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ANALYSIS OF REDI-ROCK BLOCKS SUBJECT TO DRAG SHEAR FORCE FROM FLOWING WATER

The calculation of drag force acting on a flat plate parallel to the direction of flow is intended to simulate the force acting on a Redi-Rock block in a wall on the side of a river channel. This calculation was prepared by LMNO Engineering, Research, and Software, Ltd. for Redi-Rock International based on information contained in *Fundamentals of Fluid Mechanics*, Munson et. al. (1998). The main components of the calculation are reproduced here in abbreviated form.

Force on a Redi-Rock block in a wall on the side of a river channel varies with velocity of the flow, coefficient of drag on the block, and face area exposed to the flowing water. The first step in calculating the force on the block is to determine the drag coefficient, which is dependent on the Reynolds number of the flow. The Reynolds number is calculated by:

$$R_e = \frac{Vb}{\nu}$$

where

R_e = Reynolds number (unitless)
V = water velocity (ft/sec)
b = length of block face parallel to flow = 3.83' for Redi-Rock
ν = kinematic viscosity of water = 1.25×10^{-5} ft^2/sec at 60°F

The friction drag coefficient for a flat plate parallel to upstream flow can be determined from the Reynolds number and the ratio of roughness to plate length. For concrete, roughness varies from 0.001 to 0.01. Using the upper end of roughness values, e = 0.01 and plate length, b = 3.83', e/b = 2.6×10^{-3}. Figure 9.15, Munson et. al. (1998) can be used to determine the drag coefficient, CD. For Reynolds numbers from 3.2×10^6 to 7.9×10^6 (corresponding to flows of 10 to 25 ft/sec) and e/b value of 2.6×10^{-3}, the drag coefficient is approximately 0.012.

The shear force on the block is computed from equation 9.33, Munson et. al. (1998):

$$F = \frac{\frac{1}{2} C_D A V^2 \gamma}{g}$$

where

F = shear force (lb)
C_D = friction drag coefficient
A = shear area = area tangent to flow = 5.75 ft^2 for Redi-Rock
V = water velocity (ft/sec)
γ = specific weight of water $\approx$ 62.4 lb/ft^3
g = acceleration of gravity = 32.2 ft/sec^2

Resisting forces which keep the retaining wall blocks in place are provided by block to block friction. The buoyant unit weight of a Redi-Rock wall is

$$\gamma_{buoyant} = \gamma_{infilled} - \gamma_{water} = 130 \text{ lb/ft}^3 - 62.4 \text{ lb/ft}^3 = 67.6 \text{ lb/ft}^3$$

and the buoyant weight of a block is

$W_{buoy\ block}$ = $\gamma_{buoyant}$ x l_{block} x h_{block} x w_{block}

= 67.6 lb/ft^3 x 3.83 ft x 1.5 ft x 3.41 ft

= 1,324 lb

Using a coefficient of friction for concrete on concrete = 0.2, the sliding resistance of a Redi-Rock block can be computed as:

$F_{Resisting}$ = μ x $W_{buoy\ block}$

= 0.2 x 1,324

= 264 lb/block

The shear forces acting on the face of a Redi-Rock block at different flow rates are as follows:

At a stream velocity of 10 feet per second

V = 10 $^{ft}/_{sec}$, C_D = 0.012

$$F = \frac{\frac{1}{2} C_D A V^2 \gamma}{g} = \frac{\frac{1}{2} x 0.012 x 5.75 x 10^2 x 62.4}{32.2} \approx 7\ lb/block \quad < \quad 264\ lb/block\ resisting$$

At a stream velocity of 25 feet per second

V = 25 $^{ft}/_{sec}$, C_D = 0.012

$$F = \frac{\frac{1}{2} C_D A V^2 \gamma}{g} = \frac{\frac{1}{2} x 0.012 x 5.75 x 25^2 x 62.4}{32.2} \approx 42\ lb/block \quad < \quad 264\ lb/block\ resisting$$

References

LMNO Engineering, Research, and Software, Ltd., Report: *Shear Force on Retaining Wall Block*, Prepared for Redi-Rock International, Dated July 21, 2006.

Munson, B.R., D.F. Young, and T.H. Okiishi, *Fundamentals of Fluid Mechanics*, John Wiley and Sons, 3rd Edition, 1998.