Calculation and Installation of TMP Concrete Anode

Typical current demands for reinforcing steel in concrete as stated in ISO 12696:2012 Cathodic Protection of Steel in Concrete are the following:

- For new structure and before corrosion initiation	0.2 – 2.0	mA/m^2	(Cathodic Prevention)
- For existing corroded structure with uncoated steel	2.0 – 20.0	mA/m^2	(Cathodic Protection)
- For passive steel in non-chloride contaminated concrete	0.2 – 2.0	mA/m^2	(Cathodic Prevention)
- For steel in chloride contaminated concrete	2.0 – 20.0	mA/m^2	(Cathodic Protection)

1. Calculation of Steel Density Ratio (SDR)

For cathodic corrosion protection (CP), we need to know the surface area of steel to be protected in concrete. Therefore, the ratio of steel surface to the exposed surface area of concrete must be considered first to find out SDR for one-meter square area.

$$\text{Steel density ratio} = \frac{\text{Surface Area of Steel}}{\text{Exposed Surface Area of Concrete}}$$

2. Number of Concrete Anode Calculation

$$\text{Required zinc anode, } m_{Zn}\text{ (g)} = \frac{[(i_1 \times Y_1)+(i_{2\rightarrow n} \times Y_{n-1})] \times 8{,}760 \times A_c \times SDR \times 1{,}000}{\varepsilon_{Zn}}$$

โดย i_1 = current density at the first year (A/m^2)

$I_{2\rightarrow n}$ = current density at the second year to n year (A/m^2)

n = the design life (year)

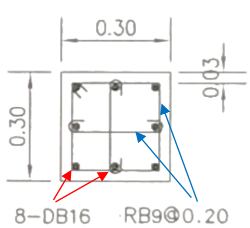
Y_1 = 1 for the first year

Y_{n-1} = n – 1

A_c = exposed surface area of concrete (m^2)

ε_{Zn} = electrochemical capacity of zinc anode, 780 Ah/kg

Example # 1 New building column 30 × 30 cm. with 1 m. height



From the picture, the detail of steel rebars are the following:

1. 8 of steel rebar with 16 mm OD and 1 m. length
2. 2 of steel wire with 9 mm OD and 30 cm. length and 1 of steel wire with 9 mm OD and 120 cm. length @20 cm.

$$\text{Steel density ratio} = \frac{\left[8\times3.14\times\left(\frac{16}{1,000}\right)\times1\right]+5\left\{\left[2\times3.14\times\left(\frac{9}{1,000}\right)\times\left(\frac{30}{100}\right)\right]+\left[1\times3.14\times\left(\frac{9}{1,000}\right)\times\left(\frac{120}{100}\right)\right]\right\}}{4\times0.3\times1}$$

$$= 0.447$$

During the first year of CP, the steel rebar will require high current density for corrosion prevention and the required current will decline with time due to polarization (chemical changes at and around the steel/concrete interface). The current density for the first year shall be 2 mA/m^2. The current density for the next years should be 0 .2 mA/m^2 but for safety purpose, we will use 1 mA/m^2 instead due to the possible contamination from environment.

From the calculation above, the exposed surface of concrete is 1.2 m^2 and SDR is 0.447. The mass of zinc anode required to protect the reinforcing steel for 10 years is

$$\text{Required zinc anode, } m_{Zn} = \frac{[(0.002\times1)+(0.001\times9)]\times8,760\times1.2\times0.447\times1,000}{780}$$

$$= 66.27 \text{ g}$$

Anode Type	Zinc Anode (g)	No. of Anode	
		Per actual concrete area	Per one square meter
CR60 or CB60	60	66.27/60 = 1.10	1.10/1.2 = 0.92
CR100 or CB100	100	66.27/100 = 0.66	0.66/1.2 = 0.55
CR160 or CB160	160	66.27/160 = 0.41	0.41/1.2 = 0.35

From the table above, 2 of CR60 or CB60 should be selected for CP of new building column. One shall be tied with the reinforcing steel on one side of the building column with about 50 cm high from the floor and another one is installed on the opposite side.

Example # 2 Existing concrete floor 2 × 2 m with corroded steel bars. The detail of reinforcing steel is 10-DB16@0.20

$$\text{Steel density ratio} = \frac{\left[10\times3.14\times\left(\frac{16}{1,000}\right)\times2\right]+\left[10\times3.14\times\left(\frac{16}{1,000}\right)\times2\right]}{2\times2}$$

$$= 0.503$$

During the first year of CP, the rusted steel rebar will require high current density for corrosion protection and the required current will decline with time also. Therefore, the current density for the first year shall be 20 mA/m^2 and 2 mA/m^2 for the next years.

