FIBERGLASS REBAR IN CAST-IN-PLACE RESIDENTIAL WALLS

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Fiberglass Rebar in Cast-In-Place Residential Walls

Description:

Fiberglass Rebar has already established itself as an economical installed reinforcing material versus traditional carbon steel in residential/commercial slab-on-ground applications, and now it can be properly implemented into the vertical wall systems as well. Using a blending of the ACI 332 code for structural concrete along with the ACI 440 guide for fiberglass rebar design, the path to using this cost saving material is now readily available. In addition to being structurally capable of meeting the project demands, fiberglass rebar also offers the opportunity to save money due to its lower installed cost versus steel and the improved durability that comes with a non-corrosive product. In this session we will learn about the material properties of fiberglass rebar, how the material design is completed, and what the potential labor ramifications are to the owner and contractor. In addition, a readily available software tool that streamlines the process will be on display to exhibit the ease of conversion.

Learning Objectives:

- Recognizing the material benefits of fiberglass rebar
- Understanding the design of vertical poured basement walls using existing codes/guides
- Learning about the potential cost benefits of fiberglass rebar in this space
- Seeing firsthand a demonstration of design software for proper implementation

OWENS CORNING

We build market leading businesses – global in scope, human in scale

COMPANY HISTORY

1938

19,000 EMPLOYEES

33 COUNTRIES WHERE WE OPERATE

66 CONSECUTIVE YEARS AS A FORTUNE® 500 COMPANY

COMPANY FINANCIALS

$7.2 BILLION IN SALES

2019 REVENUE

2019 Composites Business Revenues:

$2 billion

MARKET LEADING BUSINESSES

ROOFING

INSULATION

COMPOSITES

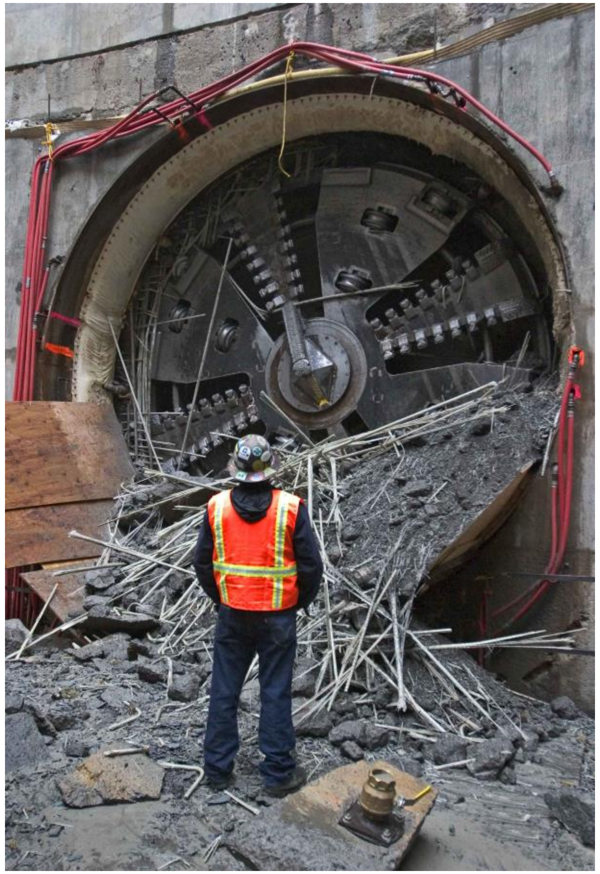
PRODUCT OFFERING

PINKBAR® Fiberglas™ Rebar

Owens Corning® MATEENBAR™ Fiberglas™ Rebar and Fiberglas™ Dowel Bars

WHY AND WHERE SHOULD FIBERGLASS REBAR BE USED?

- **Concrete structures susceptible to corrosion:**
  - Steel corrosion by chlorides / salts
  - Aggressive agents that lower concrete Ph
  - Slender structures with minimum cover concrete
- **Concrete structures requiring non-ferrous reinforcement due to:**
  - Electro-magnetic considerations
  - Thermal non-conductivity
- **Where machinery will "consume" the reinforced concrete member (i.e., mining and tunneling)**
- **In low demand applications, where labor savings can result in project savings while also providing a longer lasting element**



KEY BENEFITS COMPARED TO TRADITIONAL REBAR

- **Extended Service Life**
    - **Improved Durability**
    - **No Corrosion means no spalling/concrete degradation**
- Ease of Installation
- Higher Tensile Strength
- No need for expensive overlays or admixtures
- **Labor Savings**
    - **Lightweight – 1/4th of steel**
    - **Upwards of 50% reduction of man hours**
- Improved Working Conditions
- Transparent to magnetic fields
- Electrically & thermally non-conductive
- **More Stable Pricing**

CONCRETE REINFORCEMENT MARKET SEGMENTS

Each segment involves specific opportunities for steel rebar replacement

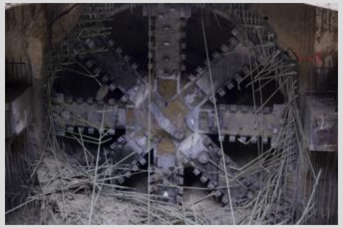
Heavy-Load Structural

- Structure failure has risk for human lives
- Under Codes & Standards

Higher Load Demand

- Building skeletons (incl. foundation)
- Bridges
- Piles
- Tunnel segments
- *Soft-eyes (temporary)*





Lower Load Demand

- Sea walls
- Dowel bars
- Industrial floors
- Tram slabs
- Rail plinths



Residential/Light Commercial

- Structure failure has no risk for human lives
- May be under Codes & Standards (depends on country)

- House foundations
- Basement walls
- Wall/façade panels
- Commercial floors




- Parking and driveways (flatwork)
- Roads
- Precast architectural elements
- Canals

