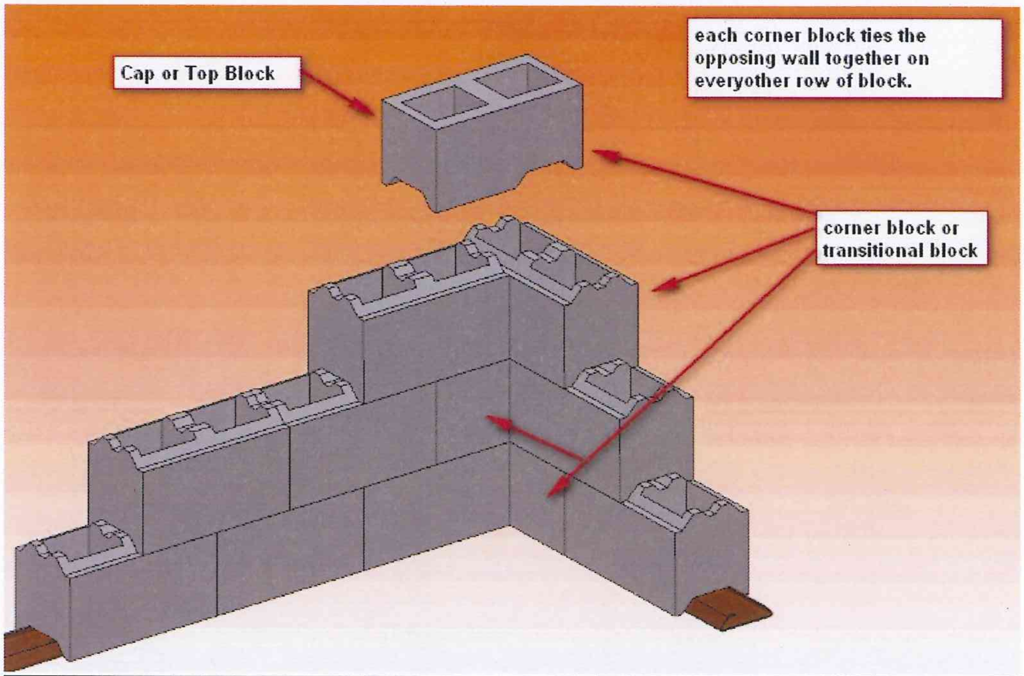
ENGINEERING REPORT

O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM



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ABSTRACT

An innovative technology has been established to fill an urgent need to supplement age-old concrete block and mortar based construction. Present times world wide require new technologies which are sustainable in terms of use of labor force, locally available materials, cost effectiveness and are ecologically friendly. This new material and technique is also faster to build and can be energy efficient.

The Interlocking Dry Stacked Block Masonry System by Dan O'Connor is a building system which can provide most of the needs in being a sustainable masonry system. The National Concrete Masonry Association (NCMA) (TEK 14-22) has found that similar block masonry systems have been tested in the field or by experiment and were superior to conventional block masonry using cement and mortar. In fact the NCMA recommends that the allowable stress design practices as per the International Building Code for conventional masonry block design be used for Interlocking dry stacked block masonry systems. Additionally, the same code recommends that a prism test of the Interlocking dry stacked block masonry system be done and these values may be accepted for designing of the masonry.

I. INTRODUCTION

This Interlocking dry stacked masonry known as O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM can replace conventional block and mortar based construction masonry. The other components of the conventional building system would remain largely unchanged. For example, the concrete footing, floor slab, bond beam, lintel beam, control joints and water proofing systems would be similar to a conventional system. The O'Connor Interlocking Dry Stacked Block Masonry System would enable an aesthetic and affordable building with speedier construction of high quality in a stretcher bond configuration. The blocks can be made with an extremely appealing face-brick finish. The walls could be left exposed, plastered or finished with cement paint.

Typical applications for O'Connor Interlocking Dry Stacked Block Masonry System include basement walls, foundation walls, retaining walls, both exterior and interior bearing walls, and partitions. Table 1 is a summary of acceptable heights for which O'Connor Interlocking Dry Stacked Block Masonry Systems can be built.