The exposed surface of concrete is 4 m^2 and SDR is 0.503. Then, the mass of zinc anode required to protect the reinforcing steel for 10 years is

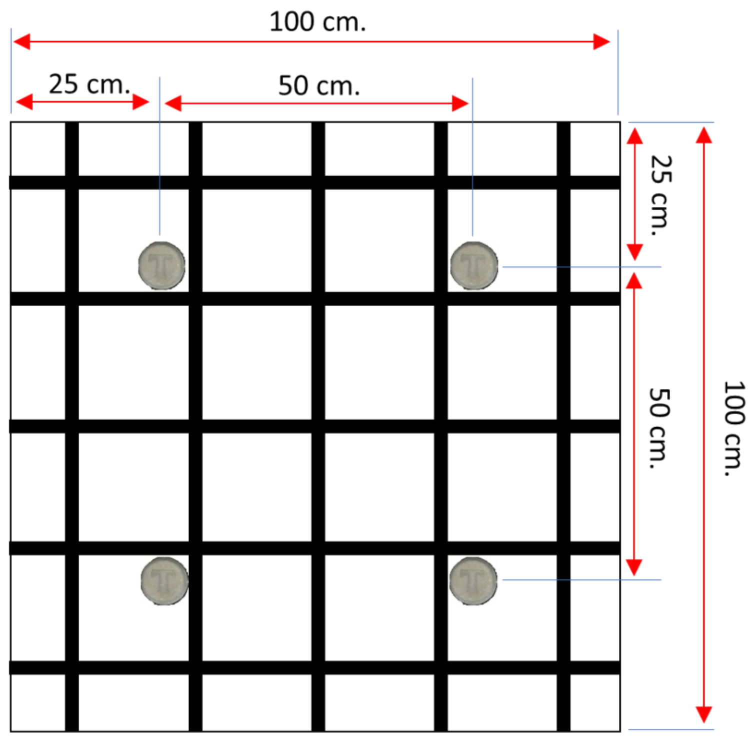
$$\text{Required zinc anode, } m_{Zn} = \frac{[(0.020\times1)+(0.002\times9)]\times8{,}760\times4\times0.503\times1{,}000}{780}$$

$$= 858.66 \text{ g}$$

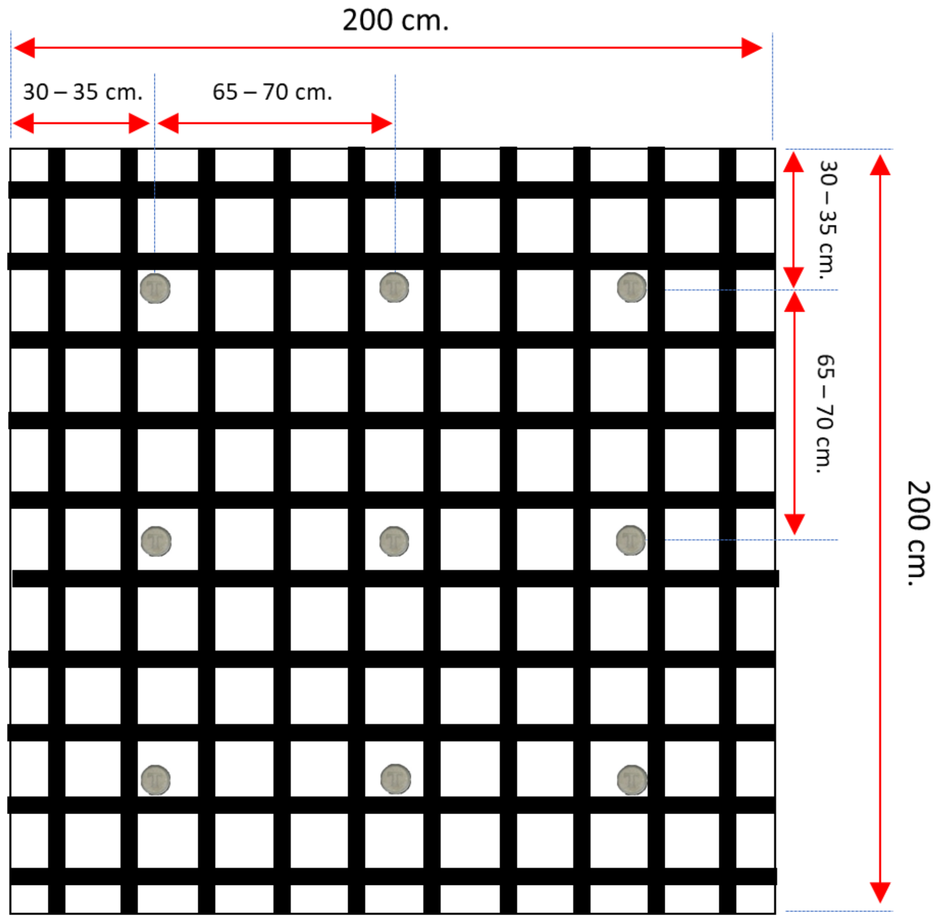
Anode Type	Zinc Anode (g)	No. of Anode	
		Per actual concrete area	Per one square meter
CR60 or CB60	60	858.66/60 = 14.31	858.66/60 = 3.58
CR100 or CB100	100	858.66/100 = 8.59	858.66/100 = 2.15
CR160 or CB160	160	858.66/160 = 5.37	858.66/160 = 1.34

