Rounding the Corner on Infrastructure Deterioration

Tried and Emerging Technologies

AAPA Facilities Engineering Conference

Vancouver, BC

November 2013

Contributing/Precipitating Factors at End of Service Life

Design

Workmanship

Environmentals

Utilization

Assessment Tools

In Service

- Timber: Microscopy and Mechanical Testing
- Concrete: Petrography

Preventatives

- Mix Design: Ion Transfer Modeling
- Pile Driving: Embedded Technology for Monitoring Geotechnical Capacity and Pile Integrity

Definitions

- **Life Expectancy**: duration in number of years remaining before the uniform allowable live load deteriorates to a value of 250 psf or any other value that prohibits utilization of wharf-mounted equipment (e.g., cranes) that is critical to current or forecast operational logistics

- **Design Service Life**: maintenance free (maint <= 1% construction cost) target duration in number of years in advance of the deterioration of the uniform allowable live load to a value of 250 psf or any other operationally critical value; **75-125^{+}** yr min new structures and repairs

Facility Acquisition

- Maryland Port Authority 1956
  - Harbor Field City Airport➔570 ac Dundalk
  - Private Terminal Acquistions ➔ Locust Point, Hawkins Point Railroad Piers and Clinton Street, Fairfield Piers
- Maryland Port Administration 1971
  - Construction of Marginal Wharves
  - Harbor Tunnel Dredge Material ➔Seagirt 1989
  - Seagirt Channel Dredge Mat’l ➔ Masonville 2014

Marine Structure Inventory

- Piers
  - 532,000 sf timber (circa 1923)
  - 784,000 sf concrete (circa 1940- 2014)

- Marginal Wharves
  - 7,800 lf timber (circa 1930)
  - 4,400 lf concrete and steel (circa 1930 - 2014)

12 yr Maintenance and Reconstruction Costs

Contract #	Expenditure ($M)	Title	Material	Type
512912, 515000	8.1	AWSR3-4	Concrete	Repair
511006	2.47	DMT HLA	Concrete	Targeted
509915	1.5	SLP HLA	Concrete	Targeted
506921,	1.18	AWDR1-3	Concrete	Repair
513017	.52	DMT Crane Bm	Concrete	Repair
513015	.23	DMT A Row	Concrete	Repair
512901	22	FMT3	Concrete	Reconstr
502009	24	DMT 5/6	Timber	Reconstr
513003	22	DMT4	Timber	Reconstr
512015	5.37	DMT 1 – 3	Timber	Targeted
510015	1.65	DMT HLA	Timber	Targeted
504518	1.8	FMT3/4	Steel	Targeted
	$92.93M			

