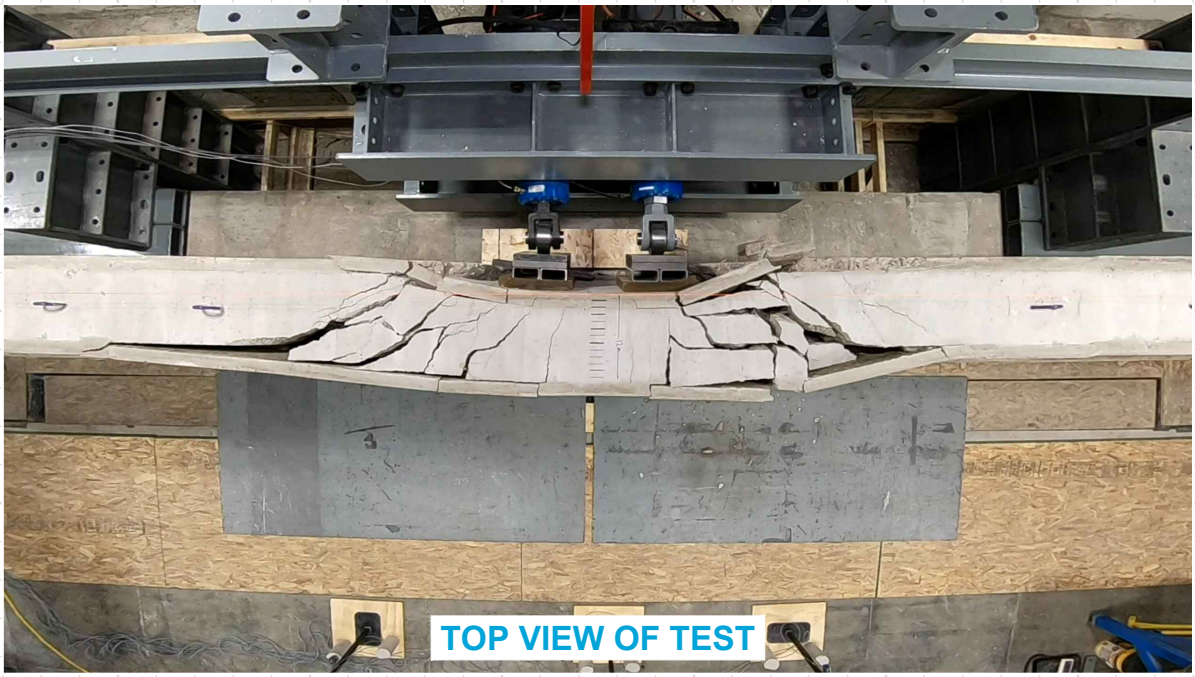
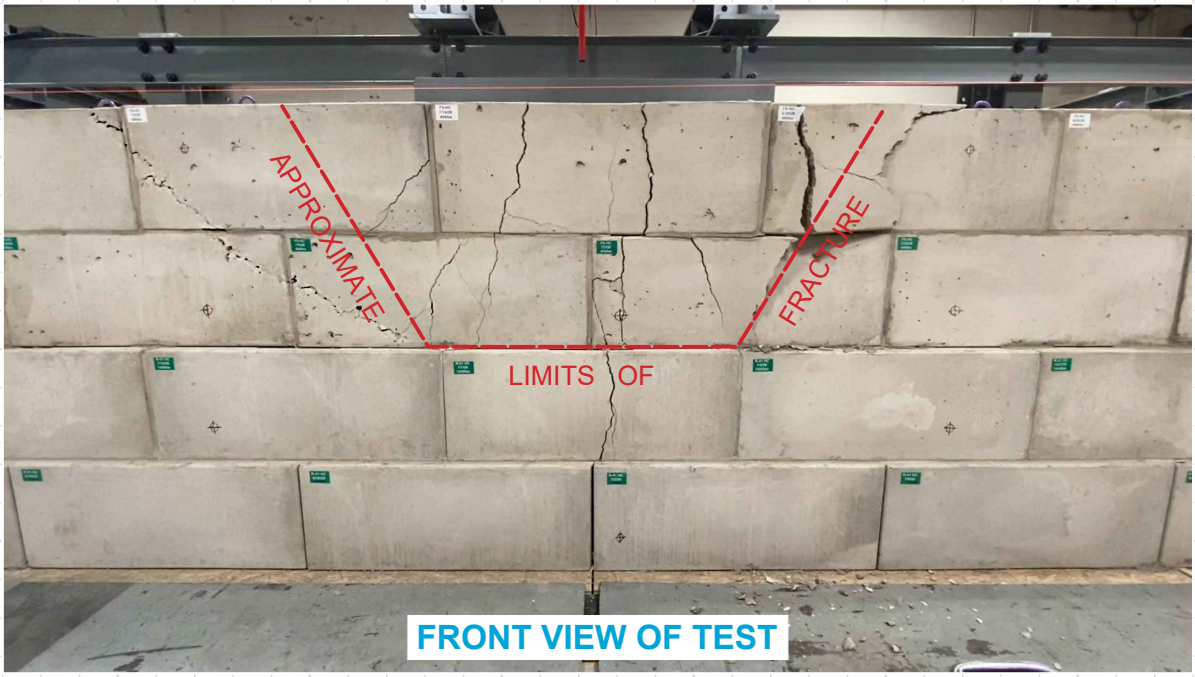
REDI-ROCK	PROJECT: REDI-ROCK R-41HC AND F-HC BARRIER WALL	SHEET: 1 / 7
	PREPARED BY: REDI-ROCK INTERNATIONAL	DATE: APRIL 15, 2021

