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
COMMON PROBLEMS ENCOUNTERED

1. Many foundations are leaking moisture from the 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 the exterior grade of the 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 the 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 1.5-2.0 inches for a 12 course high wall. Walls with deflections greater than 2.0 inches must be evaluated for stability or replacement.

Kenneth W. Jensen, P.E., P.S.

BASIS FOR DESIGN

Earth-Average Weight

\[ P = \frac{1}{1 + \sin \phi} \]

100 P.C.F.  
\( \phi = 35^\circ 00' \)

Angle of Repose

Concrete Block Masonry

F'c = 2000 P.S.I.  
Ec = 2,000,000 P.S.I.

Carbon Fiber Reinforced Polymer

F't = 500,000 P.S.I.  
Ec = 30,000,000 P.S.I.  
Width 24 Inches  
Thickness (2mm) = 0.0787 Inches

Adhesive—See Attached Sheet
TYPICAL 11 COURSE WALL

SEE P. 2

\[ P_{max} = 0.271 \times 100 \times 0.55 \]
\[ = 172 \text{ PPF} \]

\[ P_n = 0.5 \times 172 \times 0.35 \]
\[ = 54.3 \text{ kip/ft} \]

\[ R_f = 54.3 \times 2.11 \times 1 \]
\[ = 164 \text{ PPF} \]

\[ R_b = 54.3 - 164 = 379 \text{ PPF} \]

**MAXIMUM BENDING**

\[ x = 3.47 + 0.67 = 4.14' \]

\[ M = 164(4.14) - 0.5(29.17)(3.47)^{\frac{3}{2}} \]
\[ = 625.14 \text{ ft-lb/ft} \]

**N.A.**

18 (0.75) = 13.50

14.17 (4.67) = 108.68

32.17 (3.80) = 122.18

\[ A_c = 18.01 \text{ in}^2 \]

\[ N.A. = 12(0.08) \times 15 \]
\[ = 14.17 \text{ in}^2 \]
Concrete Masonry Stress

\[ C = T = \frac{625(12)}{12.92} \]
\[ = 1084 \text{ kPa} \]
\[ f_c = \frac{1084}{18} = 60.2 \text{ psi} \]
\[ f_f = \frac{1084}{12(0.078)} = 1148 \text{ psi} \]

Allowable \( f_f = \frac{500000}{3.5} = 142857 \text{ psi} \)
(Safety Factor \( = 3.5 \))

Typical 12 Course Wall

SEE P. 9

\[ P_{\text{max}} = 0.2710(100)(7.00) \]
\[ = 190 \text{ PPF} \]
\[ P_h = 0.5(190)(7) = 665 \text{ kPa} \]
\[ P_t = 665(2.33) \div 7.67 \]
\[ = 202 \text{ PPF} \]
\[ P_{\text{ff}} = 465 \text{ PPF} \]

Maximum Bending

\[ x = 3.86 + 0.67 = 4.53' \]
\[ \mu = 202(4.53) - 0.5(27.14)(3.86)^{1/2} \]
\[ = 814 \text{ kPa} \]
\[ C = T = \frac{814(12)}{6.92} = 1412 \text{ kPa} \]
Typical 13 Course Wall

See P. 10

\[
\begin{align*}
  \Phi_{ax} &= 0.2710(100)(7.67) = 20.8 \text{ PPF} \\
  \Phi_{h} &= 0.5(20.8)(7.67) = 7.97 \text{ #/ft} \\
  \Phi_{t} &= 7.97(2.56)/8.33 = 2.85 \text{ PPF} \\
  \Phi_{13} &= 5.52 \text{ PPF}
\end{align*}
\]

Maximum Bending

\[
\begin{align*}
  h &= 4.25 + 0.67 = 4.92' \\
  M &= 20.8(4.92) - 0.5(27.12)4.25' = 901 \text{ #/ft} \\
  C &= T = 901(12)/6.92 = 1562 \text{ #/ft} \\
  f_c &= 1562/18 = 86.8 \text{ PSI} \\
  f_f &= 1562/0.94 = 1642 \text{ PSI}
\end{align*}
\]

Recommend Vertical Length

Use 24" Above and Below

Principal Course

Typical Panel 24" Wide
4'8" 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 feet center to center of panels.
WALL ASSEMBLY

