# ICC-ES Evaluation Report

**ESR-3949**

*Reissued September 2023*

*This report also contains:*

**- NYC Supplement**

*Subject to renewal September 2024*



| DIVISION: 03 00 00 - CONCRETE<br><br>Section: 03 31 00— Structural Concrete | REPORT HOLDER:<br>HELIX® STEEL | EVALUATION SUBJECT:<br><br>HELIX® 5-25 MICRO REBAR™ & HELIX® 5-25U MICRO REBAR™ REINFORCEMENTS | |
|---|---|---|---|

## 1.0 EVALUATION SCOPE

**Compliance with the following codes:**

- 2021, 2018 and 2015 *International Building Code*® (IBC)
- 2021, 2018 and 2015 *International Residential Code*® (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 *International Building Code*. 2018 IBC code sections referenced in this report may be considered as equivalent sections under in the ADIBC.

**Properties evaluated:**

- Durability
- Structural
- Crack control

## 2.0 USES

Helix® Micro Rebar™ reinforcements (Helix® 5-25 Micro Rebar™ and Helix® 5-25U Micro Rebar™) are used as alternatives to the shrinkage and temperature reinforcement specified in Section 24.4 of ACI 318 for plain concrete footings and for plain concrete slabs (as defined by ACI 360) supported directly on the ground.

Helix® Micro Rebar™ reinforcements are also used to increase the modulus of rupture for the design of structural plain concrete using linear elastic design in applications within the scope of ACI 318 Chapter 14, IBC Section 1906 and ACI 332 Section 8.2.1, IRC Sections R404.1.3 and R608.1, or Tables 8.2.1.3a and 8.2.1.3b of ACI 332.

Helix® Micro Rebar™ reinforcements are also used as an alternative to horizontal temperature and shrinkage reinforcement in structural plain concrete walls as described in IBC Section 1906, IRC Sections R404.1.3 and R608.1, and ACI 332 Sections 8.2.1 and 8.2.7.

Helix® Micro Rebar™ reinforcements also applies to slabs-on-ground applications that are designed in accordance with Chapter 7 or Chapter 11 of ACI 360.

Helix® Micro Rebar™ reinforcements also applies to plain concrete parking lot applications that are designed in accordance with Chapter 3 of ACI 330.

Helix® Micro Rebar™ reinforcement also applies to concrete over composite steel decks when used as temperature and shrinkage reinforcement as an alternative to SDI-C Section 2.4-B-15-a (as referenced by the 2021 and 2018 IBC Section 2210.1.1) or SDI-C Section 2.4-B-13-a (as referenced by the 2015 IBC Section 2210.1.1).

Under the IRC, an engineered design in accordance with IRC Section R301.1.3 must be submitted to the code official for approval, except in the following cases:

1. Below grade walls designed in accordance with the requirements included in EER-3949.
2. When Helix 5-25 is used at a dosage rate of 9 lb/yd$^3$ (5.4 kg/m$^3$) to replace temperature and shrinkage reinforcement in footings in Seismic Design Categories A, B and C meeting the requirements of IRC Section R403.1.1.

## 3.0 DESCRIPTION

Helix® Micro Rebar™ reinforcements are made from minimum 240 ksi (1650 MPa), 0.020 in +/-0.007 in (0.51 mm +/- 0.02 mm) cold drawn steel wire. Each Helix® Micro Rebar™ has a minimum of one 360-degree twist. Helix® Micro Rebar™ reinforcement is used in minimum dosage of 6.7 lbs/yd$^3$ (4.0 kg/m$^3$) for Type C applications, and dosages between 9 lb/yd$^3$ and 34.5 lbs/yd$^3$ (5.4 kg/m$^3$ and 21 kg/m$^3$) for all other application types as given in Section 4.0 of this report. Helix® 5-25 is electroplated with zinc; whereas, Helix® 5-25U is uncoated.

**3.1 Structural Plain Concrete:** Structural normal-weight plain concrete must comply with Section 1906 of the IBC. Concrete design must follow ACI 211.1 and ACI 318 Section 26.12.3.1 with specified design compressive strength, $f'_c$, between 3000 psi and 5000 psi (21 MPa and 35 MPa) [minimum 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

## 4.0 DESIGN & INSTALLATION

**4.1 Type N (Temperature and Shrinkage):** Helix® Micro Rebar™ reinforcements are used as an alternative to shrinkage and temperature reinforcement specified in Section 24.4 of ACI 318 for plain concrete footings and for plain concrete slabs (as defined by ACI 360) supported directly on the ground for dosage rates between 9 lb/yd$^3$ and 34.5 lbs/yd$^3$ (5.4 kg/m$^3$ and 21 kg/m$^3$).

**4.2 Type S (Linear Elastic Design)**: Type S applications fall within the scope of ACI 318 Chapter 14, IBC Section 1906 and ACI 332 Section 8.2.1, IRC Sections R404.1.3 and R608.1, or Tables 8.2.1.3a and 8.2.1.3b of ACI 332. Design for flexure in accordance with Section 4 of this report must be limited in capacity by the values presented in Table 1 and Equations 1 or 2, and all designs must be verified to meet the criteria of ACI 318 Section 14.1.3 excluding slabs on grade (e.g. slabs designed per ACI 360 Chapter 7.2.1 PCA method where only flexural capacity is required).

a) For pure flexure

$$M_u \leq \lambda_s \, \varphi \, L_f \sqrt{f'_c} S_m \qquad \text{(Equation 1)}$$

b) For combined flexure and axial compression

$$\frac{M_u}{S_m} - \frac{P_u}{A_g} \leq \lambda_s \, \varphi \, L_f \sqrt{f'_c} \qquad \text{(Equation 2)}$$

Where

$L_f * \sqrt{f'_c}$ = Maximum limit for flexural capacity.