BARRIER WALLS WITH REDI-ROCK RETAINING HOLLOW CORE (R-41HC) BLOCKS, FREESTANDING HOLLOW CORE (F-HC) BLOCKS, AND CAST-IN-PLACE CONCRETE INFILL WERE CONSTRUCTED AND TESTED AT THE ASTER BRANDS TEST LAB IN CHARLEVOIX, MICHIGAN. COMPLETE DETAILS ARE PROVIDED IN TEST REPORTS AVAILABLE ON THE WEBSITE, www.redi-rock.com.

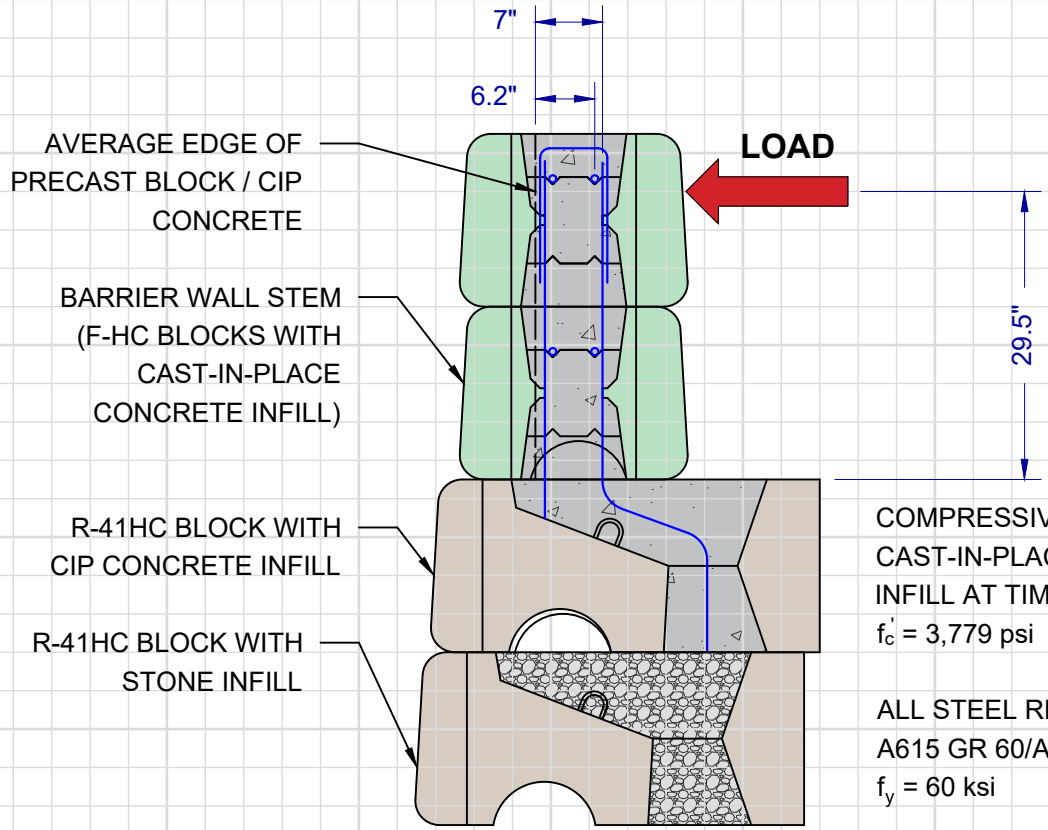


TOP VIEW OF TEST



FRONT VIEW OF TEST