Table I – Summary of Allowable Wall Heights for 8" Dry-Stacked Units (after TEK 14-22)

	CONSTRUCTION TYPE (Dry-Stacked Units)		
	Grouted Un-reinforced	Grouted Reinforced	Surface Bond
Basement Walls	8'-0"	10'-8"	8'-0"
Cantilevered Retaining Walls	5'-0"	8'-8"	5'-4"
Single Story Building	15'-0"	20'-0"	16'-0"
Multi - Story Building	3 Stories less than 32'-8" in height	4 Stories less than 40'-8" in height	2 Stories less than 20'-8" in height

As can be seen from Table I, there is little difference from the allowable wall heights for un-reinforced or surface bonded dry stacked walls. As yet the NCMA has not formulated a table for dry stacked and interlocking block walls which have been proven to be superior to just plain dry stacked systems. Prism tests can be used to determine design values for these types of systems or conservative values can be used from building codes.

2. DESCRIPTION OF THE O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

The O'Connor Interlocking Dry Stacked Block Masonry System is a mortar-less system using an interlocking keyway which will provide stability at wall completion. The cells can be filled with grout and reinforcement rods which can enhance the vertical load carry capabilities. The blocks have been designed to be the same dimensions as a mortared in-place standard masonry block (8" x 16") however a 1-1/4" x 6-1/2" keyway has been provided to increase shear resistance.

A detailed dimensional illustration of the O'Connor Interlocking Dry Stacked Block Masonry System is shown as Figure 1. A recess located at the top of the block allows space for the horizontal placement of electrical conduits or horizontal reinforcement if needed.

A unique feature of the O'Connor Interlocking Dry Stacked Block Masonry System is the incorporation of a 6-1/2" wide steel starter strip which is placed under the first (starter) course of block and is attached to the foundation system. (See Figure 2). The starter steel plate is configured to accept the bottom keyway of the O'Connor Interlocking Dry Stacked Block Masonry System and acts as a solid guide platform from which the all important first course can be constructed. This is quite different from other block systems which require a mortar setting bed which is comparatively speaking much more difficult to construct and keep level.

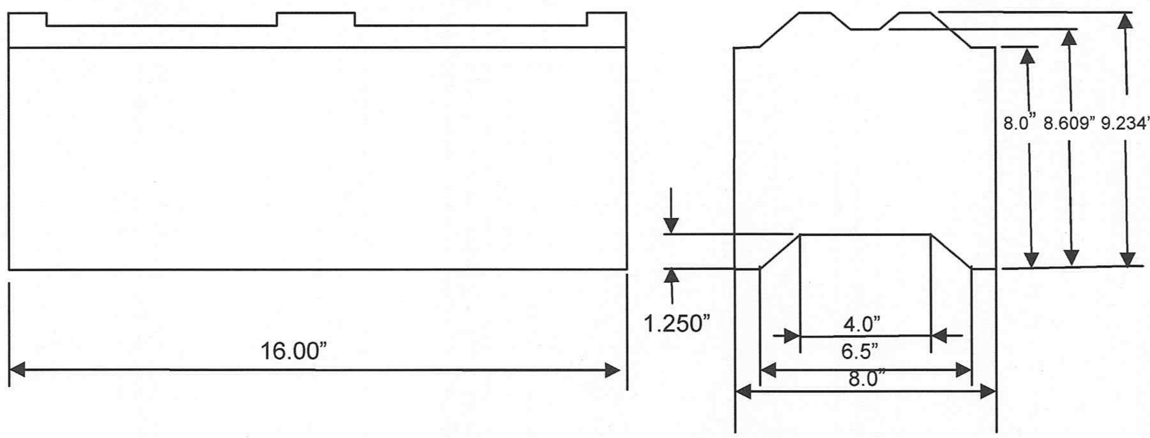


Figure 1 - O'Connor Interlocking Dry Stacked Block Masonry System Stretcher Block