Temperature & shrinkage reinforcement



FIBERGLASS REINFORCEMENT SOLUTIONS – MULTIPLE PRODUCTS

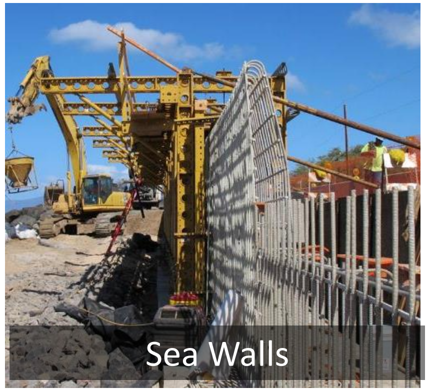
CIVIL / HEAVY CONSTRUCTION

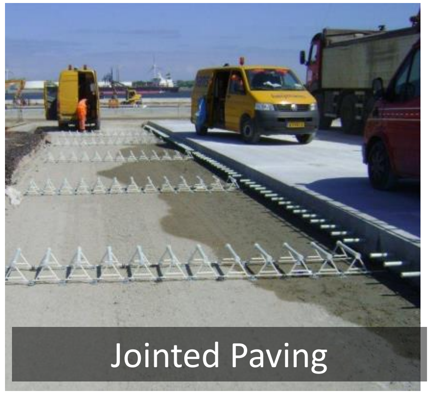
20+ YEARS

- ASTM D7957 Fiberglass Rebar
  - Durable, economic concrete reinforcement solutions vs. corrosion resistant steel reinforcement
  - Owens Corning® MATEENBAR™ Fiberglas™ Rebar
  - Owens Corning® Fiberglas™ Dowel Bars

General Concrete Reinforcement


Bridge Decks


Sea Walls


Jointed Paving

RESIDENTIAL / LIGHT COMMERCIAL

- Economic solution for crack mitigation vs. black steel in slab-on-ground applications
- Residential Walls and Footings
- PINKBAR® Fiberglas™ Rebar

Always Demand an ASTM D7957 Compliant Product!

Crack Mitigation and Residential Walls

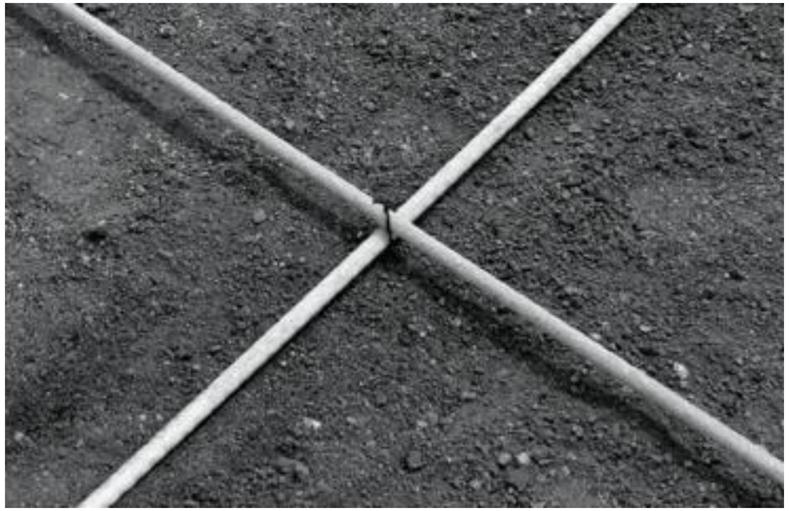

Agricultural Pads

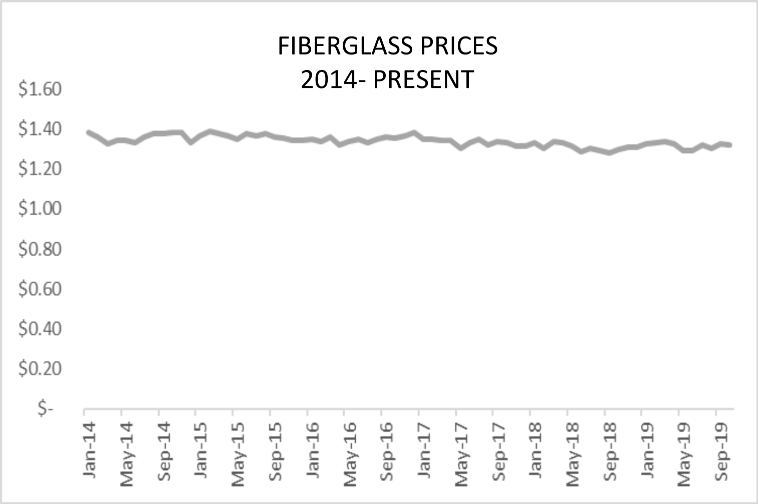

Driveways


Industrial Pads

Owens Corning purchased Hughes Brothers in 2017. OC has been a major supplier of continuous filament glass fibers to the fiberglass rebar industry for 20+ years.”

VALUE PROPOSITION





No Corrosion

- More Durable
- Less Cost for Owners

4x Less Weight 1:1

- Faster Installation
- Easier to Haul
- More Jobs & Revenue

Lower Installed Cost, Stable Price

- More Money in Wallet

RESIDENTIAL WALLS

- Cast in place concrete “Basement” Walls
- Single mat reinforcement
- Designed as an “Uncracked Section”
- Structural by nature

WHY IS THIS “STRUCTURAL CONCRETE” ?