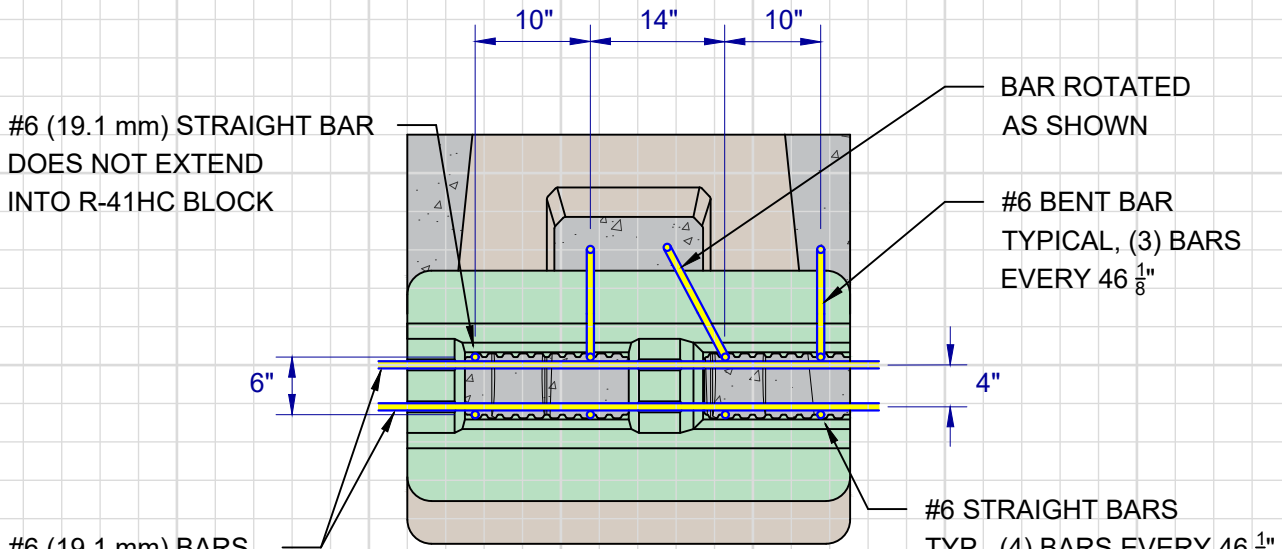
REDI-ROCK	PROJECT: REDI-ROCK R-41HC AND F-HC BARRIER WALL	SHEET: 2 / 7
	PREPARED BY: REDI-ROCK INTERNATIONAL	DATE: APRIL 15, 2021



COMPRESSIVE STRENGTH OF CAST-IN-PLACE CONCRETE INFILL AT TIME OF TEST, $f_c' = 3{,}779$ psi

ALL STEEL REBAR WAS A615 GR 60/AASHTO M31, $f_y = 60$ ksi

CROSS-SECTION



TOP VIEW (1 BLOCK LENGTH OF WALL SHOWN)

