slope angles were determined from a slope angle heat map from onXmaps.

Slope Stability support

RocPlane model for the existing face:



Calculated driving force, RocPlane: $F_{dr.exis} := 21994.16 \cdot plf$

Calculated existing normal force, RocPlane: $F_{norm.exis} := 36069.58 \cdot plf$

Calculated existing water force, RocPlane: $F_{water} := 534.84 \cdot plf$

Upper face angle, KUE: $\sigma_{up} := 28 \cdot deg$

Failure plane angle, KUE: $\sigma_{fp} := 31 \cdot deg$

Total height, RocPlane: $H := 28 \cdot ft$

Upper face width, RocPlane: $w_{up} := 33.88 \cdot ft$

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tension crack length, RocPlane: $t_{cr} := 4.12 \cdot ft$

Joint cohesion, KUE: $c := 50 \cdot psf$

Joint friction angle, KUE: $\phi_{jt} := 25 \cdot deg$

Anchor inclination: $\phi_{st} := 45 \cdot deg$

Upper face length: $L_{up} := \frac{w_{up}}{\cos(\sigma_{up})} = 38.37\,ft$

Required tieback load: $T_{max} := 15 \cdot klf$ Iterative to achieve FS

per slope length

Area of sliding plane per linear foot: $A := \frac{(H - t_{cr})}{\sin(\sigma_{fp})} = 46.37\,ft$

Total resisting force, Wyllie & Mah:

$$F_{res} := c \cdot A + \left[T_{max} \cdot \sin\left(\left(\sigma_{fp} + \phi_{st}\right)\right) + F_{norm.exis} - F_{water}\right] \cdot \tan\left(\phi_{jt}\right) = 25.68 \cdot klf$$

Total driving force, Wyllie & Mah: $F_{driving} := F_{dr.exis} - T_{max} \cdot \cos\left(\sigma_{fp} + \phi_{st}\right) = 18.37 \cdot klf$

Factor of safety: $FS := \frac{F_{res}}{F_{driving}} = 1.4$

Pattern vertical spacing: $V_{sp} := 10 \cdot ft$

Pattern Horizontal spacing: $H_{sp} := 15 \cdot ft$

Required resisting force per anchor column: $T_{req} := T_{max} \cdot H_{sp} = 225 \cdot kip$

Number of anchors in column: $n := 1$

Required resisting force per anchor $T_{req\_an} := \frac{T_{req}}{n} = 225 \cdot kip$

Tieback Anchor

Multi strand anchors, class 1

Bond strength in lower Limestone layer: $BS := 150 \cdot psi$

Factor of safety - pullout: $FS_{po} := 2$

Anchor inclination from perpendicular to slope: $\phi_{st} = 45 \cdot deg$

Strand max design load: $T_{t\_s} := 246 \cdot kip$ 7 strand anchor

Strand Anchor System ASTM A416

Number of Strands	Cross-Sectional Area (Aps)	Ultimate Load (fpu*Aps)	Maximum Jacking Load (0.8*fpu*Aps)	Maximum Design Load (0.6*fpu*Aps)	HDPE Tubing	Anchor Heads	Weight per Foot
1	0.217 in² (140 mm²)	58.6 kips (261 kN)	46.9 kips (209 kN)	35.2 kips (157 kN)	3" nom. (3.5" OD)	C4.6	0.74 lbs (0.34 kg)
2	0.434 in² (280 mm²)	117 kips (522 kN)	93.8 kips (418 kN)	70.4 kips (314 kN)	3" nom. (3.5" OD)	C4.6	1.48 lbs (0.67 kg)
3	0.651 in² (420 mm²)	176 kips (783 kN)	141 kips (627 kN)	106 kips (471 kN)	3" nom. (3.5" OD)	C4.6	2.22 lbs (1.01 kg)
4	0.868 in² (560 mm²)	234 kips (1044 kN)	188 kips (836 kN)	141 kips (628 kN)	3" nom. (3.5" OD)	C7.6 - Class 1 C4.6 - Class 2	2.96 lbs (1.34 kg)
5	1.09 in² (700 mm²)	293 kips (1305 kN)	235 kips (1045 kN)	176 kips (785 kN)	3" nom. (3.5" OD)	C7.6	3.70 lbs (1.68 kg)
6	1.30 in² (840 mm²)	352 kips (1566 kN)	281 kips (1254 kN)	211 kips (942 kN)	3" nom. (3.5" OD)	C7.6	4.44 lbs (2.01 kg)
7	1.52 in² (980 mm²)	410 kips (1827 kN)	328 kips (1463 kN)	246 kips (1099 kN)	3" nom. (3.5" OD)	C7.6	5.18 lbs (2.35 kg)
8	1.74 in² (1120 mm²)	469 kips (2088 kN)	375 kips (1672 kN)	282 kips (1256 kN)	3" nom. (3.5" OD)	C9.6	5.92 lbs (2.69 kg)
9	1.95 in² (1260 mm²)	527 kips (2349 kN)	422 kips (1881 kN)	317 kips (1413 kN)	4" nom. (4.6" OD)	C9.6	6.66 lbs (3.02 kg)
10	2.17 in² (1400 mm²)	586 kips (2610 kN)	469 kips (2090 kN)	352 kips (1570 kN)	4" nom. (4.6" OD)	C12.6	7.40 lbs (3.36 kg)