FLOOR SYSTEM

FIN. GIZADE

"ACTIVE" SOIL WEDGE

SOIL PRESSURE DIAGRAM

190 #11 = Pmax

P# = 665 #11

X = 9.53'

1/2" = 1'-0"

TYPICAL 12 COURSE WALL - 8"
TYPICAL 13 COURSE WALL 8''
TYPICAL 8" PLAIN CONCRETE WALL

SEE P. 5

\[ P_{\text{MAX}} = 0.2710(100)(7,0) = 190 \text{ PPF} \]
\[ P_h = 0.5(190)(7) = 665 \text{ PPF} \]
\[ P_r = 665(2.33)/7.67 = 202 \text{ PPF} \]
\[ P_b = 665 - 202 = 463 \text{ PPF} \]

MAXIMUM BENDING MOMENT

\[ x = 3.86 + 0.67 = 4.53' \]
\[ M = 202(4.53) - 202(3.86)/2 \]
\[ = 550 \text{ ft-lb} \]

CHECK FOR TENSION

\[ f_{t} = 665(12)(4)/512 = 61.4 \text{ PSI} \]
\[ f_{cr} = 7.5(3000)^{1/2} = 411 \text{ PSI} \]

COMMENT

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 STEEL FIBER REINFORCEMENT IS RECOMMENDED.
Sheets can be applied to provide the required tensile force. Required reinforcement:

\[ M = 655 (12) = 7860 \text{ in. lb} \]
\[ C = T = 7860 / 8 = 982.5 \text{ in.}^2 \]

Area of carbon fiber reinforced polymer per foot of wall:

\[ A = 982.5 / 20000 = 0.0049 \text{ in.}^2 \]
\[ L = 0.0049 / 0.08 = 0.06 \text{ in.} / \text{ ft.} \]

Recommended use:

**Horizontal Cracks**

1. 2'-0" square panels centered 12" above & below the crack.

2. Space panels at 6'-0" center along length of wall.

**Vertical Cracks**

1. 2'-0" square panels centered 12" on either side of the crack.

2. Space panels at 4'-0" 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" CENTERS TO CENTER ALONG THE CRACK.

TYPICAL SPACING FOR DIAGONAL CRACK

CARBON REINFORCED POLYMER SHEET 2'-0" X 2'-0"

FLOOR

CRACK
**SPEC DATA SHEET**

**PART #** 289U-24HM | **ITEM #** FCU12HM-300-6L

**DESCRIPTION:** FABRIC 100% Carbon-Uni 300g/6.9oz/60cm/24" w/Hotmelt, 12k warp&3ends, 5pic glass fill

**PACKAGING:** Fabric tightly wound onto 3" i.d. cardboard tube, wrapped in clear plastic packaged into double-walled 330/psi test cardboard boxes, roll is suspended in center of box by end-plates on both ends of tube, roll held tight in box by cardboard spines filling free end-play.

**SPEC TYPE** | **SPEC DESCRIPTIONS** | **DEFINITIONS**
--- | --- | ---

**"FABRIC"** | **"FABRIC "U.S." SPECS:** | **"FABRIC "METRIC" SPECS:** | **FABRIC DEFINITIONS:**
--- | --- | --- | ---
Areal Weight | oz/yd² = 8.9 oz. | g/m² = 300 gr. | The weight of the fabric per square meter or square yard.
Fabric Width | inches = 24" | cm = 50 cm | The width of the fabric in US inches, width in centimeters.
Thickness: Dvl/amine | inch = NA | mm = NA | Thickness in inches or millimeters.
Roll Length | yards (+/-) = 100 yd.(+/-2) | meters(+/-) = 91 m.(+/-1.5) | Roll linear length, plus/minus tolerance.

**"WEAVE"** | **WEAVE DETAIL SPECS:** | **WEAVE DEFINITIONS:**
--- | --- | ---
Style / Pattern | WARP = Uni Carbon, "Commercial" | | Weave style or pattern of woven fabric or material.
WARP "Ends" | Count/inch = 12 ends/in. | Count/meter = 472 ends/m. | Lengthwise direction fiber count.
FILL "Picks" | Count/inch = 5 pics glass fill | Count/meter = ND | Width / Across direction fiber count.
Fill Style | Type = NA | Stitch detail = NA | Lengthwise stitching style & fabric edge
Edge Fiber | Type = NA | Denier = NA | Type of fiber used in lengthwise stitching.
Edge Fiber | Type = NA | Denier = NA | Length of the fibers outside the usable fabric area.
Tracers "TYPE" | Material = NONE | Count/inch = NA | Fibers of different type & pattern inserted into weave.