- Forces applied to the house are supported by the foundation walls & footings
  ✓Snow Loads
  ✓Wind
  ✓Furnishings & Occupants (Parties)
- Earth pressure from the soil outside the basement walls
  ✓Hydraulic pressure from moisture
  ✓Freeze Thaw
- Due to structural nature and differing material properties, a direct replacement or a downsizing may NOT be appropriate with fiberglass rebar
- Structure should be designed and adhere to applicable codes and standards

GUIDE TO RESIDENTAL CONCRETE CONSTRUCTION (ACI 332.1R-18)

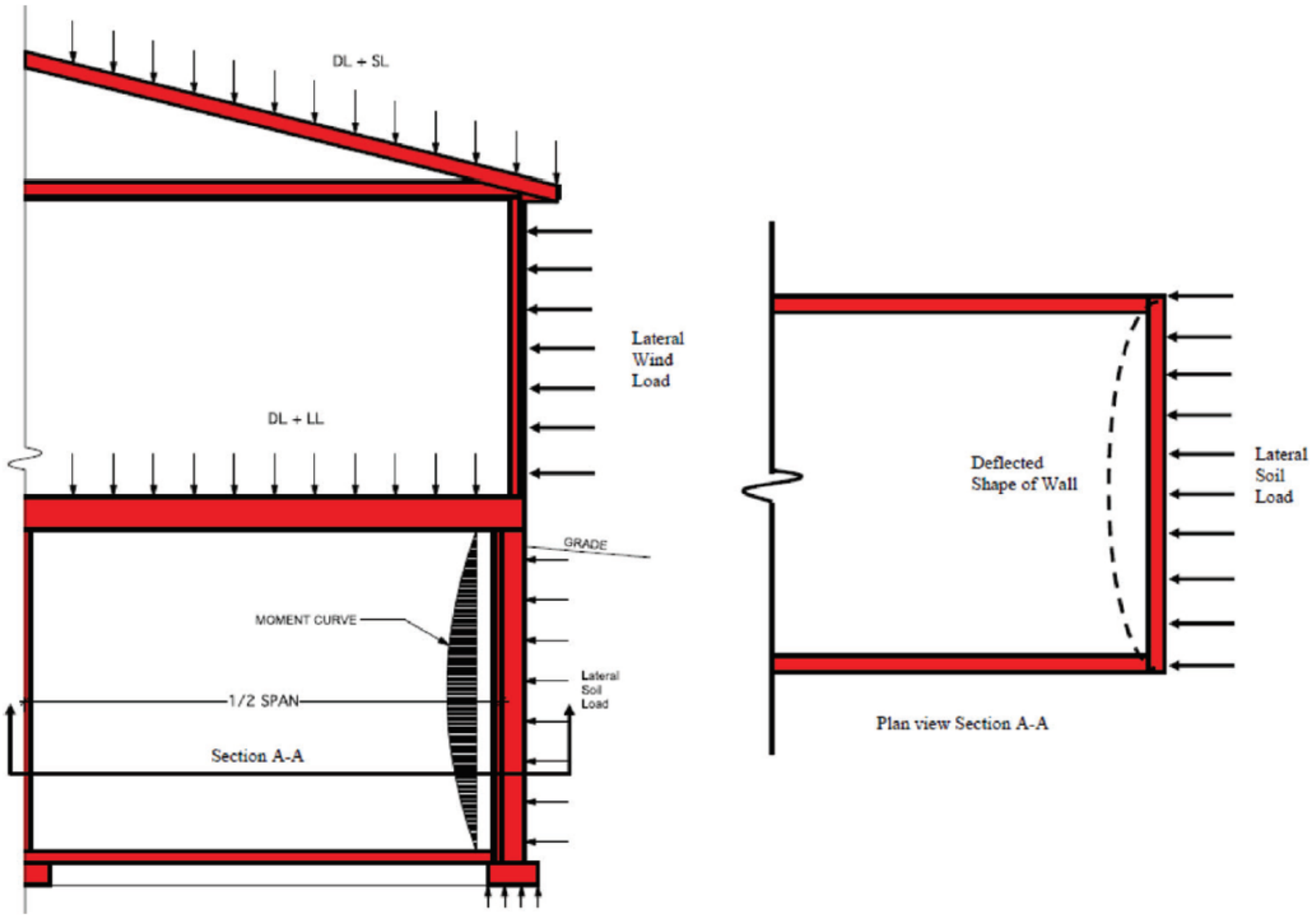


Fig. 4.3.1.1—Load diagram.