Free length, PTI: $T_{fl} := 15 \cdot ft$ through upper limestone

Required tail length: $T_t := 2 \cdot ft$

Hole diameter: $d_t := 6 \cdot in$

Required bond length, PTI:

$$T_{bl} := \frac{T_{req} \cdot FS_{po}}{3.14 \cdot BS \cdot d_t} = 13.27\,ft$$

Check strand tensile capacity (ASD):

$$Ckeck := \begin{cases} "OK" & \text{if } T_{t\_s} \geq T_{req\_an} \\ "WARNING" & \text{otherwise} \end{cases} = "OK"$$

Anchor total length:

$$L_{total} := T_{fl} + T_{bl} + T_t = 30.27\,ft$$

$$L_{total} = 30\,ft$$

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Number of anchors in column: $n := 1$

Required resisting force per anchor $T_{req\_an} := \frac{T_{req}}{n} = 30 \cdot kip$

Tieback Anchor

Multi strand anchors, class 1

Bond strength in lower Limestone layer: $BS := 150 \cdot psi$

Factor of safety - pullout: $FS_{po} := 2$

Anchor inclination from perpendicular to slope: $\phi_{st} = 45 \cdot deg$

Bar ultimate strength: $T_{t\_s} := 79 \cdot kip$ 8 bar

R61 Grade 75 & Grade 80 All-Thread Rebar ASTM A615*

Bar Designation & Pitch	Minimum Net Area Thru Threads	Minimum Ultimate Strength	Grade 75 Minimum Yield Strength	Grade 80 Minimum Yield Strength	Nominal Weight	Approx. Thread Major Diameter	Part Number
#6 - 5 (19 mm)	0.44 in² (284 mm²)	44 kips (196 kN)	33 kips (147 kN)	35 kips (156 kN)	1.5 lbs/ft (2.4 kg/m)	7/8" (22 mm)	R61-06
#7 - 5 (22 mm)	0.60 in² (387 mm²)	60 kips (267 kN)	45 kips (200 kN)	48 kips (214 kN)	2.0 lbs/ft (3.0 kg/m)	1" (25 mm)	R61-07
#8 - 3-1/2 (25 mm)	0.79 in² (510 mm²)	79 kips (351 kN)	59 kips (264 kN)	63 kips (280 kN)	2.7 lbs/ft (3.9 kg/m)	1-1/8" (29 mm)	R61-08
#9 - 3-1/2 (29 mm)	1.00 in² (645 mm²)	100 kips (445 kN)	75 kips (334 kN)	80 kips (356 kN)	3.4 lbs/ft (5.1 kg/m)	1-1/4" (32 mm)	R61-09
#10 - 3 (32 mm)	1.27 in² (819 mm²)	127 kips (565 kN)	95 kips (424 kN)	102 kips (454 kN)	4.3 lbs/ft (5.5 kg/m)	1-3/8" (35 mm)	R61-10
#11 - 3 (36 mm)	1.56 in² (1006 mm²)	156 kips (694 kN)	117 kips (521 kN)	125 kips (556 kN)	5.3 lbs/ft (7.9 kg/m)	1-1/2" (38 mm)	R61-11
#14 - 3 (43 mm)	2.25 in² (1452 mm²)	225 kips (1001 kN)	169 kips (750 kN)	180 kips (801 kN)	7.65 lbs/ft (11.8 kg/m)	1-7/8" (48 mm)	R61-14