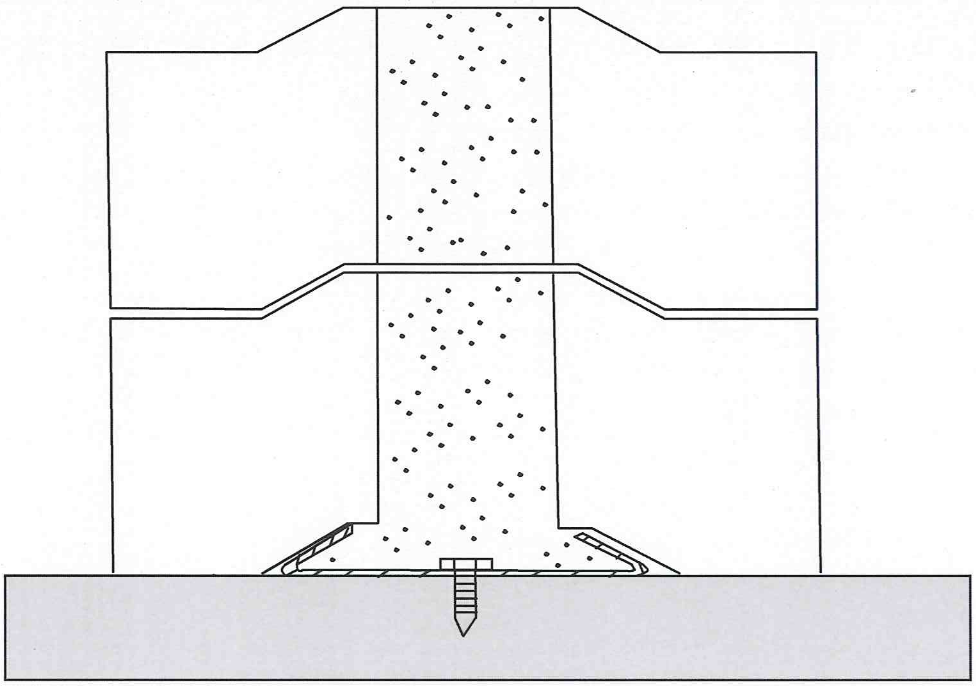


Figure 2 - O'Connor Interlocking Dry Stacked Block Masonry System Attachment Steel Starter Strip

There would be several methods of differing strengths by which the O'Connor Interlocking Dry Stacked Block Masonry System could be utilized. These would be:

A. Walls requiring a higher strength could be constructed by grouting the hollow cells and placing vertical reinforcement rods at sizes and intervals determined by analysis. Also, horizontal reinforcement can easily be added in the notch provided if necessary. Fiberglass surface bonding on the sides of the dry-stacked wall will increase the strength of the wall system substantially. Walls in this manner could be designed to resist earthquake induced loads.

B. Walls of lesser strength requirements can be designed with filling the hollow cells with grout. Some minimal reinforcement no doubt would be required at lintels, corners and doorways.

C. Surface bonding with a fiberglass surface bonding mortar along the exterior wall surfaces can provide an effective means when considering moderate loading situations. Because the bonding reinforcement layer is placed on both exterior surfaces this would be considered superior to plain un-reinforced masonry wall systems.

D. For low walls and free standing walls, an adhesive could be considered to join the blocks together much in the same way the top cap layer of a segmental block retaining wall is secured.

E. For basement walls, the surface bonding layer followed by a bitumastic waterproofing layer would be necessary to keep the installation water-tight. A typical installation is detailed in the attached drawing located in the rear map pocking and listed as DS-1.

Also depicted in Appendix A are instances where the O'Connor Interlocking Dry Stacked Block Masonry System can be adapted to accommodate typical building situations such as lintels, doors and windows, control joints and bond beams.

3. DESIGN METHODS FOR MASONRY BLOCK WALLS

Model building codes and most local codes contain empirical values for allowable stresses relating to the design of masonry walls. These are somewhat conservative numbers and have been based upon early years of experience when the structural behavior of masonry walls was not completely understood. New codes allow for design of masonry walls using rational methods which have been developed from more sophisticated analysis. Typically, allowable compressive and flexural stresses are related to the ultimate net compressive strength f'_m in pounds per square inch. Typical values for this important design parameter range between 900 to 2,100 psi depending on the net compressive strength of the block used and the quality of mortar when considering conventional masonry systems.

The design of engineered concrete masonry shall be the responsibility of qualified engineers or architects whose task will be to determine what value of f'_m will be used. This value may be determined by one of the two following methods:

1. A value of f'_m can be assumed from knowledge of what strength can produce an economical design. Then this value can be compared with the governing design code to determine the compressive strength of the block and the type of mortar (if using a mortared system) needed to achieve the selected value of f'_m. Figure 3 illustrates some of these typical design values.