CODES & STANDARDS

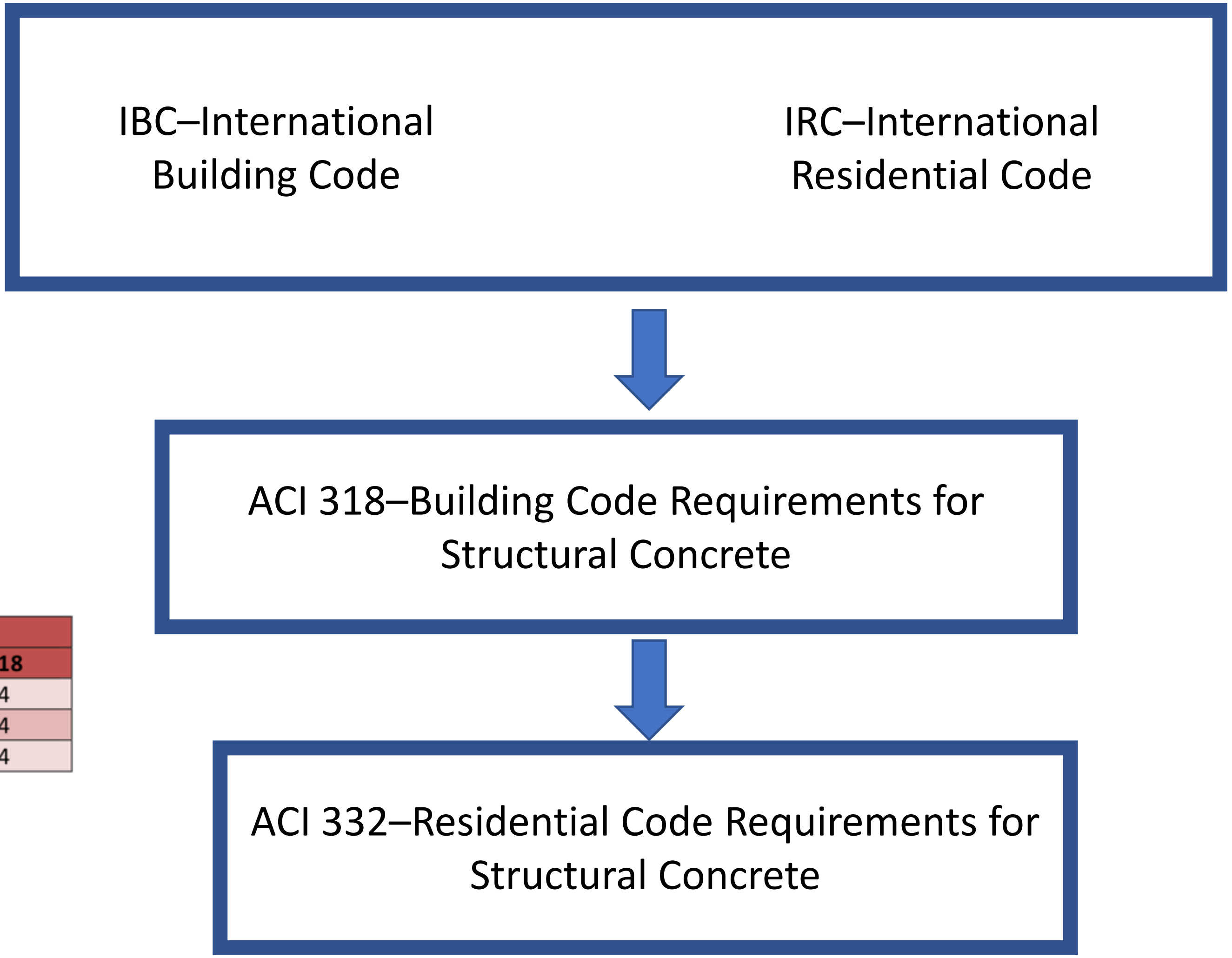


Table 3 – Editions of ACI Documents Referenced in the IBC and IRC

ACI Document	Editions of the IBC and IRC					
	2003	2006	2009	2012	2015	2018
216.1	97	97	07	07	14	14
318	02	05	08	11	14	14
332	NA[1]	NA[1]	08	10	14	14

[1] ACI 332 was not available prior to the 2008 edition.

ACI 332 – PROVIDES PRESCRIPTIVE DESIGN TABLES

R4.2—Reinforcement

R4.2.1 Refer to Table R4.2.1 for properties of bars.

Table R4.2.1—Steel reinforcing bar information

Bar size, no.	Nominal diameter, in.	Nominal area, in.^{2}	Nominal weight, lb/ft	Development length ($30d_b$), in.
3	0.375	0.11	0.376	11.25
4	0.500	0.20	0.668	15.00
5	0.625	0.31	1.043	18.75
6	0.750	0.44	1.502	22.50

Based on ACI 318 and using steel rebar

In the vast majority of homes, the “engineering” of the wall has already been done by ACI 332.

ACI 332 – PROVIDES PRESCRIPTIVE DESIGN TABLES

An ACI Standard

Residential Code Requirements for Structural Concrete (ACI 332-14) and Commentary

Reported by ACI Committee 332

ACI 332-14

American Concrete Institute
Always advancing

CODE | COMMENTARY

(f) One layer of vertical reinforcement placed at the tensile face, maintaining concrete cover in accordance with Item (b) of construction requirements

Table 8.2.1.3a—Vertical reinforcing bar spacing for concrete basement walls

	f_c' = 2500 psi		Maximum equivalent fluid pressure of soil, psf/ft											
	f_y = 40,000 psi		30			45			60			100		
			Minimum wall thickness, in.			Minimum wall thickness, in.			Minimum wall thickness, in.			Minimum wall thickness, in.		
Unsupported wall height, ft	Unbalanced backfill, ft	Reinforcing bar	7.5	9.5	11.5	7.5	9.5	11.5	7.5	9.5	11.5	7.5	9.5	11.5
8	5	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
	6	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	12	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	18	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	26	Plain	Plain
	7	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	14	Plain	Plain	8	11	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	22	Plain	Plain	13	17	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	31	Plain	Plain	18	24	Plain
9	5	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	17	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	26	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	37	Plain	Plain
	6	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	11	15	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	17	22	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	24	31	Plain
	7	No. 4 @ ... in.	Plain	Plain	Plain	17	Plain	Plain	13	Plain	Plain	8	10	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	27	Plain	Plain	20	Plain	Plain	12	16	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	37	Plain	Plain	28	Plain	Plain	17	22	Plain
	8	No. 4 @ ... in.	Plain	Plain	Plain	13	Plain	Plain	10	13	Plain	6	8	9
		No. 5 @ ... in.	Plain	Plain	Plain	20	Plain	Plain	15	20	Plain	10	12	15
		No. 6 @ ... in.	Plain	Plain	Plain	28	Plain	Plain	21	28	Plain	14	16	21
10	5	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	16	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	25	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	35	Plain	Plain
	6	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	17	Plain	Plain	10	14	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	27	Plain	Plain	16	21	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	37	Plain	Plain	22	29	Plain
	7	No. 4 @ ... in.	Plain	Plain	Plain	16	Plain	Plain	12	Plain	Plain	7	9	12
		No. 5 @ ... in.	Plain	Plain	Plain	25	Plain	Plain	18	Plain	Plain	11	14	18
		No. 6 @ ... in.	Plain	Plain	Plain	35	Plain	Plain	26	Plain	Plain	15	20	25
	8	No. 4 @ ... in.	18	Plain	Plain	12	Plain	Plain	9	12	Plain	6	7	9
		No. 5 @ ... in.	27	Plain	Plain	18	Plain	Plain	13	18	Plain	10	11	13
		No. 6 @ ... in.	38	Plain	Plain	25	Plain	Plain	19	25	Plain	14	15	19
	9	No. 4 @ ... in.	14	Plain	Plain	9	12	Plain	7	9	11	5	5	7
		No. 5 @ ... in.	21	Plain	Plain	14	19	Plain	10	14	17	8	8	10
		No. 6 @ ... in.	30	Plain	Plain	20	26	Plain	15	20	24	11	12	14