There are 2 options for anode installation

Option 1 Use 4 of CR60 or CB60 for 1 square meter with anode spacing about 50 cm.



Option 2 Use 9 of CR100 or CB100 for actual concrete area with anode spacing about 65 – 70 cm.



3. Protected Area per One Concrete Anode (A_{CP})

$$A_{CP}\,(m^2) = \frac{m_{Zn} \times \varepsilon_{Zn}}{[(i_1 \times Y_1) + (i_{2\to n} \times Y_{n-1})] \times 8{,}760 \times SDR \times 1{,}000}$$

Assume the protected area to be square. Then, the spacing of concrete anode can be calculated using below equation.

$$\text{Anode spacing (cm)} = \sqrt{A_{CP}} \times 100$$

Example # 3 Recall the repair of concrete floor from example # 2. If we want to use concrete anode type CR60 or CR100 to protect the concrete floor for 10 years, the calculation for both types are:

Option 1 Concrete anode type CR60

$$A_{CP} = \frac{60 \times 780}{[(0.02 \times 1) + (0.002 \times 9)] \times 8{,}760 \times 0.503 \times 1{,}000}$$

$= 0.28\ m^2$

Anode spacing = $\sqrt{0.28} \times 100$ = 52.87 cm

No. of CR60 = $\frac{A_C}{A_{CP}} = \frac{4}{0.28}$ = 14.29 = 15 ea.

Option 2 Concrete anode type CR100

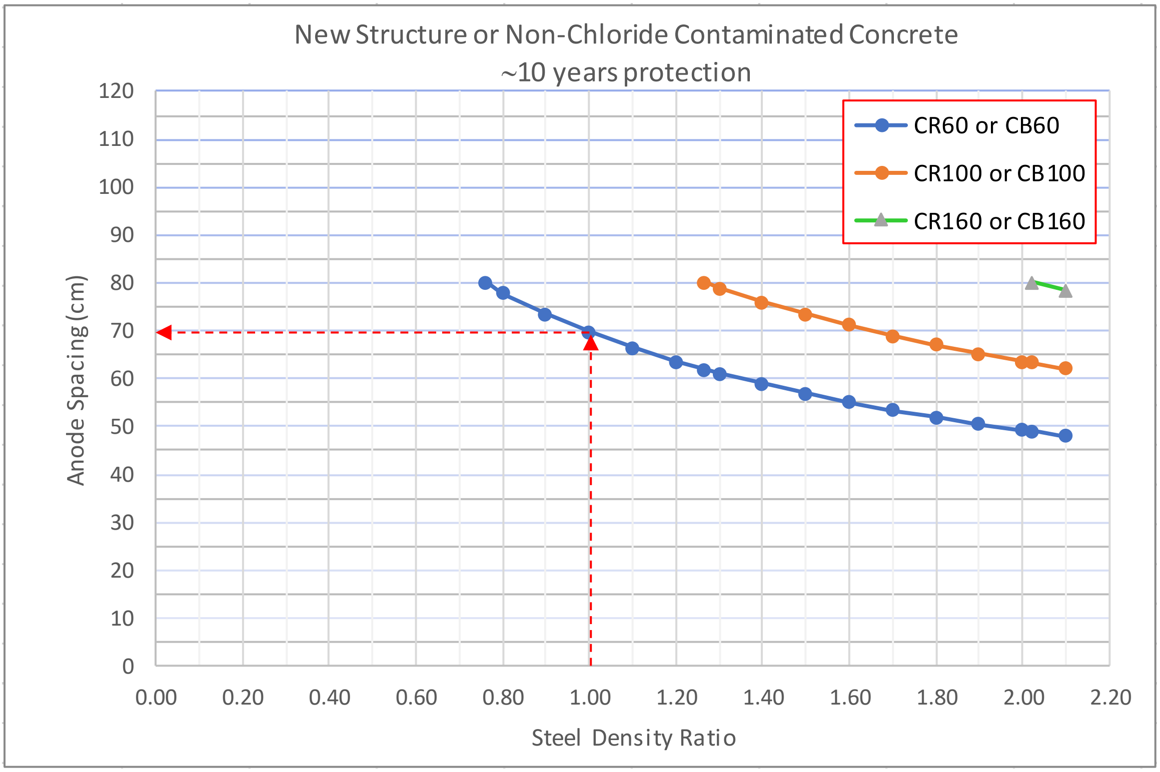
$$A_{CP} = \frac{100\times780}{[(0.02\times1)+(0.002\times9)]\times8{,}760\times0.503\times1{,}000}$$