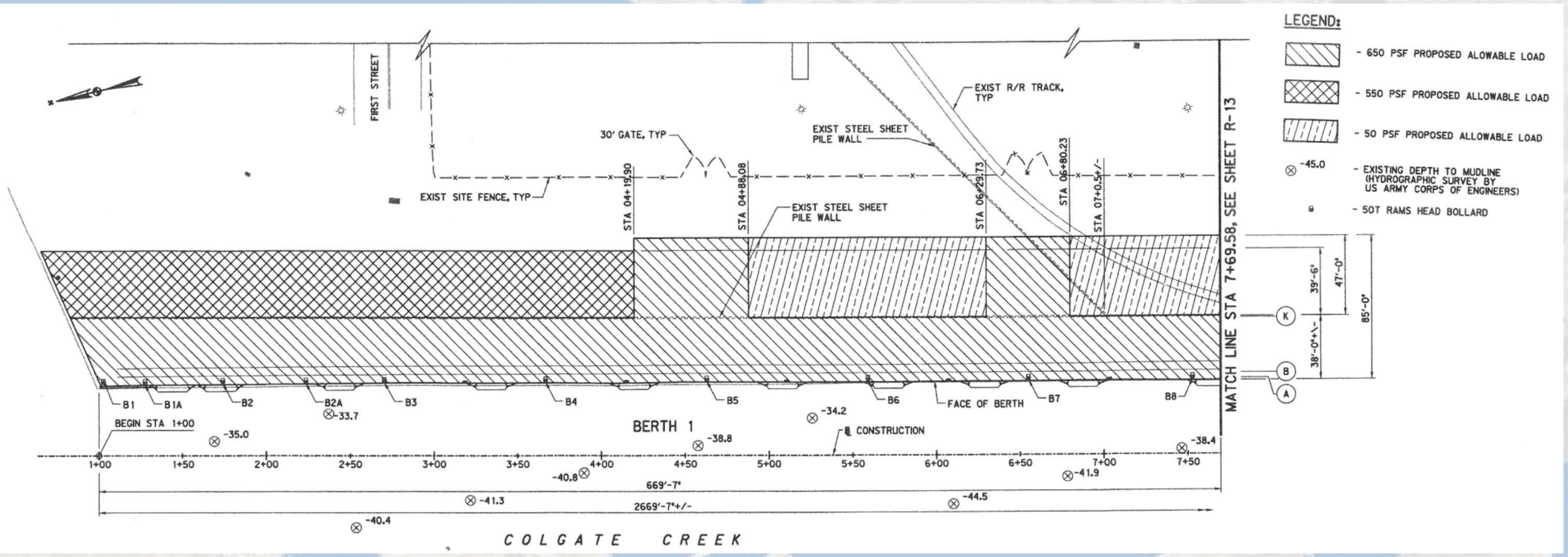
12 yr Maintenance and Reconstruction Summary

Expenditure ($M)	Proportion of Maintenance Budget (%)	Contract Type/Material
66.0	71%	Reconstruction
14.1	15%	Repair
12.8	14%	Targeted reconstruction
36.3	39%	Concrete
54.9	59%	Timber
1.8	2%	Steel

