FERMILAB ENGINEERING NOTE	SECTION PPD/ETT	PROJECT NuMI	SERIAL - CATAGORY MD-ENG-029	PAGE 1
SUBJECT: Winch Cable Force for Carrier & Pre-Target Tunnels			NAME: Mayling Wong	
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Given: The NuMI B2 magnet transport cart will be pulled up a slope 15% by a winch through the pre-target tunnel. The cart (including the spreader) weighs 3300 pounds, and the B2 magnet weighs 25,900 pounds. The breakaway coefficient of friction is no more than 5%.

Find: The force that the winch must pull.

Solution:

$B2wgt := 25900$ lb Weight of B2 magnet

$cartwgt := 3300$ lb Weight of magnet cart

$slope := 0.15$ Slope of tunnel floor

$angle := atan(slope)$

$angle = 0.149$ rad Angle of tunnel floor

$angled := \frac{360}{2 \cdot \pi} \cdot angle$

$angled = 8.531$ deg Angle of tunnel floor

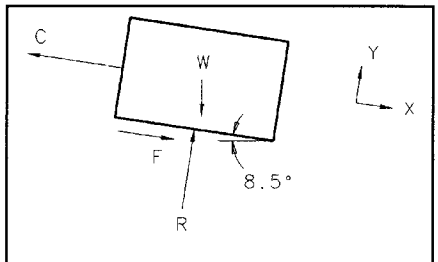

Figure 1

As seen in Figure 1, the forces acting on the cart are the pull of the winch cable, the resultant force of the floor on the cart, the friction force, and the weight of the cart. Assuming that the cart is in equilibrium, the forces can be summed up:

$-C+Wx+F = 0$
$R-Wy = 0$

The floor's resultant force can be calculated:

$Wy := (B2wgt + cartwgt) \cdot cos(angle)$

$Wy = 2.888 \times 10^4$ lb Y-component of the weight

$R := Wy$

$R = 2.888 \times 10^4$ lb Resultant force of the floor on the cart

When the winch begins to pull on the cart, it is assumed that the cart will not move immediately because the winch pull force has to overcome static friction. It is also assumed that the kinetic friction of the rollers on the cart is less than the the static friction. The maximum force due to static friction is calculated:

$mu := 0.05$ Static coefficient of friction

$F := mu \cdot R$

$F = 1.444 \times 10^3$ lb Friction force

Assuming the maximum force that the winch cable sees occurs when the winch is starting to pull on the cart (before the cart begins to move), the cable force is:

$Wx := (B2wgt + cartwgt) \cdot sin(angle)$

$Wx = 4.332 \times 10^3$ lb X-component of the weight

$C := Wx + F$

$C = 5.775 \times 10^3$ lb Force in the winch cable

The total length of 9/16-inch diameter wire rope specified for the winch is 615 feet (distance from STA 2+40 [upstream of CMU wall in Carrier Tunnel] to STA 6+40 [NuMI tunnel shaft] is 400 feet; the winch sits at about STA 4+50 [beginning of Pre-Target Tunnel], so additional 210 feet of cable is needed; extra 5 feet of rope added).

The Thern winch model number 4HS11M-11000-15 has the following specifications:
- Load rating 11,000 lb 1st layer, 7600 lb mid drum, 5800 lb full drum
- Motor 5 hp, 460V, 3-phase, TEFC severe brakemotor
- Line speed: 15 ft/minute 1st layer, 28 ft/minute full drum
- Helical/Spur gear drive
- Drum spool diameter 9-inch, drum flange diameter 20-inch, drum width 18-inch
- Using 9/16-inch wire rope, layer 7 has a line pull of 6100 lb.(drum capacity 9 layers)

Winch dimensions can be found on Thern's online catalog:
http://www.thern.com/product/section3/4hs11mdim.htm

Bridon wire rope that has a 9/16-inch diameter (part number 6x19IWRC) has a minimum breaking force of 16.8 tons.

Crosby Eye Hoist Hook, 7/8-inch size (part number S-320AN), has a working load limit of 34,200 lb.