Notes:
a) The term "plain" refers to concrete where no vertical reinforcement is required other than reinforcement consistent with 8.2.7 and where horizontal reinforcement is required in accordance with 8.2.8 and 8.2.9.
b) This table is applicable to walls of specified height, unbalanced backfill height, equivalent fluid pressure of soil, concrete strength, and the yield strength of reinforcement.
c) This table is applicable only when the structure is not assigned to SDC D, E, or F.
d) Values in this table are derived in accordance with ACI 318 and 8.2.

ACI 332 – WHAT ARE THE VARIABLES

- **Wall Height**
  - Unsupported Wall Height
  - Backfill Height
- Concrete Strength
- Rebar Grade
  - Rebar Size
  - Rebar Spacing
- **Wall Thickness**
- Maximum Earth Pressure of soil

CODE | **COMMENTARY**

(f) One layer of vertical reinforcement placed at the tensile face, maintaining concrete cover in accordance with Item (b) of construction requirements

Table 8.2.1.3a—Vertical reinforcing bar spacing for concrete basement walls

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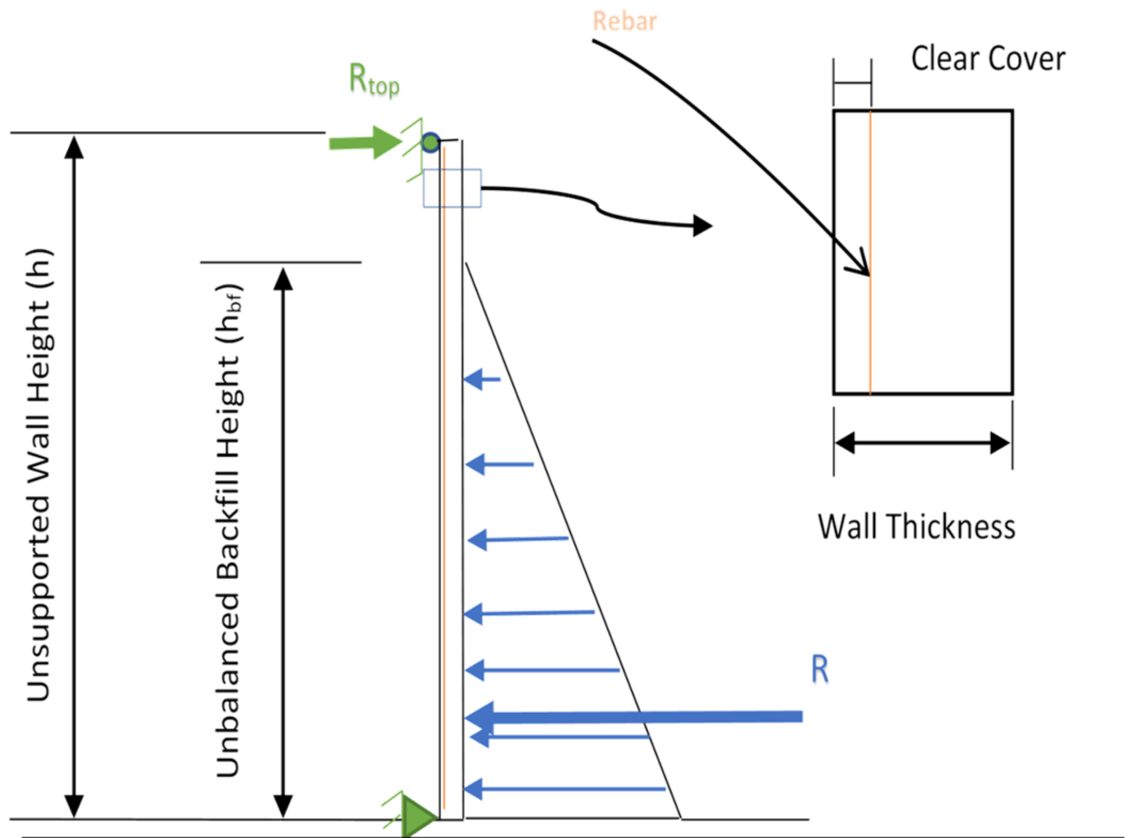
			Minimum wall thickness, in.			Minimum wall thickness, in.			Minimum wall thickness, in.			Minimum wall thickness, in.		
Unsupported wall height, ft	Unbalanced backfill, ft	Reinforcing bar	7.5	9.5	11.5	7.5	9.5	11.5	7.5	9.5	11.5	7.5	9.5	11.5
8	5	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
	6	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	12	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	18	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	26	Plain	Plain
	7	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	14	Plain	Plain	8	11	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	22	Plain	Plain	13	17	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	31	Plain	Plain	18	24	Plain
9	5	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	17	Plain	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	26	Plain	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	37	Plain	Plain
	6	No. 4 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	11	15	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	17	22	Plain
		No. 6 @ ... in.	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain	24	31	Plain
	7	No. 4 @ ... in.	Plain	Plain	Plain	17	Plain	Plain	13	Plain	Plain	8	10	Plain
		No. 5 @ ... in.	Plain	Plain	Plain	27	Plain	Plain	20	Plain	Plain	12	16	Plain