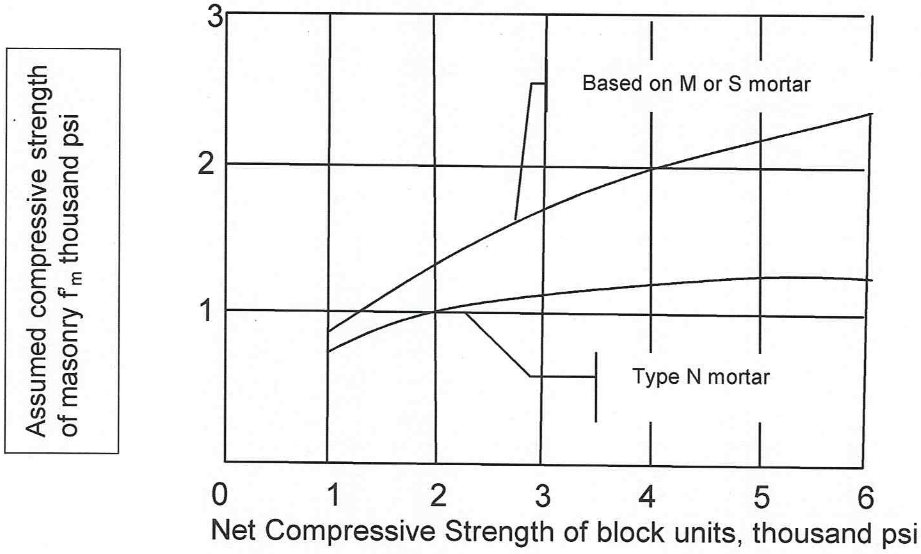


Figure 3- Value of f'_m based on strength of blocks

2. An alternative method involves the construction of a prism and to conduct a compression test prior to the design. The prism is constructed as shown in Figure 4 with the block units proposed for use. If the design calls for grouted cores, the cores of the prism are filled with grout. However no reinforcing bars are placed within the cores even if called for in the design. The prism is cured as per code. The prism is then loaded to failure and the value of f'_m is calculated by dividing the ultimate test load by the solid cross-sectional area of the prism block.

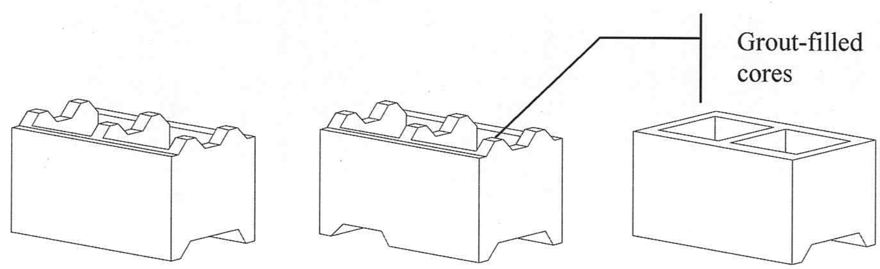


Figure 4 - Masonry Compression Test Prism

4. COMPARISON WITH STANDARD BLOCK WALL SYSTEM

A strength comparison between the O'Connor Interlocking Dry Stacked Block Masonry System and a conventional mortared block wall was calculated using a 9' high free standing wall subjected to a 110 mph wind force (See computations contained in Appendix "B"). Based on these calculations the O'Connor Interlocking Dry Stacked Block Masonry System has an allowable moment capacity of 1.75 ft-kips versus 1.60 ft-kips for a conventional mortared block system. Also it has been shown that the shear capacity favors the O'Connor Interlocking Dray Stacked Block Masonry System by over 10% (2.00 kips/ft versus 1.77 kips/ft). In addition it can be proven that the O'Connor Interlocking Dry Stacked Block Masonry System has almost twice the shear capacity when considering a single block element over a conventional mortared block.

5. CONCLUSIONS AND RECOMMENDATIONS

The O'Connor Interlocking Dry Stacked Block Masonry System offers a cost-effective, structurally sound, and sustainable alternative to standard block and mortar systems. There is no apparent reason when designed and constructed properly the O'Connor Interlocking Dry Stacked Block Masonry System can achieve the same or superior strength to those for standard masonry units. New codes allow for the construction of these types of systems and offer design strength parameters for use by engineers. As Section 3 above illustrates, these strength parameters are dependent upon the compressive strength of the block to be utilized and therefore are not entirely standardized. To determine firm net compressive strength (f'_m) design values it is recommended that several prism tests as described in Section 3 be performed so that there is no question over the inherent strength of the O'Connor Interlocking Dry Stacked Block Masonry System.