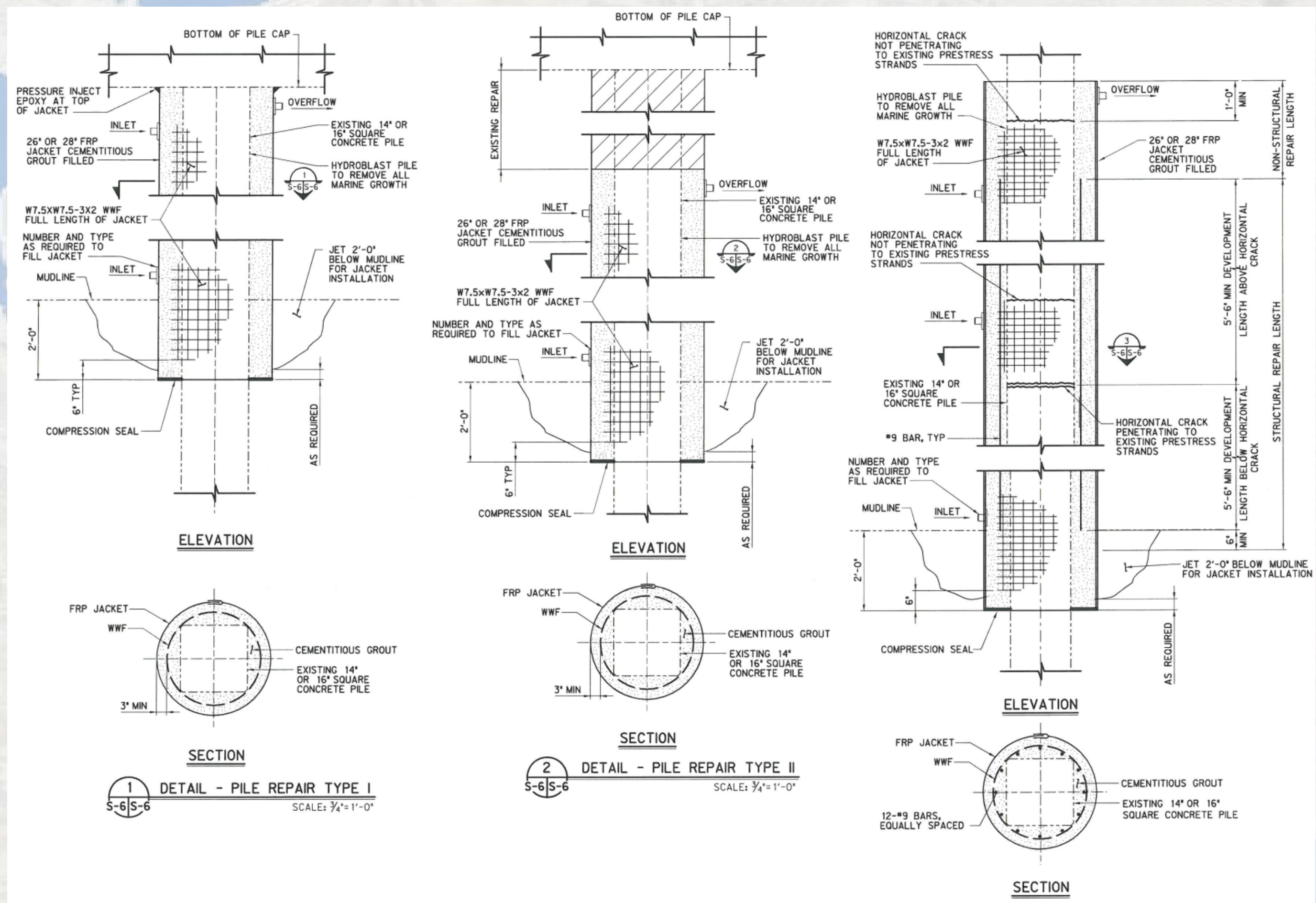
Targeted Reconstruction

- A marine facility rehabilitation consisting of a combination of super- and substructure repairs, replacements and reconstruction in targeted areas resulting in upgraded load capacity to meet precise operational geometric and load parameters. While extended life expectancy and zeroing of maintenance costs prevail for upgraded elements, continued vigilance and maintenance costs are associated with unrepaired structural members that remain within and adjacent to the upgraded footprint.