#18 - 3 (57 mm)	4.00 in² (2581 mm²)	400 kips (1780 kN)	300 kips (1335 kN)	320 kips (1423 kN)	13.6 lbs/ft (19.6 kg/m)	2-7/16" (62 mm)	R61-18
#20 - 2-3/4 (64 mm)	4.91 in² (3168 mm²)	491 kips (2184 kN)	368 kips (1637 kN)	393 kips (1748 kN)	16.7 lbs/ft (24.8 kg/m)	2-3/4" (70 mm)	R61-20
#24 - 2-3/4 (76 mm) *	6.82 in² (4400 mm²)	682 kips (3034 kN)	512 kips (2277 kN)	546 kips (2429 kN)	24.0 lbs/ft (35.8 kg/m)	3-3/16" (81 mm)	R61-24
#28 - 2-3/4 (89 mm) *	9.61 in² (6200 mm²)	961 kips (4274 kN)	720 kips (3206 kN)	769 kips (3421 kN)	32.7 lbs/ft (48.6 kg/m)	3-3/4" (95 mm)	R61-28
#32 - 2-3/4 (102 mm) *	12.56 in² (8103 mm²)	1256 kips (5587 kN)	942 kips (4190 kN)	1004 kips (4466 kN)	43.0 lbs/ft (64.0 kg/m)	4-1/4" (108 mm)	R61-32

Free length, PTI: $T_{fl} := 15 \cdot ft$ through upper limestone

Required tail length: $T_t := 2 \cdot ft$

Hole diameter: $d_t := 4 \cdot in$

Required bond length, PTI:

$$T_{bl} := \frac{T_{req} \cdot FS_{po}}{3.14 \cdot BS \cdot d_t} = 2.65\,ft$$

Check strand tensile capacity (ASD):

$$Ckeck := \begin{cases} "OK" & \text{if } 0.6 \cdot T_{t\_s} \geq T_{req\_an} \\ "WARNING" & \text{otherwise} \end{cases} = "OK"$$

Anchor total length:

$$L_{total} := T_{fl} + T_{bl} + T_t = 19.65\,ft$$

$$L_{total} = 20\,ft$$

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Client	RMR Aggregates, Inc.	Date 8/10/2023	
Project	Mid Continent Mine	Designed By	KRF
Subject	Active Slope Stabilization	Checked By	AC

Technical Summary

Scope

Preliminary design of active stabilization of the west face of the Mid Continent Mine utilizing tensioned tiebacks. Anchored slope design was performed for upper limestone thicknesses of 15 feet.

Design References

- Rock Slope Engineering 4th edition, Wyllie and Mah, 2005
- PTI DC35.1-14, Recommendations for prestressed rock and soil anchors, 2014.

Design Assumptions

1. Rock parameters were assumed from a back analysis of the west wall ground disturbance performed in RocPlane.
2. Existing west face slope angles were determined from a slope angle heat map from onXmaps.