$= 0.47\ m^2$

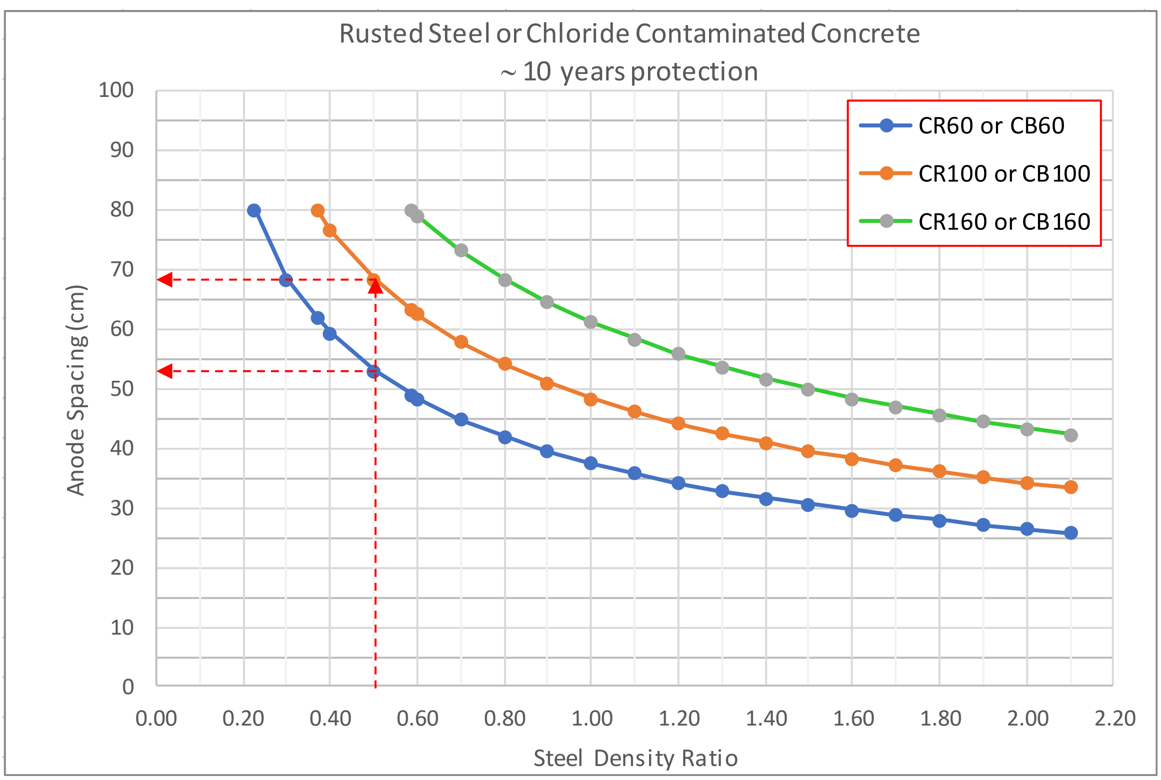
Anode spacing = $\sqrt{0.47} \times 100$ = 68.25 cm