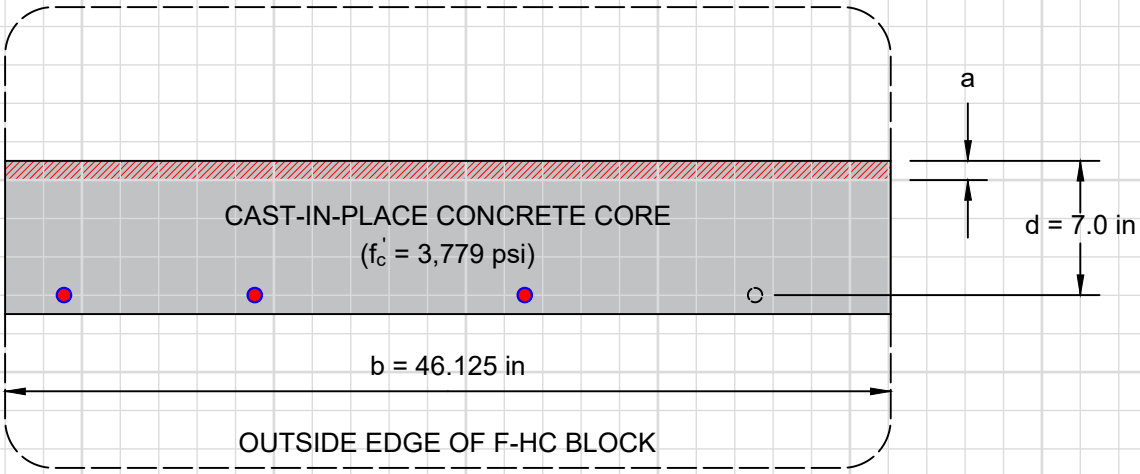
THE CAPACITY OF THE BARRIER CAN BE CALCULATED BY THE YIELD LINE PROCEDURE DETAILED IN *AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS, NINTH EDITION, 2020*, APPENDIX A13, A13.3.1 - CONCRETE RAILINGS.

DETERMINE M_c (FLEXURAL RESISTANCE OF THE STEM WALL ABOUT AN AXIS PARALLEL TO THE LONGITUDINAL AXIS OF THE BARRIER)

TO DETERMINE M_c, THE NOMINAL FLEXURAL STRENGTH OF THE STEM WALL IS CALCULATED AT THE BASE OF THE STEM, WHICH IS LOCATED AT THE JOINT BETWEEN THE TOP ROW OF RETAINING HOLLOW CORE (R-41HC) BLOCKS AND THE BOTTOM ROW OF FREESTANDING HOLLOW CORE (F-HC) BLOCKS. STRENGTH IS CONSIDERED TO BE PROVIDED BY THE CAST-IN-PLACE CONCRETE CORE WITH NO CONTRIBUTION FROM THE TEXTURED FACE PANELS OF THE FREESTANDING HOLLOW CORE (F-HC) BLOCKS.

STEEL REINFORCEMENT IS PROVIDED BY (3) #6 BENT BARS EVERY 46 $\frac{1}{8}$" OF WALL (LENGTH OF A REDI-ROCK BLOCK). A 4TH #6 STRAIGHT BAR WAS CAST INTO THE CORE BUT DID NOT EXTEND ACROSS THE JOINT AT THE BASE OF THE STEM AND DOES NOT CONTRIBUTE TO M_c.