$M_u$ = Ultimate moment, lb.-in.

$P_u$ = Ultimate axial load, lb.

$S_m$ = Section modulus, in$^3$.

$A_g$ = Gross section area, in$^2$.

$f'_c$ = Specified compressive strength as defined in ACI 318-14 26.12.3.1 and ACI 214R.

$\varphi$ = Strength reduction factor as reported in Table 1 for Type S.

$\lambda_s$ = Scale-effect adjustment factor per Table 2 of this report, or computed using Equation 3 by a registered design professional (RDP).

$$\lambda_s = \frac{2.5\left(\frac{h_b}{h_o}\right)^{0.7}}{1+1.5\left(\frac{h_b}{h_o}\right)^{0.7}} \qquad \text{(Equation 3)}$$

Where:

$h_o$= depth of member being designed.

$h_b$= depth of test beam 12.00 in (300 mm).

Axial compression and shear capacity, when required for design, must be based on the requirements of Sections 14.5.3 and 14.5.5 of ACI 318, respectively. Resistance to lateral forces, as part of a lateral force resisting system, must be based on the requirements of ACI 318, Chapter 14. Connections between members must be based on ACI 318, Chapter 16. Provisions of Section 14.6.1 of ACI 318-14, IRC Section R608.8.1, and Section 8.2.7 (g) of ACI 332 must apply.

See Tables 3 and 4 for prescriptive square pad and wall strip footings designs, respectively. See Examples 1, 2 and 3 for sample calculations using the Type S Method.

**4.3 Type G (Design Limits for Slabs-on-Ground):**

**4.3.1 Plain Concrete Method**: When the modulus of rupture is required for plain concrete slabs-on-ground design in accordance with ACI 360, Chapter 7, the modulus of rupture ($f_r$) must be applied using Equation 4 and the values presented in Table 1:

$$f_r = L_f\sqrt{f_c'} \qquad \text{(Equation 4)}$$

**4.3.2 Fiber Reinforced Concrete Slabs-on-Ground**: When the modulus of rupture is required for plain concrete slabs-on-ground design using the Elastic method or Yield Line Method in accordance with ACI 360, Sections 11.3.3.2 and 11.3.3.3, respectively, the modulus of rupture ($f_r$) must be taken as Equation 4 using the values presented in Table 1.

**4.3.3 Factor of Safety:** For all plain concrete slabs-on-ground design, a factor of safety must be applied to the loads in accordance with ACI 360 Section 5.9. The resistance factors specified for Type S structures do not apply.

See Example 4 and 6 for sample calculations using the Type G Methods.

**4.4 Type P (Design Limits for Concrete Parking Lots):**

**4.4.1 Plain Concrete Method**: When the modulus of rupture is required for design of plain concrete parking lots in accordance with Chapter 3 of ACI 330, the modulus of rupture ($f_r$) must be determined using Equation 5 and the values presented in Table 1. Factor of safety of the pavement design (reliability) must be in accordance with ACI 330 Appendix A provisions.

$$f_r = L_f\sqrt{f_c'} \qquad \text{(Equation 5)}$$

See Tables 5 and 6 for prescriptive commercial and industrial parking pavement designs, respectively. See Example 5 for sample calculation using the Type P Method.

**4.5 Type C – Composite Concrete Slabs Over Steel Deck:** Helix® Micro Rebar™ are used in applications that are alternative to SDI-C Code Section 2.4-B-15-a (as referenced by the 2021 and 2018 IBC Section 2210.1.1) or SDI-C Code Section 2.4-B-13-a (as referenced by the 2015 IBC Section 2210.1.1), as applicable, for concrete over composite steel decks as temperature and shrinkage reinforcement.

**4.6 Installation:** Helix® Micro Rebar™ reinforcements may be added to the concrete at the concrete batch plant or to the ready-mix truck at the jobsite. The manufacturer's published installation instructions and this report must be strictly adhered to for adequate dispersal of fibers throughout the batch mixture. A copy of the manufacturer's published installation instructions must be available at all times at the location of the Helix® Micro Rebar™ installation into the concrete.

**4.7 Special Inspection:** Periodic special inspection is required in accordance with Sections 1705.1.1 and 1705.3 of the IBC.

## 5.0 CONDITIONS OF USE

The Helix® Micro Rebar™ reinforcements described in this report comply with, or are suitable alternatives to, what is specified in those codes listed in Section 1.0 of this report, subject to the following conditions:

**5.1** Helix® Micro Rebar™ reinforcements must be blended into the concrete mixture in accordance with the installation requirements in the ICC-ES evaluation report and the manufacturers published installation instructions.

**5.2** When Helix® 5-25 Micro Rebar™ and Helix® 5-25U Micro Rebar™ reinforcements are added at the ready-mix plant, a batch ticket signed by a ready-mix representative shall be available to the code official upon request.

**5.3** Type N applications must comply with Section 4.1 of this report. Joints as specified in Chapter 14.3.4 of ACI 318 (IBC and IRC) are required.