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Client	RMR Aggregates, Inc.	Date 8/10/2023	
Project	Mid Continent Mine	Designed By	KRF
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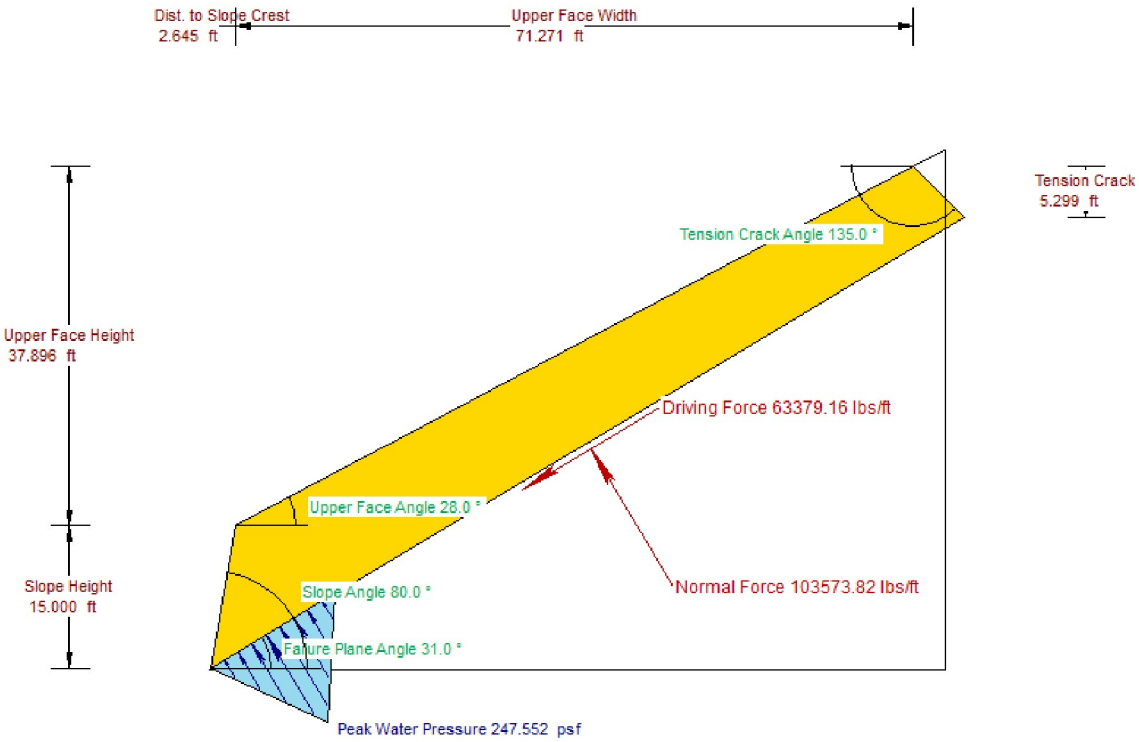
Slope Stability support

RocPlane model for the existing face:



Calculated driving force, RocPlane: $F_{dr.exis} := 63379.16 \cdot plf$

Calculated existing normal force, RocPlane: $F_{norm.exis} := 103573.82 \cdot plf$

Calculated existing water force, RocPlane: $F_{water} := 1906.81 \cdot plf$

Upper face angle, KUE: $\sigma_{up} := 28 \cdot deg$

Failure plane angle, KUE: $\sigma_{fp} := 31 \cdot deg$

Total height, RocPlane: $H := 52.9 \cdot ft$

Upper face width, RocPlane: $w_{up} := 71.3 \cdot ft$

tension crack length, RocPlane: $t_{cr} := 5.3 \cdot ft$

Joint cohesion, KUE: $c := 50 \cdot psf$

Joint friction angle, KUE: $\phi_{jt} := 25 \cdot deg$

Anchor inclination: $\phi_{st} := 45 \cdot deg$

Upper face length: $L_{up} := \frac{w_{up}}{\cos(\sigma_{up})} = 80.75\,ft$

Required tieback load: $T_{max} := 47 \cdot klf$ Iterative to achieve FS

per slope length

Area of sliding plane per linear foot: $A := \frac{(H - t_{cr})}{\sin(\sigma_{fp})} = 92.42\,ft$

Total resisting force, Wyllie & Mah:

$$F_{res} := c \cdot A + \left[T_{max} \cdot \sin\left(\left(\sigma_{fp} + \phi_{st}\right)\right) + F_{norm.exis} - F_{water}\right] \cdot \tan\left(\phi_{jt}\right) = 73.29 \cdot klf$$

Total driving force, Wyllie & Mah: $F_{driving} := F_{dr.exis} - T_{max} \cdot \cos\left(\sigma_{fp} + \phi_{st}\right) = 52.01 \cdot klf$