A SIMPLIFIED SKETCH OF A (1) BLOCK LONG SECTION OF WALL FOR ANALYSIS IS AS SHOWN:



$b = 46.125$ in $d = 7.0$ in $A_s = 3 \times 0.44 = 1.32$ in^2

$$a = \text{HT OF THE COMPRESSIVE BLOCK} = \frac{A_s\ f_y}{0.85\ f_c'\ b} = \frac{1.32 \times 60{,}000}{0.85 \times 3{,}779 \times 46.125} = 0.534 \text{ in}$$

$M_c = A_s\ f_y\ (d - a/2) = 1.32 \times 60{,}000 \times (7.0 - 0.534/2) = 533{,}232$ lb * in / 46.125 in

$M_c = 11{,}560$ lb * ft / ft = 11.56 kip * ft / ft

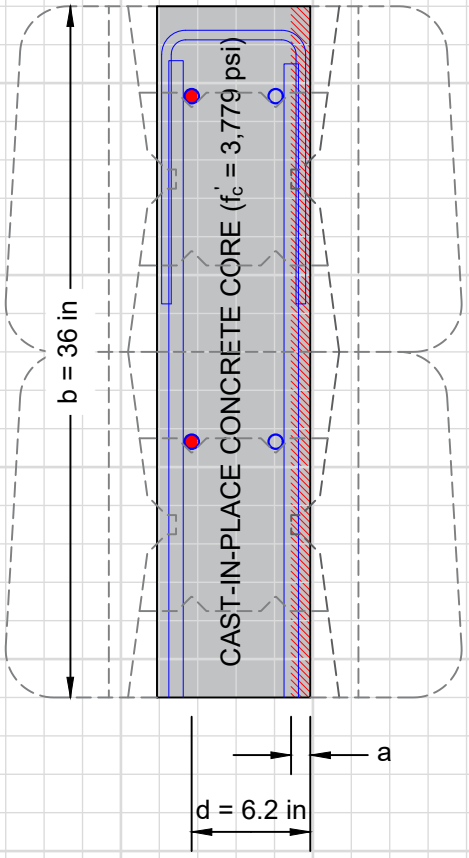
✓ LAB TESTING PRODUCED LOADS OF 18,574 AND 17,978 lb, WHICH CORRESPOND TO FLEXURAL STRENGTHS (M_c) OF 11.9 AND 11.5 kip * ft / ft FOR A (1) BLOCK LONG SECTION. REFER TO OUR PHASE 1 BARRIER TEST REPORT.

DETERMINE M_w (FLEXURAL RESISTANCE OF THE STEM WALL ABOUT ITS VERTICAL AXIS)

TO CALCULATE M_w, THE NOMINAL FLEXURAL STRENGTH OF THE STEM WALL PARALLEL TO THE BARRIER IS CALCULATED. STRENGTH IS CONSIDERED TO BE PROVIDED BY THE CAST-IN-PLACE CONCRETE CORE WITH NO CONTRIBUTION FROM THE TEXTURED FACE PANELS OF THE FREESTANDING HOLLOW CORE (F-HC) BLOCKS.

STEEL REINFORCEMENT IS PROVIDED BY (2) #6 BARS THAT ARE CONTINUOUS ALONG THE LENGTH OF THE BARRIER WALL.

A SIMPLIFIED SKETCH OF THE WALL CROSS SECTION FOR ANALYSIS IS AS SHOWN:



b = 36 in

d = 6.2 in

$A_s = 2 \times 0.44 = 0.88 \text{ in}^2$

a = HT OF THE COMPRESSIVE BLOCK = $\dfrac{A_s \ f_y}{0.85 \ f_c' \ b}$

$= \dfrac{0.88 \times 60{,}000}{0.85 \times 3{,}779 \times 36} = 0.456 \text{ in}$

$M_w = A_s \ f_y \ (d - a/2) = 0.88 \times 60{,}000 \times (6.2 - 0.456/2)$

$= 315{,}306 \text{ lb} * \text{in} = 26{,}275 \text{ lb} * \text{ft} = \underline{26.3 \text{ kip} * \text{ft}}$

✓ LAB TESTING PRODUCED FIRST YIELD AT LOADS OF 14,402 AND 12,772 lb, WHICH CORRESPONDS TO FLEXURAL STRENGTHS (M_w)OF 36.0 AND 32.0 kip * ft.