**5.4** Design for Type S applications must follow Section 4.2 of this report.

**5.5** Design for Type G applications must follow Section 4.3 of this report.

**5.6** Design for Type P applications must follow Section 4.4 of this report.

**5.7** For Type C applications, the minimum dosage rate that is permitted to be used as minimum temperature and shrinkage reinforcement as alternative to SDI-C Section SDI-C 2.4-B-15-a (2021 and 2018 IBC Section 2210.1.1) or SDI-C Section SDI-C 2.4-B-13-a (2015 IBC Section 2210.1.1), as applicable, is 6.7 $lbs/yd^3$ (4.0 $kg/m^3$) when used in normal-weight concrete with minimum specified design compressive strength of 3000 psi (20.6 MPa).

**5.8** The fire-resistance rating of constructions with Helix® Micro Rebar™ reinforcements have not been evaluated by ICC-ES and is outside the scope of this report. When requested, evidence of the fire-resistance rating of the construction must be submitted to the code official for their approval.

**5.9** Special inspection must comply with Section 4.6 of this report.

**5.10** Helix® Micro Rebar™ reinforcements are produced by Helix® Steel under an inspection program with inspections by ICC Evaluation Service, LLC.

## 6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Use of Twisted Steel Micro-rebar (TSMR) in Concrete (AC470), approved May 2020 (editorially revised June 2023).

## 7.0 IDENTIFICATION

**7.1** The ICC-ES mark of conformity, electronic labeling, or the evaluation report number (ICC-ES ESR-3949) along with the name, registered trademark, or registered logo of the report holder must be included in the product label.

**7.2** In addition, each container of Helix® Micro Rebar™ reinforcement must bear the manufacturer's name, trademark and address; and the product name.

**7.3** The report holder's contact information is the following:

**HELIX® STEEL**
**2300 WASHTENAW AVENUE, SUITE 201**
**ANN ARBOR, MICHIGAN 48104**
**(734) 322-2114**
**www.helixsteel.com**

**TABLE 1—CALCULATED $L_f$ VALUES[1,2,3,4]**

| Dosage rate ($lbs/yd^3$) | Compressive strength (psi) | | | | |
|---|---|---|---|---|---|
| | 3000 | 3500 | 4000 | 4500 | 5000 |
| | φ Strength Reduction Factor | | | | |
| | 0.56 | 0.58 | 0.59 | 0.6 | 0.6 |
| 9 | 8.93 | 9.25 | 9.58 | 9.90 | 9.90 |
| 13.5 | 9.01 | 9.43 | 9.84 | 10.25 | 10.25 |
| 18.0 | 9.10 | 9.60 | 10.10 | 10.61 | 10.61 |
| 22.5 | 9.19 | 9.78 | 10.37 | 10.96 | 10.96 |
| 27.0 | 9.28 | 9.96 | 10.63 | 11.31 | 11.31 |
| 31.5 | 9.37 | 10.13 | 10.90 | 11.66 | 11.66 |
| 33.8 | 9.41 | 10.22 | 11.03 | 11.84 | 11.84 |
| 34.5 | 9.43 | 10.25 | 11.08 | 11.90 | 11.90 |

For **SI**: 1 psi = 0.0069 Mpa. 1 $lb/yd^3$ = 0.59 $kg/m^3$.

[1]Interpolation between dosage rates and compressive strengths is permitted. Minimum of 24 Mpa compressive strength is required under ADIBC Appendix L, Section 5.1.1.
[2]Structures assigned to Seismic Design Category D, E or F must be in compliance with Section 14.1.4 of ACI 318, and combined flexure and axial compression must be considered in accordance with Section 14.5.4 of ACI 318.
[3]RDP must calculate project-specific scale-effect factor (Equation 3) and multiple it with Table 1 values.
[4] To convert $L_f$ from psi to Mpa, reported values must be multiplied by 0.083, which is $\sqrt{0.0069}$.

**TABLE 2—SCALE-EFFECT ADJUSTMENT FACTOR*, $\lambda_s$**

| Member Depth, $h_o$ | | $\lambda_s$ |
|---|---|---|
| in | mm | |
| 4 through12 | 100 Through300 | 1.00 |
| 18 | 460 | 0.88 |
| 24 | 600 | 0.80 |
| 36 | 910 | 0.68 |

* See Section 4.2, Equation 3 of this report for other member depths.

**TABLE 3 – SQUARE PAD FOOTING THICKNESS[1,2,3,4,5,6,7]**

| | Minimum Thickness w/ 13.5 lb/yd³ Helix® 5-25 | | | |
|---|---|---|---|---|
| Bearing Pressure | 2000 psf | | 3000 psf | |
| Footing Width (ft) | f'c = 3000 psi | f'c = 4000 psi | f'c = 3000 psi | f'c = 4000 psi |
| | *d, in* | | *d, in* | |
| 3 | 8 | 8 | 9 | 8 |
| 4 | 11 | 10 | 13 | 11 |
| 5 | 13 | 12 | 16 | 14 |
| 6 | 16 | 14 | 20 | 17 |
| 7 | 19 | 17 | 24 | 21 |
| 8 | 23 | 20 | 28 | 25 |
| 9 | 26 | 22 | 33 | 28 |
| 10 | 29 | 25 | 37 | 32 |

For **SI**: 1 in = 25.4 mm, 1 ft = 305 mm, 1 psi = 0.0069 Mpa, 1 kPa = 21 psf, 1 lb/yd³ = 0.59 kg/m³

1. Ultimate moment taken as factored moment due to effective allowable bearing pressure; assuming top of footing is at grade. More detailed analysis based on loads may allow for smaller/thinner designs (refer to example 2).
2. Live load is no more than 3 times dead load (Effective Load Factor = 1.5)
3. Column base plate is assumed 12in. x 12 in.
4. Minimum footing thickness is 8 inches per IBC 1809.8
5. Subtract 2 inches from thickness when footing is not cast against soil (ACI 318 14.5.1.7)
6. Subject to ICC-ES ESR 3949 Class S restrictions and limited to seismic design category A, B & C only
7. Interpolation is permitted.