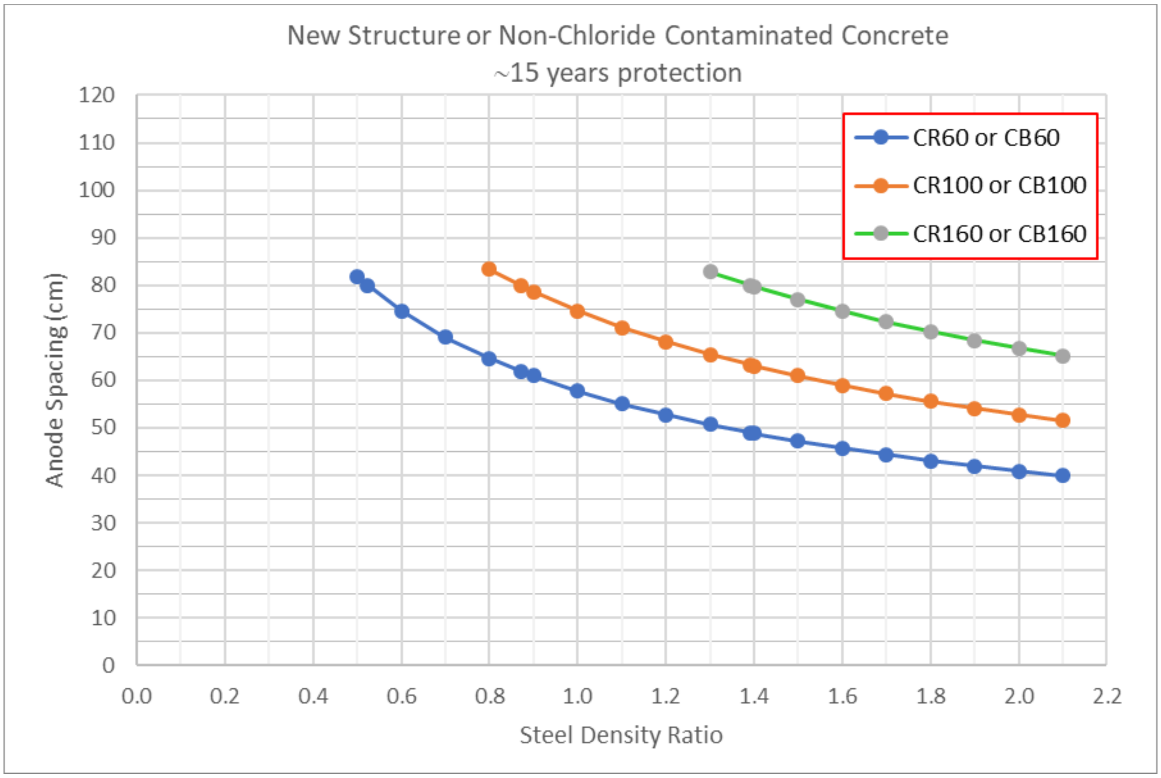
No. of CR100 = $\frac{A_C}{A_{CP}} = \frac{4}{0.47}$ = 8.51 = 9 ea.

Use the same calculation to make the graphs for anode spacing of each type with different design life. The samples are the following:

