FEASIBILITY OF USING CARBON FIBER REINFORCED POLYMER SHEETS ON CRACKED RESIDENTIAL FOUNDATION WALLS

PREPARED FOR STABL-WALL INCORPORATED
365 HIGHLAND ROAD EAST
MACEDONIA, OHIO 44056

PREPARED BY CRAMER ENGINEERING, LLC
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COMMON PROBLEMS ENCOUNTERED

1. Many foundations are leaking moisture from earth against the exterior of the walls.
2. The earth pressure has caused the concrete block (or clay tile in older foundations) to crack and bow inward. These cracks may be classed as “stair-step”, vertical, or horizontal.
3. The pressure from the ground freezing adds to the normal earth pressures and tends to cause horizontal cracks in the mortar joints usually in the area between 16 inches and 40 inches below exterior grade of earth. The magnitude of the pressure from freezing cannot be easily determined, but combined with the earth pressure clearly exceeds the ability of an unreinforced masonry wall to resist these forces.

CORRECTIVE MEASURES

Through the years, there have been several methods developed to stabilize these cracked walls. The more common methods are:

1. Install vertical steel beams or channels to transfer a part of the horizontal earth load to the basement floor slab and floor system above.
2. Cut out a vertical chase (12 inches – 16 inches wide) and create a reinforced concrete or masonry pilaster.
3. Cut out only a portion of the wall and place vertical reinforcing rods in the block cells. These are then grouted in another attempt to create a pilaster.
4. Core horizontal holes in the wall and install earth anchors horizontally to provide a tie-back system for resisting the earth pressure against the wall.
5. Remove and replace the entire damaged portions of the wall.

All of the above corrective measures are costly, messy and only partially successful at restraining a wall from further movement and cracking.

Also, none of these corrective measures address the basic engineering reason for the cracking, lack of tensile strength in masonry.

A NEW SOLUTION

This analysis will estimate the usual loads on three typical foundation walls and show by conventional engineering analysis that the carbon fiber reinforced polymer sheets can provide the required tensile strength for masonry walls needed to resist the earth loads.

The use of this material will not, nor is it intended to straighten walls, which are presently bowed.
This material is not intended to be used on walls, which have deflected inward more than 1.5-2 inches for a 12 course high wall. Walls with deflections greater than 2.0 inches must be evaluated for stability or replacement.

James Cramer, P.E.

**DESIGN BASIS**

**Stabwall Carbon Fiber Calculations**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Design capacity</td>
<td>100 pcf</td>
</tr>
<tr>
<td>Angle of repose</td>
<td>35 degrees</td>
</tr>
<tr>
<td>P = (1-SinΦ)/(1+SinΦ)</td>
<td>0.270990054</td>
</tr>
</tbody>
</table>

**Concrete Block Masonry**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fc'</td>
<td>2000 psi</td>
</tr>
<tr>
<td>Ec</td>
<td>2,000,000 psi</td>
</tr>
</tbody>
</table>

**Carbon Fiber Reinforced Polymer**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ft'</td>
<td>500,000 psi</td>
</tr>
<tr>
<td>Ec</td>
<td>30,000,000 psi</td>
</tr>
<tr>
<td>width</td>
<td>24 in</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.0787 in</td>
</tr>
</tbody>
</table>

**Typical 11 Course Block Wall**

**Dimensions**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of wall (till grade ELev.)</td>
<td>6.33 ft</td>
</tr>
<tr>
<td>Height of wall above grade</td>
<td>0.666666667 ft</td>
</tr>
<tr>
<td>Total Ht of wall</td>
<td>6.996666667 ft</td>
</tr>
<tr>
<td>H/3 (location of horizontal force)</td>
<td>2.11 ft</td>
</tr>
<tr>
<td>Pmax (soil)</td>
<td>171.5367043 ppcf</td>
</tr>
<tr>
<td>Horizontal force</td>
<td>542.913669 plf</td>
</tr>
<tr>
<td>Force at top of wall</td>
<td>RT 163.7276572 plf</td>
</tr>
<tr>
<td>Force at bottom of wall</td>
<td>RB 379.1860118 plf</td>
</tr>
<tr>
<td>Location of max bending</td>
<td>x 3.476156701 ft</td>
</tr>
<tr>
<td>Add location to the top of wall</td>
<td>4.142823368 ft</td>
</tr>
<tr>
<td>Max Moment</td>
<td>596.4309356 lbs-ft</td>
</tr>
</tbody>
</table>

**Concrete Masonry stress**

**Concrete masonry dimensions**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>12 in</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Depth</td>
<td>1.5 in</td>
</tr>
<tr>
<td>Area of Concrete, Ac</td>
<td>18 in²</td>
</tr>
<tr>
<td>Compression/Tension Force</td>
<td>1034.273299 lb/ft</td>
</tr>
<tr>
<td>Compressive Stress</td>
<td>57.45962771 psi/ft</td>
</tr>
<tr>
<td>Fiber Stress</td>
<td>1095.164442 psi</td>
</tr>
<tr>
<td>Factor of safety</td>
<td>3.5</td>
</tr>
<tr>
<td>Allowable fiber stress</td>
<td>142857.1429 psi</td>
</tr>
</tbody>
</table>
### Stabwall Carbon Fiber Calculations