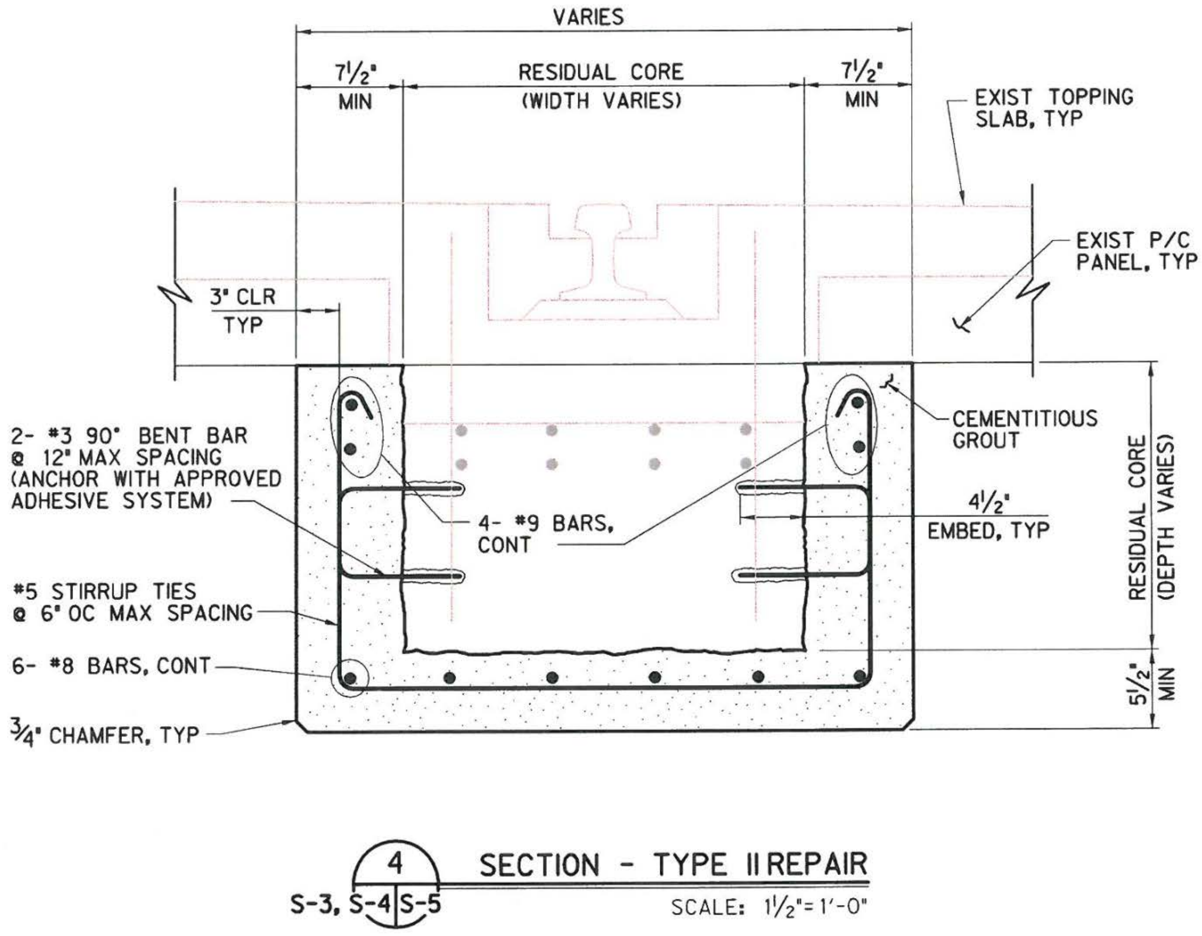
Operational Restoration - Targeted Reconstruction