DESIGN PHILOSOPHY

- Simply Supported
- Triangular Soil Load
- Fiberglass rebar vertical and horizontal reinforcement
- Design Aspects:
  - Strength
  - Deflection
  - Creep Rupture
  - Crack Control



$$w = b\gamma h_{bf}, \gamma = Max\ equivalent\ Fluid\ Pressure\ of\ Soil$$

HOW TO IMPLEMENT FIBERGLASS REBAR

- Use prescriptive ACI 332 guide based on ACI 318
  - Adapt for fiberglass rebar using ACI 440
- 332 presently uses A 615 Steel
  - We use ASTM D7957 as called for by 440.1R
- Project Specific Requirements:✓Meet Strength and Serviceability demands from ACI 332
  - Satisfy ACI 440.1R
- Provide Building Code Official/Engineer/Owner with supporting calculations for the specific variables. i.e. justification for use

STRENGTH COMPARISON BETWEEN STEEL REBAR AND FIBERGLASS REBAR:

Geometrical Properties:

- Wall thickness (t)= 7.5 in
- Clear cover (cc) = 0.75 in

Concrete:

- Concrete compressive strength (f'c)= 3 ksi
- β1=0.85 (at crushing)
- Ec = 57√3000 = 3122.02 ksi

GFRP bar:

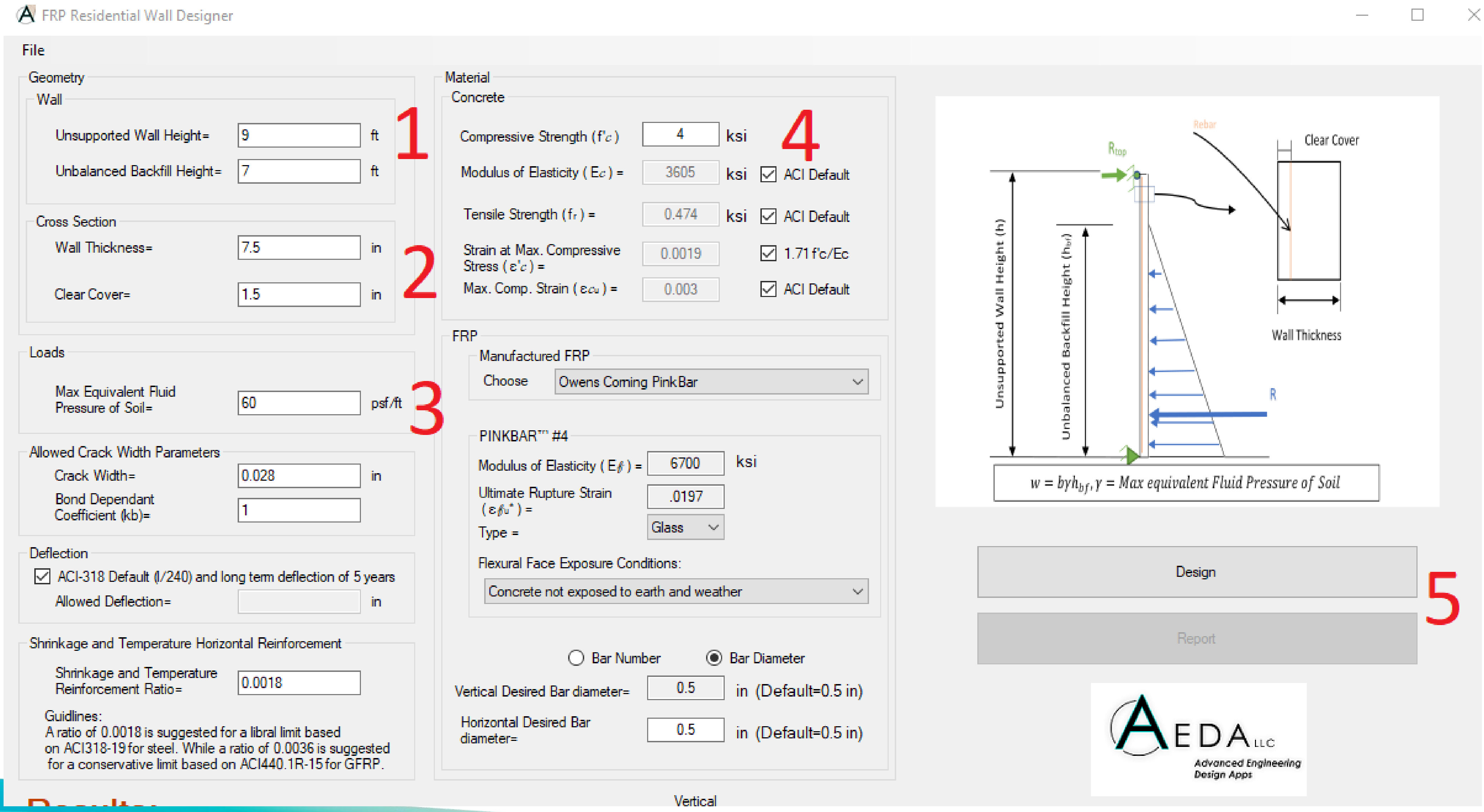
- Bar designation number = #4
- Bar diameter = 0.5 in
- Bar Area= 0.2 in2
- FRP modulus of elasticity (Ef)= 6500 ksi
- FRP ultimate tensile force (Ffu *) = 21.6 kips
- FRP ultimate tensile stress (ffu *) = 108 ksi

