Prescriptive Concrete Mix Design for 75 year Service Life of Superstructure Members in Marine Environment Splash Zone

Cover	Elevation above MHW	Wave action	Requirement
<2.5”	>12’		Follow SDG
	8’ to 12’	Rare	Ternary Blend with 50% Slag and 20% fly ash. Rebar ASTM A 1055.
		Periodic	Ternary Blend with silica fume and 20% fly ash. Rebar ASTM A 1055.
	4’ to 8’	Rare	Ternary blend with 50% slag, 10% fly ash, and super fine fly ash or Metakaolin, or silica fume. Black bar.
		Periodic	Stainless steel rebar like 304, 316LN, 2205 or better (not for Pre-stressed steels). Ternary blend with 50% slag and 20% fly ash.
	0’ to 4’	Routine	Stainless steel rebar with > 3% molybdenum like 316LN, 2205 or better (not for pre-stressed steels). Fly ash or slag per 346. ternary blend with 50% slag and 20% fly ash.
2.5 to 3.5"	> 12’		Follow SDG
	8’ to 12’	Rare	50% Slag or 20% fly ash per 346. Rebar ASTM A 1055.
		Periodic	Ternary Blend with 50% Slag and 20% fly ash. Rebar ASTM A 1055.
	4’ to 8’	Rare	Ternary blend with 50% slag and 20% fly ash. Rebar ASTM A 1055.
		Periodic	Stainless steel 304, 316LN, 2205 or better (not for pre-stressed steels). Fly ash or slag per 346. ternary blend at the designers option.
	0’ to 4’	Routine	Stainless steel with > 3% molybdenum like 316LN, 2205 or better (not for Pre-stressed steels). Fly ash or slag per 346. ternary blend at the designers option.
>3.5"	All	All	Fly ash or slag as per 346, ternary blend at the designers option

Notes:

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Lowest point of member defines the mix design and steel to use. Combination of metals is allowed, i.e. stainless on the outside, carbon steel on the inside. No combination of concrete mixes in an individual member. Better steel or mix design can be substituted.

Wave action examples:

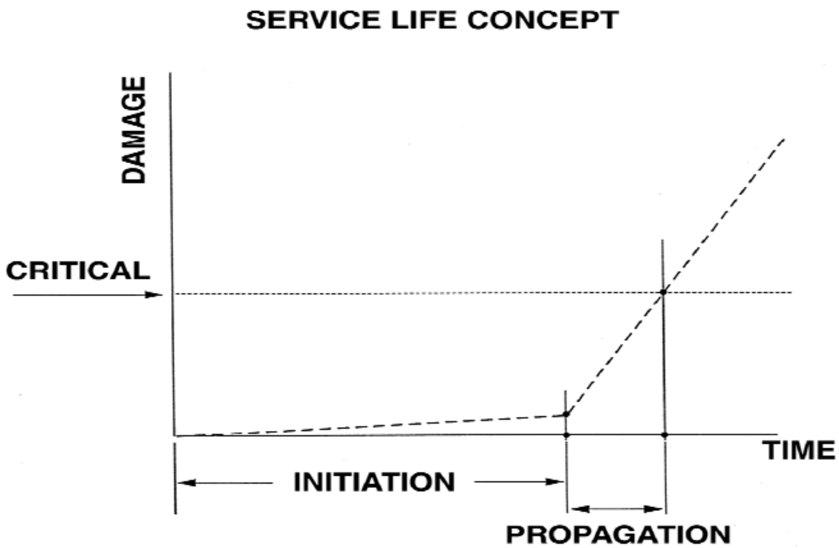
Rare: A member in a structure located in a canal that while it does see the tides, the waves are not large enough to periodically wet the concrete

Periodic: if the member is located in a structure directly exposed to the ocean or bay waves, it will see large enough waves periodically due to annual storms

Routine: Due to the low elevation, the member sees waves all the time regardless of structure location

Performance Based Concrete Mix Design for 75 year Service Life of Superstructure Members in Marine Environment Splash Zone

1. Time to Corrosion Initiation (Ti) - Time for chlorides to diffuse through the concrete until they accumulate in sufficient amounts to start corrosion. The amount of chlorides is defined as the chloride threshold (Cl_{th}). The simplest way to calculate Ti is to use Fisk's second law of diffusion. Ti for this calculations needs to be 65 years. The solution to Fisk's second law is given below.
2. Propagation time (Tp) - Time for enough oxides to accumulate until enough pressure builds up inside the concrete that a crack is generated. Tp can be assigned a length of 10 years for conservative purposes, unless



$$C_T = C_S \left(1 - \operatorname{erf} \frac{x}{2\sqrt{Dt_i}}\right)$$

Where:
x is location within the concrete. In this case the amount of concrete cover.
Ct is chloride concentration at depth x. In this case the chloride threshold. Assume 1.2Lbs/Yd^3 if unknown.
Cs is chloride concentration at surface. Assume 40 Lbs/Yd^3 if unknown.
Ti is time to initiation. In this case time to initiation would be 65 years
D is diffusion coefficient of the concrete

Convertion of the units to the appropiate values is required.

By rearrenging the equation to resolve for D, one can obtain the diffusion needed. A combination of concrete quality and cover can be used to achieve the 65 year Ti needed to get the service life.

Diffusion coefficient can be estimate by testing concrete at 28 days using Test method NT Build 492. Divide result by ten to obtain field diffusion. The maximum diffusion coefficient for each amount of cover is given below:

1 inch	2×10^{-14} m^2/s	This number is un-obtainable with High Performance Concrete. Use SS
2 inch	1×10^{-13} m^2/s	Metakaolin. silica fume, and super fine fly ash, difficult, but not impossible
2.5 inch	1.5×10^{-13} m^2/s	Metakaolin. silica fume, and super fine fly ash can achieve if properly designed
3 inches	2.2×10^{-13} m^2/s	Metakaolin. silica fume, and super fine fly ash can achieve this diffusion