**TABLE 4 – WALL STRIP FOOTING THICKNESS[1,2,3,4,5,6,7]**

| | Minimum footing thickness w/ 13.5 lb/yd³ Helix® 5-25 | | | |
|---|---|---|---|---|
| Bearing Pressure | 2000 psf | | 3000 psf | |
| Footing Width (ft) | f'c = 3000 psi | f'c = 4000 psi | f'c = 3000 psi | f'c = 4000 psi |
| | *d, in* | | *d, in* | |
| 2 | 8 | 8 | 8 | 8 |
| 2.5 | 8 | 8 | 9 | 8 |
| 3 | 9 | 8 | 10 | 10 |
| 3.5 | 10 | 9 | 12 | 11 |
| 4 | 12 | 10 | 14 | 12 |
| 4.5 | 13 | 12 | 16 | 14 |
| 5 | 14 | 13 | 18 | 15 |

For **SI**: 1 in = 25.4 mm, 1 ft = 305 mm, 1 psi = 0.0069 Mpa, 1 kPa = 21 psf, 1 lb/yd³ = 0.59 kg/m³

1. Ultimate moment taken as factored moment due to effective allowable bearing pressure; assuming top of footing is at grade. More detailed analysis based on loads may allow for smaller/thinner designs (refer to example 3).
2. Live load is no more than 3 times dead load (Effective Load Factor = 1.5).
3. Wall Thickness is assumed 7.5 inches.
4. Minimum footing thickness is 8 inches per IBC 1809.8.
5. Subtract 2 inches from thickness when footing is not cast against soil (ACI 318 14.5.1.7)
6. Subject to ICC-ES ESR 3949 Class S restrictions and limited to seismic design category A, B & C only.
7. Interpolation is permitted.

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### TABLE 5 – COMMERCIAL PARKING PAVEMENT THICKNESS [1,2,3,4,5,6,7]

| | | 13.5 lb/yd³ Helix® 5-25 | | | 9 lb/yd³ Helix® 5-25 | | |
|---|---|---|---|---|---|---|---|
| | | f'c = 3500 psi | | | f'c = 4500 psi | | |
| Category | Trucks | k=100 pci | k=200 pci | k=300 pci | k=100 pci | k=200 pci | k=300 pci |
| | | *d, in* | | | *d, in* | | |
| A | 1 | 4.25 | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| A | 10 | 4.75 | 4.25 | 4.00 | 4.25 | 4.00 | 4.00 |
| B | 10 | 5.50 | 5.00 | 4.75 | 4.75 | 4.25 | 4.00 |
| B | 25 | 5.50 | 5.00 | 4.75 | 5.00 | 4.50 | 4.25 |
| B | 50 | 5.50 | 5.00 | 4.75 | 5.00 | 4.50 | 4.50 |
| C | 5 | 7.75 | 7.25 | 6.75 | 7.00 | 6.25 | 6.00 |
| D | 1 | 5.25 | 4.75 | 4.50 | 4.50 | 4.25 | 4.00 |
| D | 10 | 5.50 | 5.00 | 5.00 | 5.25 | 5.00 | 4.75 |
| D | 25 | 6.00 | 5.50 | 5.25 | 6.00 | 5.50 | 5.25 |
| E | 1 | 6.75 | 6.50 | 6.25 | 6.25 | 6.00 | 5.50 |

For **SI**: 1 in = 25.4 mm, 1 psi = 0.0069 MPa, 1 pci = 27.6 kN/m³, 1 lb/yd³ = 0.59 kg/m³

1. No dowels at joints
2. Design Life: 20 years
3. Reliability A/B: 60%, C/D/E: 75% (ACI 330 Table A1.1b)
4. Crack 15% at end of life (ACI 330 Table A1.1b)
5. Helix Design Per ICC-ES ESR 3949 Type P (ACI 330).
6. Interpolation is permitted.

### TABLE 6 - INDUSTRIAL PARKING PAVEMENT THICKNESS[1,2,3,4,5,6,7]

| No. of trucks per day | 13.5 lb/yd³ Helix® 5-25 | | 9 lb/yd³ Helix® 5-25 | |
|---|---|---|---|---|
| | f'c = 3500 psi | | f'c = 4500 psi | |
| | k =150 pci | k=300 pci | k =150 pci | k=300 pci |
| | *d, in* | | *d, in* | |
| 10 | 5.50 | 5.00 | 5.00 | 4.75 |
| 50 | 6.00 | 5.75 | 6.00 | 5.50 |
| 100 | 6.50 | 6.00 | 6.50 | 6.00 |
| 200 | 7.00 | 6.50 | 6.75 | 6.25 |
| 500 | 7.50 | 6.75 | 7.25 | 6.50 |
| 1000 | 7.50 | 7.00 | 7.75 | 7.00 |

For **SI**: 1 in = 25.4 mm, 1 psi = 0.0069 MPa, 1 pci = 27.6 kN/m³, 1 lb/yd = 0.59 kg/m³

1. No dowels at joints
2. Category D Traffic
3. Design Life: 20 years
4. Reliability 85%
5. Crack 15% at end of life
6. Helix Design: Per ICC-ES ESR 3949 Type P (ACI 330.2R).
7. Interpolation is permitted.