Steel	Fiberglass Rebar
$0.85 * f'b\beta\ c\ c1$ $A_s =$ y $f'c\ \rho_s = 0.85\ c\ \beta_1$ f $c = 0.276\ in$ $f d\ y$	$f'c\ \rho_f = \alpha\ c$ $\varepsilon_{fu} = 0.0133\ c = 0.49\ in$ $\varepsilon_{cf} = \varepsilon_{fu}\ c = 0.00108\ d-c$ $f d\ y$ $\alpha = \varepsilon_{cf} - 1\ (\varepsilon_{cf})2$ $\varepsilon'c\ 3\ \varepsilon'c\ 1-1\ \varepsilon_{cf}$ $\beta = 2\times 3\ 12\varepsilon'c\ 1\ 1-1\varepsilon_{cf}\ 3\ \varepsilon'c$ $\alpha = 0.5246$ $\beta = \beta_1 = 0.3575\ 2$
$\rho_s = 0.0015315$	$\rho_f = 0.00137$
$M = \phi\rho f bd2(1-\beta_1 c)\ usy2d2$ $M_u = 0.7*0.0015315*60*12*7.5*(1-$ $0.85\ 0.276)$ $2\ 7.5$	$M = \phi\rho f\ bd2(1-\beta_1 c)$ $u\ ffu\ 2d\ 2$ $M_u = 0.55*0.00137*0.8*108*12*7.5$ $*\ (1-0.3575\ 0.49)\ 7.5$
$M_u = 32k.in$	$M_u = 32k.in$

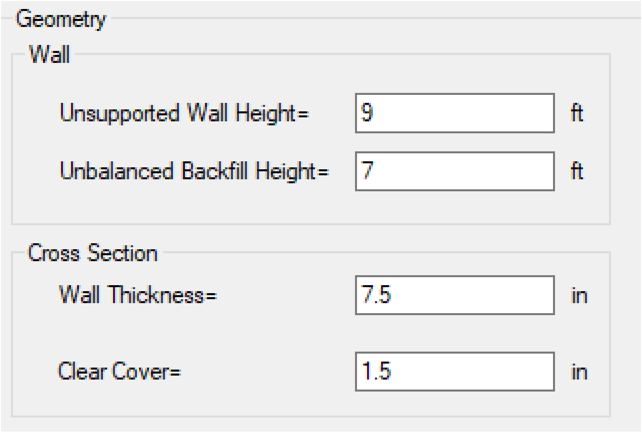
Note: BOTH Strength and Serviceability need to be considered

FIBERGLASS REBAR RESIDENTIAL WALL DESIGNER

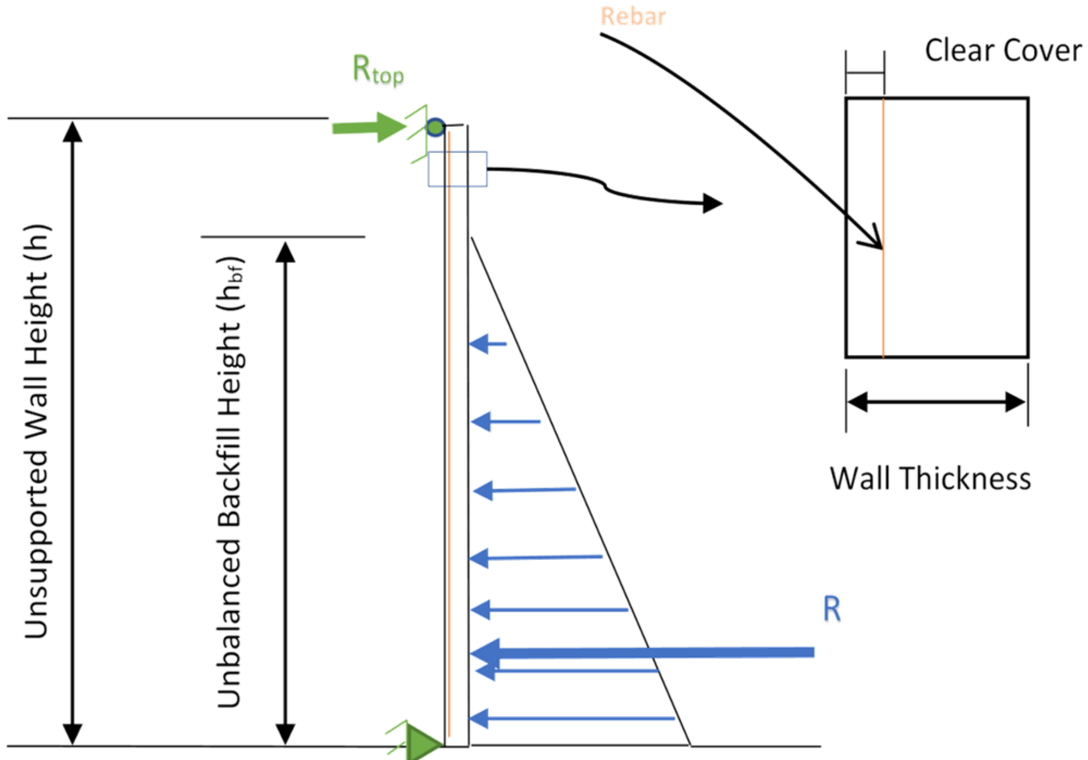
FIBERGLASS REBAR RESIDENTIAL WALL DESIGNER



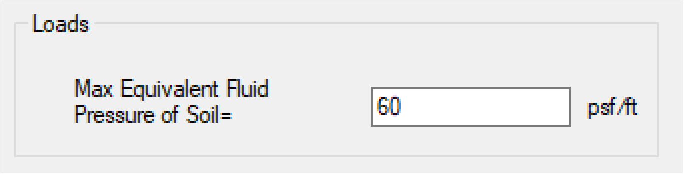
GEOMETRY


Geometry
Wall
Unsupported Wall Height=
9
ft
Unbalanced Backfill Height=
7
ft
Cross Section
Wall Thickness=
7.5
in
Clear Cover=
1.5
in