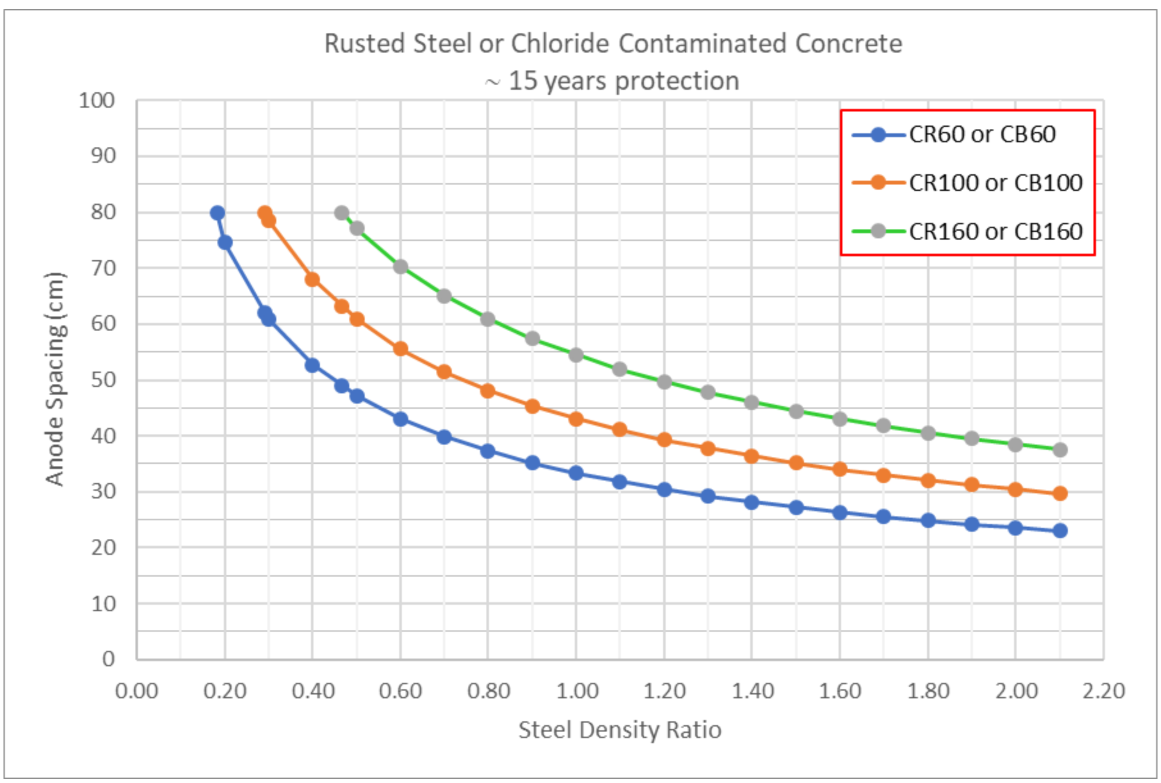


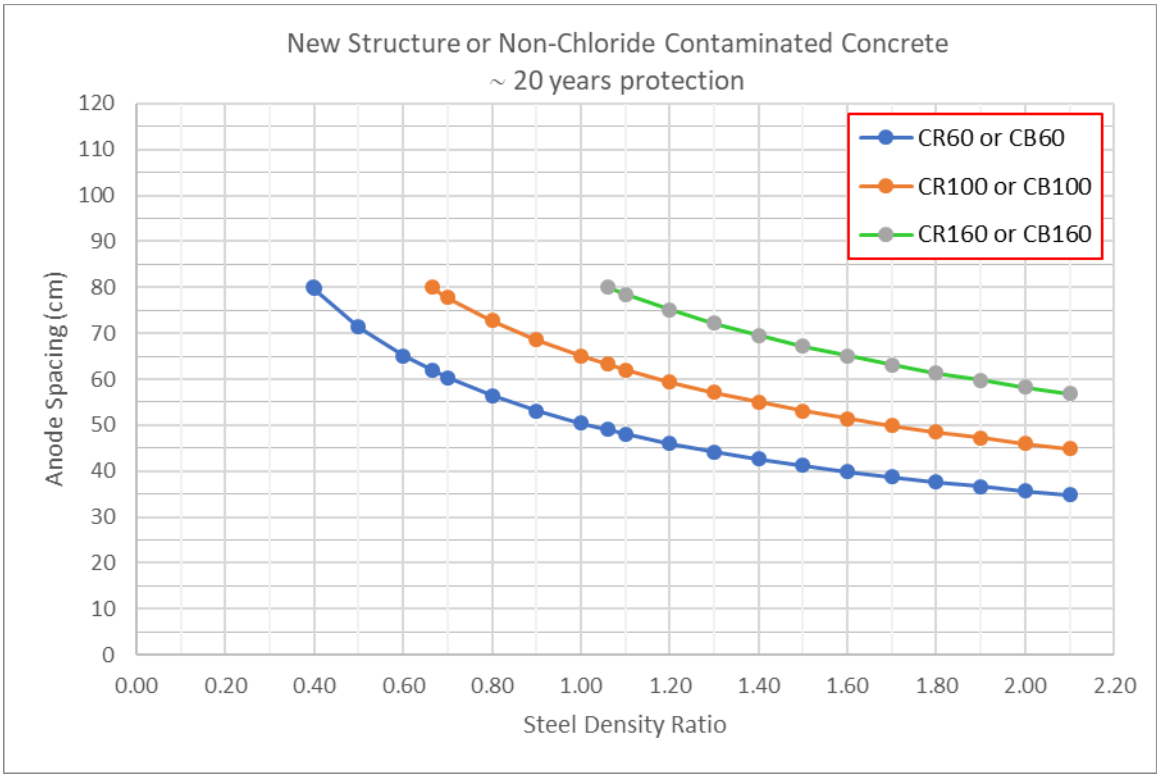
Anode spacing of TMP Concrete Anode for 10 years





Anode spacing of TMP Concrete Anode for 15 years





Anode spacing of TMP Concrete Anode for 20 years