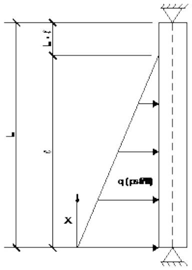
### TABLE 7 - COMPOSITE METAL DECK MININUM REINFORCEMENT[1,2,3]

| Depth of slab above deck | Minimum Welded Wire Fabric | Helix® 5-25 Dosage (lb/yd³) |
|---|---|---|
| 2.0 - 3.0" | 6x6-W1.4xW1.4 | 6.7 |
| | 6x6-W2.1xW2.1 | 9 |
| up to - 4.5" | 6x6-W2.1xW2.1 | 6.7 |
| | 6x6-W2.9xW2.9 | 9 |

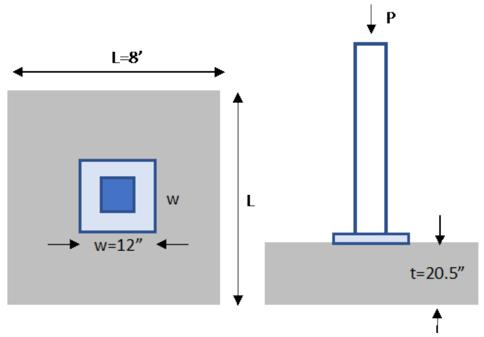
For **SI**: 1 lb/yd³ = 0.59 kg/m³

1. Minimum WWF is based on SDI - C 2.4-B-15-a or SDI - C 2.4-B-13-a
2. Minimum Helix dosage per ESR 3949 5.7 (Type C)
3. Helix 5-25 Dosage only replaces minimum temperature & shrinkage reinforcement required by SDI - C 2.4-B-15-a or SDI - C 2.4-B-13-a ($\rho$=0.00075) as referenced by IBC Section 2210.1.1

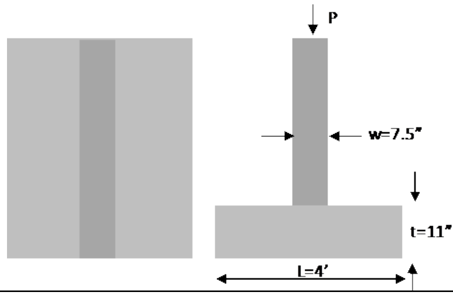
## Example 1: Foundation Wall (Type S Design)

| | |
|---|---|
|  | L=9 ft. tall<br>$\ell$= 8 ft. backfill<br>t = 8 in.<br>b= 12 in.<br>q = 45 lb/ft$^3$ soil pressure<br>$f_c'$ = 3000 psi with 9 lb/yd$^3$ Helix® 5-25<br>Neglect Axial Load<br>Seismic Design Category B |
| Step 1: Find Governing Load Combinations (ASCE 7-16) | Ultimate: $U = 1.2\text{D} + 1.6\text{H} = 0 + 45 \text{ x } 1.6 = 72 \text{ lb/ft}^3$<br>Assume lateral loads only, neglect self-weight |
| Step 2: Compute $M_u$ | $e = L - (L - l) - \frac{2}{3}l = 2.67\ ft$<br>$R_A = \frac{Ul^2e}{2L} = 683\ lbs$<br>$M_{max} = R_A((L - l) + \frac{2}{3}l\sqrt{\frac{e}{L}} =$ 2665 lb-ft/ft = 31,970 lb-in/ft |
| Step 3: Compute $V_u$ | $V_u = R_B = \frac{Ul^2}{2} - R_A = 1621\ lb$ |
| Step 4: Check Shear (ACI 318 14.5.5.1 Table 1) | Allowable Shear, $V_{c1} = 0.6\frac{4}{3}\sqrt{f_c'}bt = 4206 \text{ lb}$<br>$1621\ lb < 4206 \text{ lb}$ (OK) |
| Step 5: Scale Effect Adjustment Factor ESR 3949 Eq 3 | $\lambda_s = 1.0$ |
| Step 6: Compute Section Modulus | $S_m = \frac{bt^2}{6} = 128\ \frac{in^3}{ft}$ |
| Step 7: Compute Flexural Limit ESR 3949 Table 1 | $f_c' = 3000\ psi \quad \varphi L_f = 0.56 \times 8.93 = 5.0$ |
| Step 8: Compute $M_u$ & Check Capacity ESR 3949 Eq 1 | $M_u \leq 1.0 \times 5.0\sqrt{3000} \times 128 = 35{,}054$ in-lb/ft<br>31,970 in-lb/ft < 35,054 in-lb/ft (OK) |