Factor of safety: $FS := \frac{F_{res}}{F_{driving}} = 1.41$

Pattern vertical spacing: $V_{sp} := 10 \cdot ft$

Pattern Horizontal spacing: $H_{sp} := 10 \cdot ft$

Required resisting force per anchor column: $T_{req} := T_{max} \cdot H_{sp} = 470 \cdot kip$

Number of anchors in column: $n := 2$

Required resisting force per anchor $T_{req\_an} := \frac{T_{req}}{n} = 235 \cdot kip$

Tieback Anchor

Multi strand anchors, class 1

Bond strength in lower Limestone layer: $BS := 150 \cdot psi$

Factor of safety - pullout: $FS_{po} := 2$

Anchor inclination from perpendicular to slope: $\phi_{st} = 45 \cdot deg$

Strand max design load: $T_{t\_s} := 246 \cdot kip$ 7 strand anchor

Strand Anchor System ASTM A416

Number of Strands	Cross-Sectional Area (Aps)	Ultimate Load (fpu*Aps)	Maximum Jacking Load (0.8*fpu*Aps)	Maximum Design Load (0.6*fpu*Aps)	HDPE Tubing	Anchor Heads	Weight per Foot
1	0.217 in² (140 mm²)	58.6 kips (261 kN)	46.9 kips (209 kN)	35.2 kips (157 kN)	3" nom. (3.5" OD)	C4.6	0.74 lbs (0.34 kg)
2	0.434 in² (280 mm²)	117 kips (522 kN)	93.8 kips (418 kN)	70.4 kips (314 kN)	3" nom. (3.5" OD)	C4.6	1.48 lbs (0.67 kg)
3	0.651 in² (420 mm²)	176 kips (783 kN)	141 kips (627 kN)	106 kips (471 kN)	3" nom. (3.5" OD)	C4.6	2.22 lbs (1.01 kg)
4	0.868 in² (560 mm²)	234 kips (1044 kN)	188 kips (836 kN)	141 kips (628 kN)	3" nom. (3.5" OD)	C7.6 - Class 1 C4.6 - Class 2	2.96 lbs (1.34 kg)
5	1.09 in² (700 mm²)	293 kips (1305 kN)	235 kips (1045 kN)	176 kips (785 kN)	3" nom. (3.5" OD)	C7.6	3.70 lbs (1.68 kg)
6	1.30 in² (840 mm²)	352 kips (1566 kN)	281 kips (1254 kN)	211 kips (942 kN)	3" nom. (3.5" OD)	C7.6	4.44 lbs (2.01 kg)
7	1.52 in² (980 mm²)	410 kips (1827 kN)	328 kips (1463 kN)	246 kips (1099 kN)	3" nom. (3.5" OD)	C7.6	5.18 lbs (2.35 kg)
8	1.74 in² (1120 mm²)	469 kips (2088 kN)	375 kips (1672 kN)	282 kips (1256 kN)	3" nom. (3.5" OD)	C9.6	5.92 lbs (2.69 kg)
9	1.95 in² (1260 mm²)	527 kips (2349 kN)	422 kips (1881 kN)	317 kips (1413 kN)	4" nom. (4.6" OD)	C9.6	6.66 lbs (3.02 kg)
10	2.17 in² (1400 mm²)	586 kips (2610 kN)	469 kips (2090 kN)	352 kips (1570 kN)	4" nom. (4.6" OD)	C12.6	7.40 lbs (3.36 kg)

Free length, PTI: $T_{fl} := 15 \cdot ft$ through upper limestone

Required tail length: $T_t := 2 \cdot ft$

Hole diameter: $d_t := 6 \cdot in$

Required bond length, PTI:

$$T_{bl} := \frac{T_{req} \cdot FS_{po}}{3.14 \cdot BS \cdot d_t} = 27.72\,ft$$

Check strand tensile capacity (ASD):

$$Ckeck := \begin{cases} \text{"OK"} & \text{if } T_{t\_s} \geq T_{req\_an} \\ \text{"WARNING"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Anchor total length:

$$L_{total} := T_{fl} + T_{bl} + T_t = 44.72\,ft$$

$$L_{total} = 45\,ft$$