APPENDIX "A"

O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM – DETAIL SHEET

APPENDIX "B"

DESIGN COMPUTATION COMPARISION OF CONVENTIONAL MORTARED BLOCK WALL VS. O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

CONVENTIONAL MORTARED BLOCK WALL
VS
O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

DESIGN OF FREE STANDING MASONRY WALL

Trial 1 **Input Data**

TYPE OF MASONRY: **STANDARD CMU**

MASONRY STRENGTH f'_m = 1.50 ksi

CONCRETE STRENGTH f'_c = 3 ksi

REBAR YIELD STRESS f_y = 60 ksi

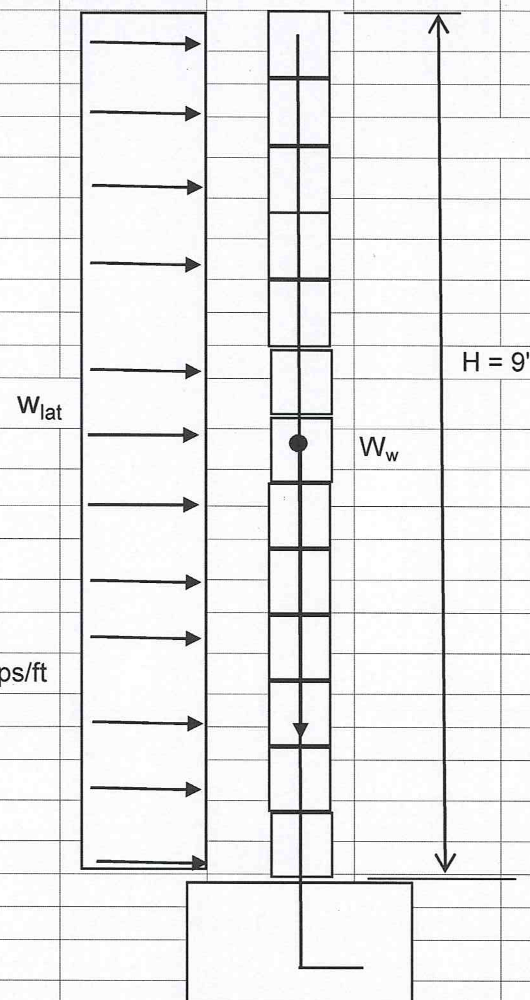
WIND PRESSURE w_{lat} = 1/1.4 x 0.7 x .56 x 110 = 30.8 psf

WEIGHT OF BLOCKS = 130 psf

HEIGHT OF STEM = 9'

THICKNESS OF WALL = 8"

WALL, VERT. REINF. (As) # 6 @ 16" O.C. = 0.33 in^2/ft



Loading Data

Service Loads

$H_{lat} = w_{lat}\ H$ = 9 x 30.8 = 0.277 kips/ft

$W_w = t \times H \times \lambda_m$ = 0.67 x 9 x 130/1000 = 0.78 kips/ft

Factored Loads

λH_{Lat} = 1.6 x 0.277 = 0.443 kips/ft

λW_w = 1.2 x 0.78 = 0.936 kips/ft

Check Flexure Capacity of Wall

$M = w_{Lat}\ H^2/2$ = 30.8 x 9^2 /2 = 1.25 ft-kips/ft

$P = W_w$ = 0.78 kips/ft

$M_{allowable} = 1/2 b_w kdF_b \{d - kd/3\} - P\{d - t_e/2\}$

$A_s\ F_s\{d - kd/3\} + P\{t_c/2 - kd/3\}$

MIN. VALUE CONTROLS

Where t_d = 7.63 in. Based on effective section area

d = 3.82 in. Based on TMS 402-08, 1.13.35

b_w = 12 in. — E_m = 1350 ksi

F_b = 0.495 ksi — E_s = 29000 ksi

F_s = 24 ksi — n = 21.48

A_s = 0.33 in2 — k = 0.54

p = 0.00034

$M_{allowable}$ = 1/2 x 12 x 0.54 x 3.82 x 0.495 {3.82 - 0.54 x 3.82/3} - 0.78 {3.82 - 7.63/2} =

21.06 in-kips/12 = **1.60 ft-kips**

APPENDIX B

CONVENTIONAL MORTARED BLOCK WALL
VS
O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