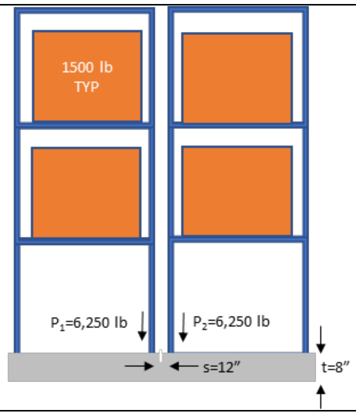
## Example 2: Square Footing (Type S Design)

| | |
|---|---|
|  | Square Column Footing, L= 8 ft. x8 ft.<br>Thickness, t = 20.5 in. (design thickness) + 2 in. (soil formed) = 22.5 in.<br>Allowable soil bearing pressure, q = 2000 psf<br>Concrete self-weight, $\rho_{conc}$ = 150 pcf<br>$f_c'$ = 3000 psi with 13.5 lb/yd$^3$ Helix® 5-25<br>Base Plate Size: w=12 in. x 12 in.<br>Column Gravity Loads (50x50 column spacing)<br>Loads: D=30,000 lb / $L_r$=75,000 lb |
| Step 1: Find Governing Load Combinations (ASCE 7-16) | $S\ (ASD) = \mathrm{D} + (\mathrm{L}_r \text{ or S}) = 105{,}000$ lb (governs)<br>$U\ (LRFD) = 1.2\mathrm{D} + 1.6(\mathrm{Lr} \text{ or S}) + \mathrm{L} = 156{,}000$ lb (governs) |
| Step 1: Size Footing | Applied Bearing Pressure, $Q_{asd} = S/L^2 = 1641$ psf<br>Eff. Allowable SBP, $Q_e = \mathrm{q} - \rho_{conc}\,(t/12) = 1744$ psf<br>$1641 < 1744$ (8 ft. x 8 ft. OK) |
| Step 2: Ultimate Moment | Cantilever Length, $c_L = \frac{\mathrm{L} \times "\frac{12"}{1'}}{2} - w/2 = 42 \text{ in} = 3.5 \text{ ft}$<br>Ult. Applied Bearing Pressure, $\mathrm{Q}_u = \frac{\mathrm{U}}{L^2} = 2438$ psf<br>Ult. Moment, $M_u = 1'/12" \times (Q_u \times \mathrm{L} \times c_L{}^2/2) = 1{,}433{,}250$ lb-in |
| Step 3: Check Bending (ESR 3949 4.2) | Scale Effect Factor (ESR 3949 Eq 3), $\lambda_s = 0.846$<br>Section Modulus, $S_m = \frac{bt^2}{6} = 6724\ in^3$<br>ESR 3949 Table 1, $\varphi L_f = 0.56 \times 9.01 = 5.05$<br>ESR 3949 Eq1, $M_u \le \lambda_s \times \varphi L_f \sqrt{f_c'} \times S_m = 1{,}573{,}440 \text{in} - \text{lb}$<br>$1{,}433{,}250\ in - lb < 1{,}573{,}440 \text{ in} - \text{lb}$ (OK) |
| Step 4: Check Beam Shear (ACI 318 14.5.5.1 Table 1) | Beam Shear, $V_{u1} = Q_u L\left(\frac{L}{2} - (\frac{w}{2} + t)/(12"/ft)\right) = 34{,}944$ lb<br>Allowable Shear, $V_{c1} = 0.6 \times \left(\frac{4}{3}\sqrt{f_c'}bt\right) = 86233$ lb<br>$34{,}944\ lb < 86{,}233$ lb (OK) |
| Step 5: Check 2-Way Shear (ACI 318 14.5.5.1 b & c) | Critical Perimeter, $b_0 = 4(t + w) = 130\ in$<br>Column Ratio, $\beta_c = 1.0$<br>Shear, $V_{u2} = Q_u * (L^2 - (w/12 + t/12)^2) = 138{,}149$ lb<br>Shear Strength, $V_{c1} = 0.6\left(1 + \frac{2}{\beta_c}\right)\left(\frac{4}{3}\sqrt{f_c'}b_0 t\right) = 350{,}323$ lb<br>Shear Strength, $V_{c2} = 0.6 \times 2\left(\frac{4}{3}\sqrt{f_c'}b_0 t\right) = 233{,}549$ lb<br>$138{,}149 \text{ lb} < 233{,}549$ lb (OK) |
| Step 6: Adjust for Thickness (ACI 318 14.5.1.7) | Adjusted Thickness (assuming formed against soil),<br>$t_{adj} = t + 2 \text{ in} = 22.5 \text{ in}$<br>8 ft. x 8 ft. x 22.5 in. footing with 13.5 lb/yd$^3$ Helix 5-25 (OK) |

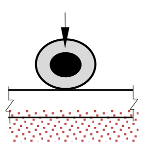
## Example 3: Wall/Strip Footing (Type S Design)

