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Calculating Steel Density

One of the main considerations when determining the appropriate spacing for galvanic anode units is the steel density ratio. Most engineers involved in concrete restoration are familiar with calculating steel ratios from a structural standpoint based on cross sectional area. But from the corrosion standpoint, we must to answer the question:

"In a given area, how much surface area of steel needs to be protected?"

To answer this question, the steel to concrete surface area ratio must be calculated to understand the density of the reinforcing steel for a given area. Therefore for typical elements we calculate the surface area of all steel based on a one square foot area. If the bar diameters are in metric, the calculations would be based on a one square meter area.

Calculations of this ratio are based on the following formula:

$$\frac{\text{Surface area of steel}}{\text{Surface area of concrete}} = \text{steel density ratio}$$

or

$$\frac{\pi \, D \times L \times n}{1 \text{ ft}^2 \, (144 \text{ in}^2)} = \text{steel density ratio}$$

where:

- π = 3.14
- D = bar diameter
- L = length of bars in calculated area
- n = number of bars in calculated area

Reinforcing Steel Density Sample Calculations

Example #1

Heavily Reinforced Slab (Bridge Deck)
 # 5 Bars @ 8" on center each way (2 mats)

Top mat longitudinal Bars (per ft²)

$$\pi \, D \times L \times n = \pi \times \frac{5"}{8} \times 12" \times \frac{12"}{8} = 35 \text{ in.}^2 \rightarrow \frac{35 \text{ in.}^2}{144 \text{ in.}^2} = .245$$

Top mat transverse bars (per ft²)

$$\pi \, D \times L \times n = \pi \times \frac{5"}{8} \times 12" \times \frac{12"}{8} = 35 \text{ in.}^2 \rightarrow \frac{35 \text{ in.}^2}{144 \text{ in.}^2} = .245$$

Bottom mat longitudinal bars (per ft²) .245

Bottom mat transverse bars (per ft²) .245

Total steel density 0.98 ≈ 1.0

Based on this calculation, the recommended anode unit spacing would be as follows:

Galvashield XP/XPT	(Prevention)	18 in. (450 mm)
Galvashield XP2	(Prevention)	22 in. (550 mm)
Galvashield XP4	(Control)	18 in. (450 mm)
Galvashield CC65/CC135		14 in. (355 mm)
Galvashield CC100		18 in. (450 mm)

Level of Protection	Description	Galvashield® XP/XPT	Galvashield® XP2/XP4	Galvashield® CC
Corrosion Prevention	Mitigates initiation of new corrosion activity	•	•	•
Corrosion Control	Reduces on-going corrosion activity		•	•
Cathodic Protection	Reduce or eliminate on-going corrosion activity			

Example #2

Medium Reinforced Slab (Parking Deck)
 # 5 Bars @ 12" on center each way (2 mats)

Top mat longitudinal bars (per ft²)

$$\pi \, D \times L \times n = \pi \times \frac{5"}{8} \times 12" \times \frac{12"}{12} = 23.6 \text{ in.}^2 \rightarrow \frac{23.6 \text{ in.}^2}{144 \text{ in.}^2} = 0.16$$

Total 4 sets of bars x 0.16 = 0.65

Based on this calculation, the recommended anode unit spacing would be as follows:

Galvashield XP/XPT	(Prevention)	20 in. (500 mm)
Galvashield XP2	(Prevention)	26 in. (650 mm)
Galvashield XP4	(Control)	22 in. (550 mm)
Galvashield CC65/CC135		18 in. (450 mm)
Galvashield CC100		20 in. (500 mm)

Example #3

Lightly Reinforced Slab (Balcony)
 # 4 Bars @ 16" on center each way (1 mat)

$$\pi \, D \times L \times n = \pi \times \frac{4"}{8} \times 12" \times \frac{12"}{16} = 14. \text{ in.}^2 \rightarrow \frac{14 \text{ in.}^2}{144 \text{ in.}^2} = 0.10$$

Total 2 sets of bars x 0.10 = 0.20

Based on this calculation, the recommended anode unit spacing would be as follows:

Galvashield XP/XPT/XP2	(Prevention)	30 in. (750 mm)
Galvashield XP4	(Control)	30 in. (750 mm)
Galvashield CC65/CC135		28 in. (700 mm)

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Example #4

Building Column

4-12" sq. Column with (4) #7 vertical reinf. & #4 @ 12" c/c ties

Concrete Area

12" x 4 sides x 12" ht = 576 sq in.

Steel Area

Vert. reinf. & ties = (3.142 x 7/8" x 12" x 4 bars) (3.142 x 4/8" x8" x 4 sides) 131.96 sq. in. + 50.27 sq. in. = 182.23 sq. in./ 576 sq. in.

Total 0.32

Based on this calculation, the recommended anode unit spacing would be as follows:

Galvashield XP/XPT	(Prevention)	24 in. (600 mm)
Galvashield XP2	(Prevention)	28 in. (700 mm)
Galvashield XP4	(Control)	28 in. (700 mm)
Galvashield CC65/CC135		24 in. (600 mm)

Example #5

Beam (Bridge or Marine Pier cap)

Underside of beam with (3) #11 bottom longitudinal (horiz) bars & #4 ties @ 12" c/c with 2" cover

Concrete Area

(18" bottom + assume 6" ht x 2-sides) 12" length = 360 sq in.

Steel Area - Longitudinal bars per lineal ft

π D x L x n = π 11/8 x 12 x 3 = 155.51 in.^{2}

Stirrups per lineal ft

π D x L x n = π 4/8 x (14" + (4" X 2 sides)) x 12/12 = 34.56 in.^{2}

Total: 1551.51 = 34.56 = 190.07 in.^{2}

Steel Density

190.01 / 360 = 0.53

Based on this calculation, the recommended anode unit spacing would be as follows:

Galvashield XP/XPT	(Prevention)	24 in. (600 mm)
Galvashield XP2	(Prevention)	28 in. (700 mm)
Galvashield XP4	(Control)	28 in. (700 mm)
Galvashield CC65/CC135		18 in. (450 mm)
Galvashield CC100		20 in. (500 mm)

Example #6

Side of Beam

#7 horizontal bars @ 12" on center

#4 ties @ 12" on center

Horizontal

π D x L x n = $\pi \times \frac{7"}{8} \times 12" \times \frac{12"}{12}$ = 33. in.^{2} → $\frac{33\ in.^2}{144\ in.^2}$ = 0.23

Ties

π D x L x n = $\pi \times \frac{4"}{8} \times 12" \times \frac{12"}{12}$ =19. in.^{2} → $\frac{19\ in.^2}{144\ in.^2}$ = 0.13

Total 0.36

Based on this calculation, the recommended anode unit spacing would be as follows:

Galvashield XP/XPT	(Prevention)	24 in. (600 mm)
Galvashield XP2	(Prevention)	28 in. (700 mm)
Galvashield XP4	(Control)	28 in. (700 mm)
Galvashield CC65/CC135		24 in. (600 mm)

Note: Spacing estimates are based on:

Galvashield XP/XPT	Corrosion Prevention
Galvashield XP2	Corrosion Prevention
Galvashield XP4	Corrosion Control
Galvashield CC	Corrosion Control

When determining spacing factors for galvanic anode units, the steel density ratio is only one factor to consider. The engineer should also consider other factors that can affect the corrosion activity such as the amount of chloride contamination, exposure conditions, temperature and humidity, etc.

The examples provided above are for illustration purposes only and are indicative of typical structural elements with low to moderate chloride content that may receive a galvanic protection system. For additional information or for assistance with determining the steel density on a specific project, contact Vector Corrosion Technologies.

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