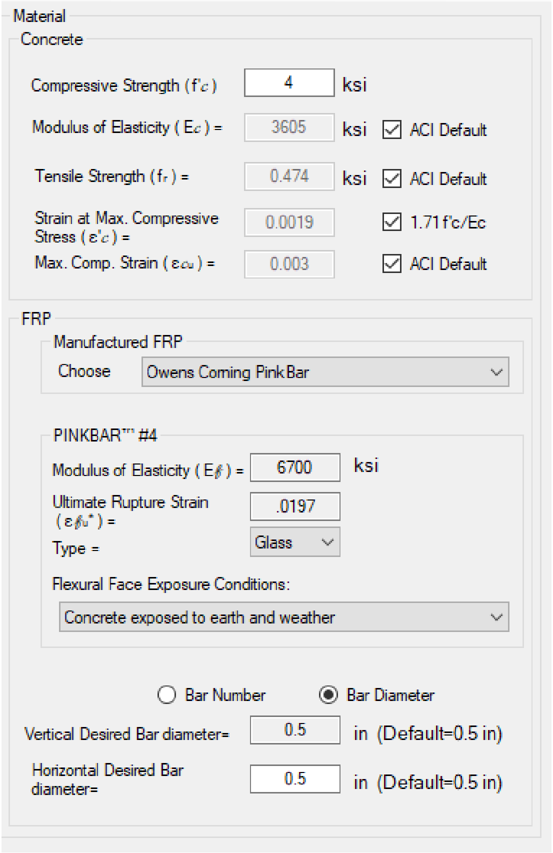
LOADS



$$w = b\gamma h_{bf}, \gamma = Max\ equivalent\ Fluid\ Pressure\ of\ Soil$$



MATERIAL


Material
Concrete
Compressive Strength (f'c) 4 ksi
Modulus of Elasticity (Ec) = 3605 ksi ACI Default
Tensile Strength (fr) = 0.474 ksi ACI Default
Strain at Max. Compressive Stress (ε'c) = 0.0019 1.71 f'c/Ec
Max. Comp. Strain (εcu) = 0.003 ACI Default
FRP
Manufactured FRP
Choose Owens Corning Pink Bar
PINKBAR™ #4
Modulus of Elasticity (Ef) = 6700 ksi
Ultimate Rupture Strain (εfu*) = .0197
Type = Glass
Flexural Face Exposure Conditions:
Concrete exposed to earth and weather
Bar Number
Bar Diameter
Vertical Desired Bar diameter= 0.5 in (Default=0.5 in)
Horizontal Desired Bar diameter= 0.5 in (Default=0.5 in)

FIBERGLASS REBAR RESIDENTIAL WALL DESIGNER

Results:

	Bar Diameter (in.)	Reinforcement for strength condition	Cracking Condition (under service load)	ε_{fu}	Vertical Reinforcement Spacing (in.)	Failure Modes	Concrete Cover Condition
Inserted Bar:	0.5	Needs Reinforcement	Uncracked	0.01576	12	FRP Rupture	dc ≤ ACI440 limit
ASTM* Bars:	0.25	Needs Reinforcement	Uncracked	0.01532	3	FRP Rupture	dc ≤ ACI440 limit
	0.375	Needs Reinforcement	Uncracked	0.01477	6	FRP Rupture	dc ≤ ACI440 limit
	0.5	Needs Reinforcement	Uncracked	0.01329	10	FRP Rupture	dc ≤ ACI440 limit
	0.625	Needs Reinforcement	Uncracked	0.01155	14	FRP Rupture	dc ≤ ACI440 limit
	0.75	Needs Reinforcement	Uncracked	0.01144	20	FRP Rupture	dc ≤ ACI440 limit
	0.875	Needs Reinforcement	Uncracked	0.01110	26	FRP Rupture	dc ≤ ACI440 limit
	1	Needs Reinforcement	Uncracked	0.01041	32	FRP Rupture	dc ≤ ACI440 limit
	1.128	Needs Reinforcement	Uncracked	0.01009	39	FRP Rupture	dc ≤ ACI440 limit
	1.27	Needs Reinforcement	Uncracked	0.00952	46	FRP Rupture	dc ≤ ACI440 limit

Horizontal Reinforcement Spacing (in.)= Horizontal Reinforcement: Bar diameter= 0.500 in @ 12 in

Notes:
-ASTM*: In accordance to Designation: D7957/D7957M – 17, Modulus of Elasticity=6500 ksi, Glass Bars, Kb=1.4
-"Spacing" in red means spacing is bigger than 48 inches (ACI 332 max. allowable spacing)
-"Concrete Cover Condition" in green complies with ACI 440 limit, red color indicates that it does not comply with ACI 440 limit.
-dc: concrete cover measured from the maximum tension face to the centroid of the tensile bars.

REPORT

AEDA LLC
FRP Residential Wall Designer
Wednesday, 14 October 2020

Design of flexural wall reinforced with FRP bars and subjected to a triangular soil pressure by AEDA LLC
Case name: report.pdf

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REPORT

9. Results

Reinforcement Condition
Needs Reinforcement
Controlling Design Mode
FRP Rupture
Cracked Condition under Service load
Uncracked
Concrete Cover condition
N/A (Uncracked)

Parameter	Value	Unit
Vertical bar diameter	0.3750	in
Vertical bar Area	0.1104	in^2
FRP depth (df)	6.19	in
Final vertical reinforcement spacing	8.00	in
Horizontal bar diameter	0.3750	in
Horizontal reinforcement ratio	0.0036	
Horizontal reinforcement spacing	4.00	in

SUMMARY

- Residential basement walls considered structural in nature and require a level of engineering validation
- Fiberglass rebar's low weight, competitive price point, and non-corrosive aspect make it an appealing product for contractors
- Fiberglass rebar can be effectively used in residential basement walls by combining the ACI 332 code with the existing ACI 440 and ASTM D7957 documents
- Software readily available to ease design, resulting in a full engineering report including calculations
- In due time, tables able to be generated similar to those displayed within ACI 332 for steel rebar
- **ALWAYS ASK FOR ASTM D7957 COMPLIANT MATERIALS!**

Questions?

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