| | |
|---|---|
|  | Wall Footing, L= 4 ft.<br>Thickness, t = 11 in. (design thickness) + 2 in. (soil formed) = 13 in.<br>Allowable soil bearing pressure, q = 3000 psf<br>Concrete self-weight, $\rho_{conc}$ = 150 pcf<br>$f_c'$ = 3000 psi with 13.5 lb/yd$^3$ Helix® 5-25<br>Wall thickness, w = 7.5"<br>Loads: D=9250 lb/ft / $L_r$=750 lb/ft |
| Step 1: Find Governing Load Combinations (ASCE 7-16) | $S\ (ASD) = \text{D} + (\text{L}_r \text{ or S}) = 10{,}000 \text{ lb/ft}$ (governs)<br>$U\ (LRFD) = 1.4\text{D} = 12{,}950 \text{ lb/ft}$ (governs) |
| Step 1: Size Footing | Applied Bearing Pressure, $Q_{asd} = S/L = 2{,}500 \text{ psf}$<br>Eff. Allowable SBP, $Q_e = \text{q} - \rho_{conc}\,(t/12\text{"/ft}) = 2863 \text{ psf}$<br>$2500 < 2863$ (4 ft. OK) |
| Step 2: Ultimate Moment | Cantilever Length, $c_L = \text{L} \times 12\text{"}/1'/2 - w/2 = 20.25 \text{ in} = 1.6875 \text{ ft}$<br>Ult. Applied Bearing Pressure, $\text{Q}_u = \frac{\text{U}}{L} = 3{,}238 \text{ psf}$<br>Ult. Moment, $M_u = 1'/12\text{"}(\,Q_u \times {c_L}^2/2) = 55324 \text{ lb} - \text{in/ft}$ |
| Step 3: Check Bending (ESR 3949 4.2) | Scale Effect Factor (ESR 3949 Eq 3), $\lambda_s = 1$<br>Section Modulus, $S_m = \frac{bt^2}{6} = 242\ in^3/\text{ft}$<br>ESR 3949 Table 1, $\varphi L_f = 0.56 \times 9.01 = 5.05$<br>ESR 3949 Eq1, $M_u \leq \lambda_s \times \varphi L_f \sqrt{f_c'} \times S_m = 66{,}880 \text{ in} - \text{lb/ft}$<br>$66{,}880\ in - lb/ft < 70{,}487 \text{ in} - \text{lb/ft}$ (OK) |
| Step 4: Check Beam Shear (ACI 318 14.5.5.1 Table 1) | Beam Shear, $V_{u1} = Q_u\left(L/2 - (\frac{w}{2} + t)/(12\text{"}/ft)\right) = 2158 \text{ lb/ft}$<br>Allowable Shear, $0.6 \times \left(\frac{4}{3}\sqrt{f_c'}bt\right) = 5784 \text{ lb/ft}$<br>$2158 < 5784 \text{ lb}$ (OK) |
| Step 5: Adjust for Thickness (ACI 318 14.5.1.7) | Adjusted Thickness (assuming formed against soil),<br>$t_{adj} = t + 2 \text{ in} = 13 \text{ in}$<br>4 ft. wide x 13 in. thick footing with 13.5 lb/yd³ Helix 5-25 (OK) |

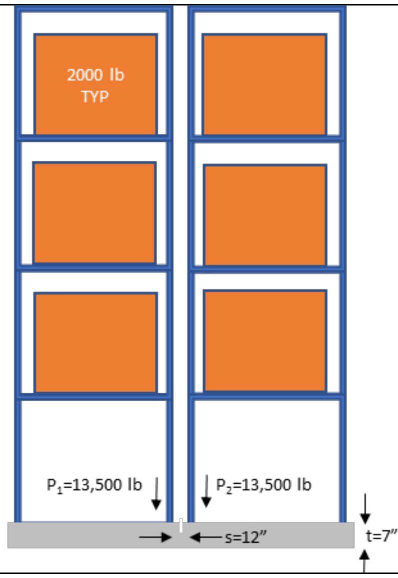
### Example 4: Slab on Grade Design Elastic Design (Type G Section 4.3.1)

| | |
|---|---|
|  | Two Post Loads, P=6250 lb. each, base plate size = 4 in. x 6 in. Back-to-back at S = 12 in. spacing), located adjacent to sawcut joint<br>Concrete thickness, h =8 in.<br>$f_c'$ = 4000 psi, Poisson's Ratio, μ = 0.15<br>Helix® 5-25 Dosage = 9 lb/yd³<br>Modulus of Subgrade Reaction, k = 100 pci<br>Factor of Safety, FS= 1.7 (ACI 360R Table 5.2) |
| Step 1: Modulus of Elasticity (ACI 318-14, Eq 19.2.2.1.b) | Modulus of Elasticity, $E_c = 57000\sqrt{f_c'} = 3{,}605{,}000$ psi |
| Step 2: Radius of Relative Stiffness (ACI 360R-10, Equation 7-3) | Radius of relative stiffness, $L = \sqrt[4]{\frac{E_c \times h^3}{12\times(1-\mu^2)\times k}} = 35.4\ in$ |
| Step 3: Radius of Contact Area | Total Contact Area, $A_c = 4" \times 6" = 24\ in^2$<br>Radius of Contact Area, $a_w = \sqrt{(A_c/\pi)} = 2.8\ in$ |
| Step 4: Combined Load (Principle of Superposition) | $P = P_1 + P_2\left(1-\left(\frac{S}{1.5L}\right)\right) = 11{,}088\ lb$ |
| Step 4: Bending Stress at Edge (ACI 360R-10, Equation 7-5) | Bending Stress, $f_b = 0.572\frac{P}{h^2}\left[\log(h^3) - 4\log\left(\sqrt{1.6a_c^2 + h^2} - 0.675h\right) - \log(k) + 5.77\right] = 435 psi$ |
| Step 5: Bending stress at sawcut (ACI 360R-10 Example A6.2.2) | $0.8f_b = 348\ psi$ (20% of load transfers across joint) |
| Step 4: Compute Flexural Strength (ICC-ESR 3949 Equation 4) | Modulus of Rupture Factor (ICC-ESR 3949 Table 1), $L_f$ = 9.58<br>Modulus of Rupture, $f_r$ = $L_f\sqrt{f'c} = 606\ psi$ |
| Step 5: Compute Allowable Bending Stress (ICC-ESR 3949 Equation 4) | Allowable Bending Stress = $f_r$/FS = 356 psi<br>Check Stress, $348\ psi < 356\ psi$ (OK) |