**FIBER"** | **FIBER DESCRIPTION SPECS:** | **FIBER DEFINITIONS:**
--- | --- | ---
Manufacturer / Source | Carbon Composites | Name of Fiber producer, or "other" company name.
Type / Model | WARP & FILL = "Commercial" 12k - w/ Hotmelt | Fiber manufacturers product or ID number.
Tow (% if Carbon) | Warp = 12k | Fill = Hotmelt | Continuous filaments per fiber bundle. (K = 1000)
Denier Size (Kevlar etc) | Warp = NA | Fill = NA | The number of grams per 9,000 m meters.
Famenet Count | Warp = 12,000 | Fill = NA | The number of filaments per tow.
Filenet Diameter | Warp = ND | Fill = ND | The diameter of the filament.
Density | lb/ft³ NA | g/cm³ NA | g/cm³ = 1.76 | Mass per unit volume in². Typically grams per cm cubed.
Yield | yd²/lb = NA | g/m² = ND | Measurement of the amount of mass per unit length.
Tensile Strength: (min) | kg/mm² = 514 | Mpa = 3350 | The force at which fiber breaks measured by the area width.
Tensile Modulus: (min) | Ton/mm² = 33.4 | Gpa = 230 | Measurement of the elastic stiffness.
Tensile Strain: (min) | % = 1.3 | % Tension recovery percentage of original size and length.
Biaxial Recovery | % = 100% | | Square surface area of material per unit of weight.
Surface Area | m²/g = NA | | Percentage of chemical treatment versus total fiber weight.
Sizing Level | % = ND | | Sizing resin system compatibility name.
Sizing Type | Name = Epoxy Compatable | | Electrical resistance in ohms per length specified.
Sizing, Solubility | ohms/cm = ND | | Electrical resistance in ohms per cross-sectional area.
Electrical Conductance | ND | | Percentage of actual carbon content in fiber.
Carbon Assay | % = 92 - 96% | | Compare Density: Water has a Specific Gravity of 1.0
Specific Gravity | g/cm³ = ND | | Ability to conduct heat along a parallel axis.
Longitudinal Thermal Conductivity | ND | | If Certified then give Certification Speed"s.

**CERTIFIED: Yes/No:** NO | Spec Name = NA

**KEY:** "NA" = Not Applicable; "ND" = No Data
## EXHIBIT A
PRODUCT SPECIFICATIONS

### Stabi-Wall Reinforcing Fiber

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MINIMUM VALUE</th>
<th>GOVERNING TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>500,000 psi</td>
<td>ASTM D3039</td>
</tr>
<tr>
<td>Tensile Strain</td>
<td>1.5%</td>
<td>ASTM D3039</td>
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<td>Roll Width</td>
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<td>Roll Length</td>
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</table>

### Stabi-Wall Adhesives: MINIMUM VALUES

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Stabi-Wall Primer</th>
<th>Stabi-Wall Paste Filler</th>
<th>Stabi-Wall Bonding Adhesive</th>
<th>Governing Test Method</th>
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<td>Color</td>
<td>Amber</td>
<td>Tan</td>
<td>Amber</td>
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</tr>
<tr>
<td>Part A</td>
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<td>Charcoal</td>
<td>Clear</td>
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<tr>
<td>Part B</td>
<td>Amber</td>
<td>Tan</td>
<td>Amber</td>
<td>None</td>
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<tr>
<td>Mixed</td>
<td>Amber</td>
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<td>Mix Ratio (Volume)</td>
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<td>3:1</td>
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<tr>
<td>Part A:Part B</td>
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<td>30 minutes</td>
<td>35 minutes</td>
<td>1 Gallon Sample</td>
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<td>Working Time @ 70 °F</td>
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<tr>
<td>Shelf Life</td>
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<tr>
<td>Tensile Strength</td>
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<td>0.05</td>
<td>0.03</td>
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<tr>
<td>Tensile Modulus</td>
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<td>230,000 psi</td>
<td>400,000 psi</td>
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