$M_{allowable}$ = 0.233 x 24 x {4 - .54 x 4/3} + 0.78{8/2 - .54 x 4/3} =

19.20 in-kips/12 = 2.38 ft-kips

1.60 ft-kips controls > 1.25 therefore OK

<u>Check Shear Capacity of Wall</u>

$V = \lambda H_{lat}$ = 0.443 kips/ft

$V_{allowable} = db_w\{f'_m{}^{1/2})$ 3.82 x 12(1500$^{1/2}$)/1000 = **1.77 kips/ft**

OK > 0.443 kips/ft

APPENDIX B

CONVENTIONAL MORTARED BLOCK WALL
VS
O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

DESIGN OF FREE STANDING MASONRY WALL

Trial 2 Input Data

TYPE OF MASONRY: **O'CONNOR BLOCK**

MASONRY STRENGTH $f'_m = 1.75$ ksi

CONCRETE STRENGTH $f'_c = 3$ ksi

REBAR YIELD STRESS $f_v = 60$ ksi

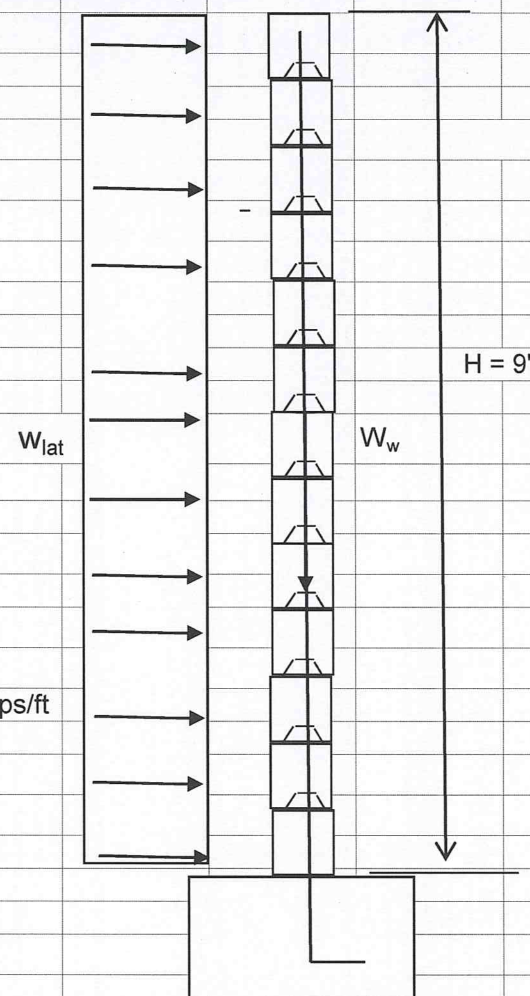
WIND PRESSURE $w_{lat} = 1/1.4 \times 0.7 \times .56 \times 110 =$ 30.8 psf

WEIGHT OF BLOCKS = 130 psf

HEIGHT OF STEM = 9'

THICKNESS OF WALL = 8"

WALL, VERT. REINF. (As) # 6 @ 16" O.C. = $0.33\ in^2/ft$



Loading Data

Service Loads

$H_{lat} = w_{lat} H$ = 9 x 30.8 = 0.277 kips/ft

$W_w = t \times H \times \lambda_m$ = 0.67 x 9 x 130/1000 = 0.78 kips/ft

Factored Loads

$\lambda H_{Lat} = 1.6 \times 0.277 = 0.443$ kips/ft

$\lambda W_w = 1.2 \times 0.78 = 0.936$ kips/ft

Check Flexure Capacity of Wall

$M = w_{Lat} H^2/2 = 30.8 \times 9^2/2 =$ 1.25 ft-kips/ft

$P = W_w =$ 0.78 kips/ft

$M_{allowable} = 1/2 b_w kdF_b \{d - kd/3\} - P\{d - t_e/2\}$

$A_s F_s\{d - kd/3\} + P\{t_c/2 - kd/3\}$

MIN. VALUE CONTROLS

Where t_d = 8 in. Based on effective section area

d = 4 in. Based on TMS 402-08, 1.13.35

b_w = 12 in.