### Example 5: Parking Lot Design (Type P)

| | |
|---|---|
|  | Industrial Trucking Parking/Site Paving (no dowels at joints)<br>Traffic category D (ACI 330.2R Table 4.2.4a), 1000 trucks/day<br>Composite k-value of substructure: 150 pci<br>Design Life: 20 years / Reliability 85% / Crack 15% at end of life<br>$f_c'$ = 3500 psi<br>Helix® 5-25 Dosage = 13.5 lb/yd³ |
| Step 1: Modulus of Elasticity (ACI 318-14, Eq 19.2.2.1.b) | Modulus of Elasticity, $E_c = 57000\sqrt{f_c'} = 3{,}372{,}165$ psi |
| Step 3: Compute 28-day Flex Strength (ICC-ESR 3949 Equation 5) | Modulus of Rupture Factor (ICC-ESR 3949 Table 1), $L_f$ = 9.43<br>Modulus of Rupture, $f_r$ = $L_f\sqrt{f_c'} = 558\ psi$ |
| Step 2: Compute Thickness ACI 330.2R B1 (www.pavementdesigner.org) | Pavement Structure: computed in step 1 and 2, user defined k<br>Recommended Thickness: 7.5 in / 14 ft joints |

## Example 6: Slab on Grade Design Yield Line Design (Type G - 4.3.2)

| | |
|---|---|
|  | Two Post Loads, P=13,500 lbs each, base plate size = 4 in. x 6 in.<br>Back-to-back at S = 12 in. spacing), located adjacent to sawcut joint<br>Concrete thickness, h = 7 in.<br>Section width, b = 12 in.<br>$f_c'$ = 4000 psi. Poisson's Ratio, μ = 0.15<br>Helix® 5-25 Dosage = 22.5 lb/yd$^3$<br>Modulus of Subgrade Reaction, k = 100 pci<br>Factor of Safety, FS= 1.7 (ACI 360 Table 5.2) |
| Step 1: Modulus of Elasticity (ACI 318-14, Eq 19.2.2.1.b) | Modulus of Elasticity, $E_c = 57000\sqrt{f_c'}$ = 3,605,000 psi |
| Step 2: Radius of Relative Stiffness (ACI 360R-10, Equation 7-3) | Radius of relative stiffness, $L = \sqrt[4]{\frac{E_c \times h^3}{12 \times (1-\mu^2) \times k}} = 29 in$ |
| Step 3: Radius of Contact Area | Total Contact Area, $A_c = 4 \times 6 = 24\ in^2$<br>Radius of Contact Area, $a_w = \sqrt{(A_c/\pi)} = 2.8\ in$ |
| Step 4: Combined Load (Principle of Superposition) | $P = P_1 + P_2\left(1 - \left(\frac{S}{1.5L}\right)\right) = 23{,}270\ lb$ |
| Step 5: Bending Moment Demand Edge (ACI 360R-10, 11.3.3.3, Case 2) | Moment Demand, $M = \frac{P}{3.5\left[1+\frac{3a_w}{L}\right]} = 5168$ lb-ft/ft<br>$= 62.0$ kip-in/ft |
| Step 5: Demand at Sawcut | $0.8M = 49.6$ kip-in/ft (20% of load transfers across joint) |
| Step 6: Compute Flexural Strength (ICC-ESR 3949 Equation 4) | Modulus of Rupture Factor (ICC-ESR 3949 Table 1), $L_f$ = 10.37<br>Modulus of Rupture, $f_r$ = $L_f\sqrt{f'c} = 656\ psi$ |
| Step 7: Bending Moment Capacity (ACI 360R-10, 11.3.3.3, Case 2) | Moment Capacity, $M_0 = \left[1 + \frac{R_{e,3}}{100}\right] \times \frac{f_r \times b \times h^2}{6} = 84.54$ kip-in/ft<br>Allowable Bending = $\frac{M_0}{FS} = 49.7 > 49.6$kip-in/ft. (OK) |

# ICC-ES Evaluation Report

# ESR-3949 NYCBC Supplement

*Reissued September 2023*

*This report is subject to renewal September 2024.*

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**DIVISION: 03 00 00—CONCRETE**
**Section: 03 31 00—Structural Concrete**

**REPORT HOLDER:**

**HELIX® STEEL**

**EVALUATION SUBJECT:**

**HELIX® 5-25 MICRO REBAR™ & HELIX® 5-25U MICRO REBAR™ REINFORCEMENTS**

## 1.0 REPORT PURPOSE AND SCOPE

**Purpose:**

The purpose of this evaluation report supplement is to indicate that Helix® Micro Rebar™ reinforcements, described in ICC-ES evaluation report ESR-3949, have also been evaluated for compliance with the code noted below as adopted by the New York City Department of Buildings.

**Applicable code edition:**

2022 *City of New York Building Code* (NYCBC)

## 2.0 CONCLUSIONS

The Helix® Micro Rebar™ reinforcements, described in Sections 2.0 through 7.0 of the evaluation report ESR-3949, comply with the NYCBC Sections BC 1908 and BC 1909, and are subject to the conditions of use described in this supplement.

## 3.0 CONDITIONS OF USE

The Helix® Micro Rebar™ reinforcements described in this evaluation report supplement must comply with all of the following conditions:

- All applicable sections in the evaluation report ESR-3949.
- The design, installation, conditions of use and identification of the anchors are in accordance with the 2015 *International Building Code®* (IBC) provisions noted in the evaluation report ESR-3949.
- The design, installation and inspection are in accordance with additional requirements of NYCBC Chapters 16 and 17, and Sections BC 1908 and BC 1909, as applicable.

This supplement expires concurrently with the evaluation report, reissued September 2023.