**Soil Design capacity**
- 100 pcf

**Angle of repose**
- 35 degrees

\[ P = \frac{(1-\sin\Phi)}{(1+\sin\Phi)} \]
- 0.270990054

**Concrete Block Masonry**

- \( Fc' \)
- 2000 psi

- \( Ec \)
- 2,000,000 psi

**Carbon Fiber Reinforced Polymer**

- \( Ft' \)
- 500,000 psi

- \( Ec \)
- 30,000,000 psi

- **width**
- 24 in

- **Thickness**
- 0.0787 in

### Typical 12 Course Block Wall Dimensions

- **Height of wall (till grade E Lev.)**
- 7 ft

- **Height of wall above grade**
- 0.666666667 ft

- **Total Ht of wall**
- 7.666666667 ft

- **H/3 (location of horizontal force)**
- 2.333333333 ft

- **Pmax (soil)**
- 189.6930379 ppf

- **Horizontal force**
- 663.9256326 plf

- **Force at top of wall**
  - \( RT \)
  - 202.064323 plf

- **Force at bottom of wall**
  - \( RB \)
  - 461.8613096 plf

- **Location of max bending**
  - \( x \)
  - 3.861740991 ft

- **Add location to the top of wall**
  - 4.528407657 ft

- **Max Moment**
  - 813.9974659 lbs-ft

### Concrete Masonry stress

- **Concrete masonry dimensions**

  - **Width**
  - 12 in

  - **Depth**
  - 1.5 in

- **Area of Concrete, Ac**
  - 18 in²

- **Compression/Tension Force**
  - 1411.556299 lb/ft

- **Compressive Stress**
  - 78.4197944 psi/ft

- **Fiber Stress**
  - 1494.65936 psi

- **Factor of safety**
  - 3.5

- **Allowable fiber stress**
  - 142857.1429 psi
### Stablwall Carbon Fiber Calculations

- **Soil Design capacity**: 100 pcf
- **Angle of repose**: 35 degrees

\[
P = \frac{(1 - \sin \Phi)}{(1 + \sin \Phi)} = 0.270990054
\]

### Concrete Block Masonry
- **$F_c'$**: 2000 psi
- **Ec**: 2,000,000 psi

### Carbon Fiber Reinforced Polymer
- **$F_t'$**: 500,000 psi
- **Ec**: 30,000,000 psi

- **width**: 24 in
- **Thickness**: 0.0787 in

### Typical 13 Course Block Wall

**Dimensions**
- **Height of wall (till grade ELev.)**: 7.67 ft
- **Height of wall above grade**: 0.666666667 ft
- **Total Ht of wall**: 8.336666667 ft
- **H/3 (location of horizontal force)**: 2.556666667 ft
- **Pmax (soil)**: 207.8493715 ppf
- **Horizontal force**: 797.1023397 plf
- **Force at top of wall**: 244.4532165 plf
- **Force at bottom of wall**: 552.6491232 plf
- **Location of max bending**: 4.247527507 ft
- **Add location to the top of wall**: 4.914194174 ft
- **Max Moment**: 1079.063964 lbs-ft

### Concrete Masonry stress

- **Concrete masonry dimensions**
  - **Width**: 12 in
  - **Depth**: 1.5 in
- **Area of Concrete, Ac**: 18 in²
- **Compression/Tension Force**: 1871.209187 lb/ft
- **Compressive Stress**: 103.9560659 psi/ft
- **Fiber Stress**: 1981.373556 psi
- **Factor of safety**: 3.5
- **Allowable fiber stress**: 142857.1429 psi
TYPICAL 13 COURSE WALL - 3"
Recommended vertical Length
1. Use 24” above and below principal crack.
2. Typical panel 24” wide and 48” high.

Horizontal Spacing along wall
1. Center of first panel at each end of principal horizontal crack.
2. Space panels equally between end panels not to exceed 6 ft center to center of panels.

Typical Section of block wall
**Typical 8” Plain Concrete Wall**

- Soil Design capacity: 100 pcf
- Angle of repose: 35 degrees
- \[ P = \frac{1-\sin\Phi}{1+\sin\Phi} \]
  \[ P = 0.270990054 \]
- Concrete Block Masonry
  - \( F_c' \): 3000 psi
  - \( E_c \): 2,000,000 psi
- Carbon Fiber Reinforced Polymer
  - \( F_t' \): 500,000 psi
  - \( E_c \): 30,000,000 psi
- 8” Plain concrete wall
  - Width: 24 in
  - Thickness: 0.0787 in
  - Height of wall (till grade ELEV.): 7 ft
  - Height of wall above grade: 0.666666667 ft
  - Total Ht of wall: 7.666666667 ft
  - \( H/3 \) (location of horizontal force): 2.333333333 ft
  - \( P_{\text{max}} \) (soil): 189.6930379 ppf
  - Horizontal force: 663.9256326 plf
  - Force at top of wall (RT): 202.064323 plf
  - Force at bottom of wall (RB): 461.8613096 plf
  - Location of max bending (x): 3.861740991 ft
  - Add location to the top of wall: 4.528407657 ft
  - Max Moment: 654.9229345 lbs-ft
  - Tension stress: 61.39902511 psi
  - \( F_{\text{cr}} \) - compression stress: 410.7919181 psi
  - \( C=T \): 982.3844017 lb
  - Area of reinforcement: 0.000491192 in²
  - \( L = \text{spacing} \): 0.006241324
Note:
Tensile stress is less than 100 psi, therefore cracking due to earth loads alone should not occur. After a crack has formed, the concrete can no longer provide tension, therefore the use of carbon fiber reinforced polymer sheets can be applied to provide the required tensile force.
**Recommended Use:**

Horizontal Cracks:
1. 2'-0" square panels centered 12" above and below the crack.
2. Space panels at 6'-0" center to center along the length of the wall.

Vertical Cracks:
1. 2'-0" square panels centered 12" on either side of the crack.
2. Space panels at 4'-0" center to center vertically.

Diagonal Cracks:
1. 2'-0" square panels. Set top of panel parallel to top of wall and center line of panel at center of crack.
2. Space panels at 5'-0" center to center along the crack.
TYPICAL STAIRCASE CRACK DETAIL