F_b = 0.495 ksi	E_m = 1350 ksi
F_s = 24 ksi	E_s = 29000 ksi
A_s = 0.33 in2	n = 21.48
p = 0.00034	k = 0.54

$M_{allowable} = 1/2 \times 12 \times 0.54 \times 4.0 \times 0.495 \{4.0 - 0.54 \times 4.0/3\} - 0.78 \{4.0 - 8.0/2\} =$

21.06 in-kips/12 = **1.75 ft-kips**

CONVENTIONAL MORTARED BLOCK WALL
VS
O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

$M_{allowable}$ = 0.233 x 24 x {4 - .54 x 4/3} + 0.78{8/2 - .54 x 4/3} =

28.52 in-kips/12 = 2.38 ft-kips

1.75 ft-kips controls > 1.25 therefore OK

Check Shear Capacity of Wall

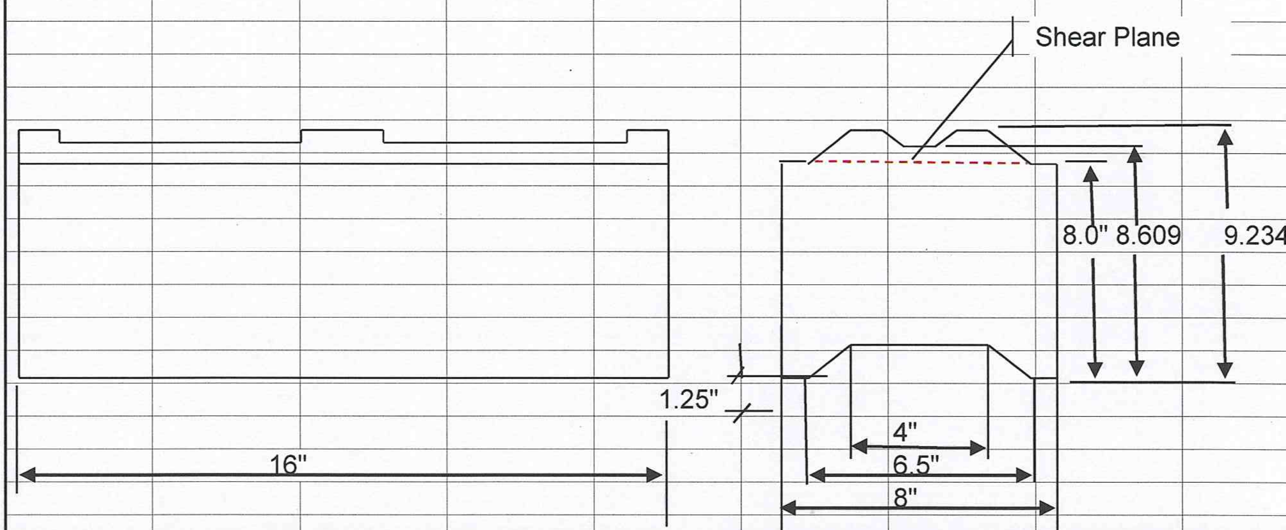
$V = \lambda H_{lat}$ = 0.443 kips/ft

$V_{allowable} = db_w\{f'_m{}^{1/2}\}$ 4 x 12($1750^{1/2}$)/1000 =

2.00 kips/ft

OK > 0.443 kips/ft

Check Shear Capacity of Single O'Connor Interlocking Dry Stacked Block Masonry System



APPENDIX B

CONVENTIONAL MORTARED BLOCK WALL
VS
O'CONNOR INTERLOCKING DRY STACKED BLOCK MASONRY SYSTEM

CONCLUSIONS:

ACI Code specifies that the nominal shear stress to be carried by concrete shall not exceed $2\ f'_c{}^{1/2}$ where f'_c = the compressive strenght of the concrete being used.

Using a compressive strength of 3,000 psi the shear stress shall not exceed a value of $2 \times 3{,}000^{1/2}$ or 110 psi

For a Type S mortar the compressive strength would =1,800 psi and thus the shear stress should not exceed 85 psi

Area of the shear plane =(6.5" x 1.25") x 2 + (6.5") x 2" +(11.5 x 1.25) x2 = 58in^2

Thus the allowable shear resistance of the block would be 110 x 58 or 6,380 lbs.

For a conventional mortared 8" CMU block the mortar bedding area would be 39 in^2

Thus the allowable shear resistance of the block would be 85 x 39 or 3,315 lbs.

Thus the O'Connor Interlocking Dry Stacked Block Masonry System has almost twice the shearing strength of a conventional mortared block.