THE WALL WAS TESTED IN AN UPRIGHT POSITION. IF FRICTION IS CONSIDERED BETWEEN THE TEST SUPPORTS AND THE WALL (ASSUMED $\mu = 0.33$) AND FRICTION LOADS ARE SUBTRACTED FROM THE MEASURED LOADS, FLEXURAL STRENGTHS AT FIRST YIELD WOULD BE 30.0 AND 26.0 kip * ft. REFER TO OUR PHASE 2 BARRIER TEST REPORT.

DETERMINE L_c (CRITICAL LENGTH OF YIELD LINE FAILURE PATTERN)

L_c CAN BE CALCULATED WITH AASHTO EQUATION A13.3.1-2 AS FOLLOWS:

H = HEIGHT OF BARRIER = 3 ft

L_t = LENGTH OF DISTRIBUTION OF FORCE = 2.2 ft (FROM TEST)

M_b = FLEXURAL RESISTANCE OF A BEAM AT THE TOP OF THE WALL (IF ANY) = 0 kip * ft

M_c = FLEXURAL RESISTANCE OF THE STEM WALL ABOUT AN AXIS PARALLEL TO THE LONGITUDINAL AXIS OF THE BARRIER = 11.56 kip * ft / ft (CALCULATED)

M_w = FLEXURAL RESISTANCE OF THE STEM WALL ABOUT ITS VERTICAL AXIS = 26.3 kip * ft (CALCULATED)

$$L_c = \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + \frac{8H(M_b + M_w)}{M_c}}$$

$$L_c = \frac{2.2}{2} + \sqrt{\left(\frac{2.2}{2}\right)^2 + \frac{8 * 3(0 + 26.3)}{11.56}}$$

$$L_c = 8.57 \text{ ft}$$

DETERMINE R_w (TOTAL TRANSVERSE RESISTANCE OF THE RAILING)

R_w CAN BE CALCULATED WITH AASHTO EQUATION A13.3.1-1 AS FOLLOWS:

$$R_w = \left(\frac{2}{2L_c - L_t}\right)\left(8M_b + 8M_w + \frac{M_c L_c^2}{H}\right)$$

$$R_w = \left(\frac{2}{2 * 8.57 - 2.2}\right)\left(8 * 0 + 8 * 26.3 + \frac{11.56 * 8.57^2}{3}\right)$$

$$R_w = 66.0 \text{ kips}$$

✓ LAB TESTING PRODUCED WAS PERFORMED ON (2) FULL SIZE WALLS. THE CRITICAL LENGTH OF THE YIELD LINE FAILURE IN BOTH TESTS WAS APPROXIMATELY 8 ft. THE MEASURED FAILURE LOADS WERE 63.5 AND 70.3 kips. REFER TO OUR PHASE 3 BARRIER TEST REPORT.

REDI-ROCK	PROJECT: REDI-ROCK R-41HC AND F-HC BARRIER WALL	SHEET: 6 / 7
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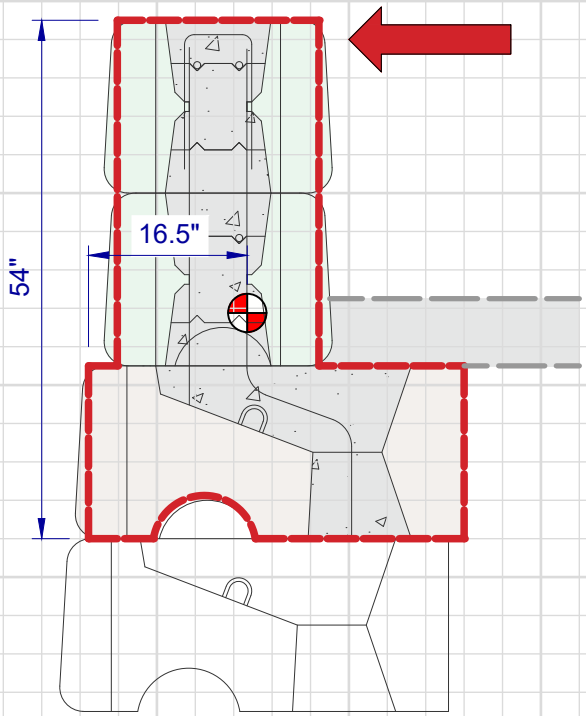
EVALUTATE OVERTURNING

10,000 lb
(EQUIV. STATIC LOAD)



OVERTURNING REISTANCE PROVIDED BY (1) R-41HC BLOCK AND (2) F-HC BLOCKS WITH INTERNAL CORES AND SPACE BETWEEEN ADJACENT RETAINING BLOCKS FILLED WITH CONCRETE.

BARRIER SECTION WAS DRAWN IN CAD. RESULTS ARE AS FOLLOWS:

VOLUME OF CONCRETE = 9.9 cft / ft
WEIGHT = 145 x 9.9 = 1,435 lb / ft
DISTANCE $_{\text{FACE OF BLOCK TO CG OF BARRIER}}$ = 16.5 in

OVERTURNING RESISTANCE,
M_R = W x d = 1,435 x 16.5/12 = 1,973 lb * ft / ft

PER NCHRP 663 *DESIGN OF ROADSIDE BARRIER SYSTEMS ON MSE RETAINING WALLS*, A 10,000 lb EQUIVALENT STATIC LOAD IS USED TO SIZE THE STRUCTURE FOR OVERTURNING RESISTANCE.

OVERTURNING MOMENT FOR AN IMPACT AT THE TOP OF THE BARRIER CAN BE CALCULATED AS FOLLOWS:

M_O = 10,000 x (54) / 12 = 45,000 lb * ft

SETTING OVERTURNING RESISTANCE EQUAL TO OVERTURNING MOMENT TIMES A FACTOR OF SAFETY, THE MINIMUM LENGTH OF BARRIER CAN BE DETERMINED.

$\phi M_R = \gamma M_O$
0.9 x (1,973 x LENGTH) = 1.0 x 45,000
LENGTH = 25.3 ft = 6.6 BLOCKS

A BARRIER WALL CONSTRUCTED WITH JOINT WIDTHS AT LEAST 7 BLOCKS APART HAS THE CAPACITY TO RESIST OVERTURNING PRODUCED BY A 10,000 lb EQUIVALENT STATIC LOAD WITH A RESISTANCE FACTOR OF 0.9.

REDI-ROCK	PROJECT: REDI-ROCK R-41HC AND F-HC BARRIER WALL	SHEET: 7 / 7
	PREPARED BY: REDI-ROCK INTERNATIONAL	DATE: APRIL 15, 2021

SUMMARY

CALCULATED YIELD LINE FAILURE PATTERNS AND TRANSVERSE RESISTANCE OF BARRIER WALLS WITH REDI-ROCK RETAINING HOLLOW CORE (R-41HC) BLOCKS, FREESTANDING HOLLOW CORE (F-HC) BLOCKS, AND CAST-IN-PLACE CONCRETE INFILL CLOSELY MATCH VALUES MEASURED IN FULL SCALE LAB TESTS.

BASED ON THE VALIDATED STRENGTH CALCULATIONS, A BARRIER WALL CONSTRUCTED ACCORDING TO THE SAME DETAILS IS CAPABLE OF RESISTING AN AASHTO TEST LEVEL TL-4 DESIGN FORCE OF 54.0 kips.

THE BARRIER SHOULD EXTEND AT LEAST 2 BLOCKS BEYOND THE REQUIRED ZONE TO PREVENT THE STRENGTH REDUCTION AT THE END OF A WALL FROM CONTROLLING PERFORMANCE OF THE BARRIER.

NO VEHICLE PERFORMANCE IMPACT TESTING WAS COMPLETED. NO ATTEMPT WAS MADE TO CONSIDER BARRIER SHAPE OR FACE TEXTURE. THIS BARRIER SHOULD ONLY BE USED IN LOW SPEED APPLICATIONS, OR IN APPLICATIONS WHERE IT WILL NOT BE SUBJECT TO DIRECT IMPACTS FROM HIGH SPEED TRAFFIC, SUCH AS BEHIND A CURB OR SIDEWALK.