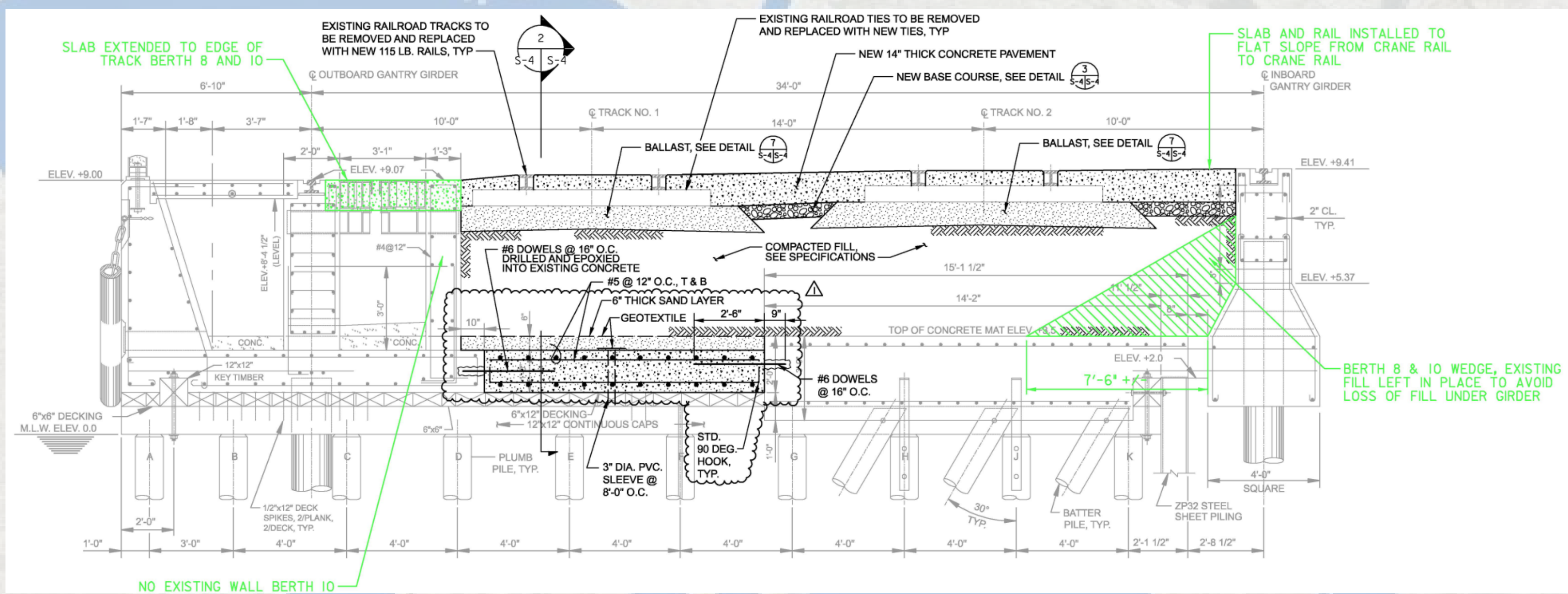
Concrete Pile – Jacketed Repairs



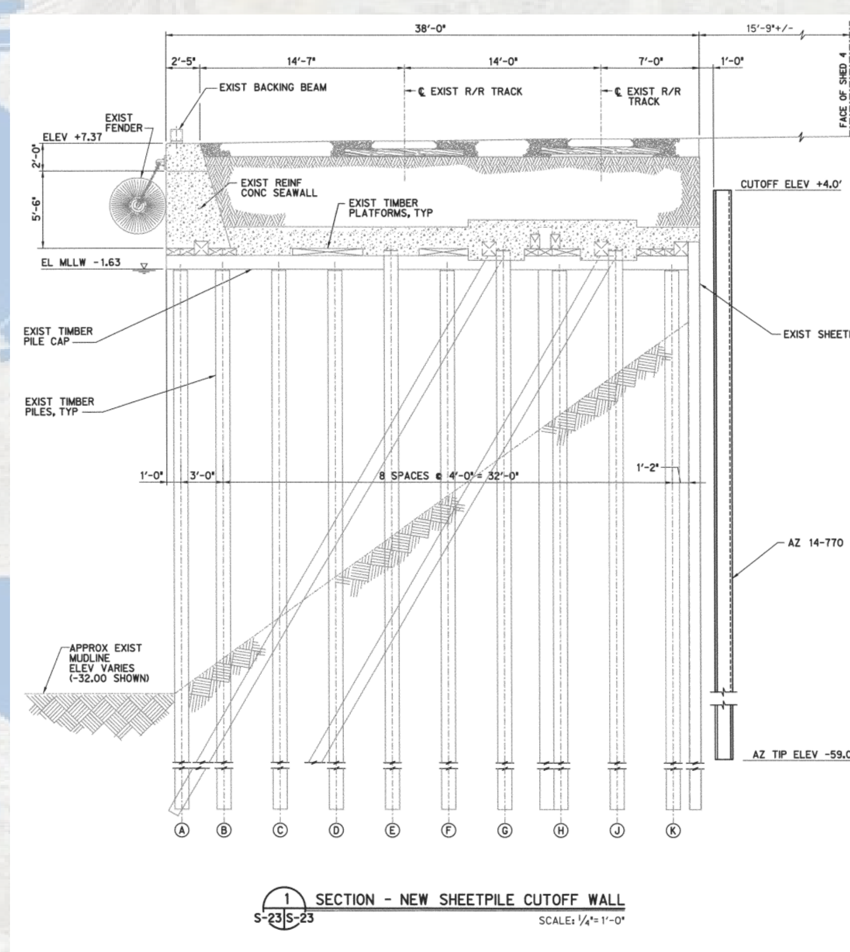
Crane Beam – Jacketed Repair of Concrete Corrosion



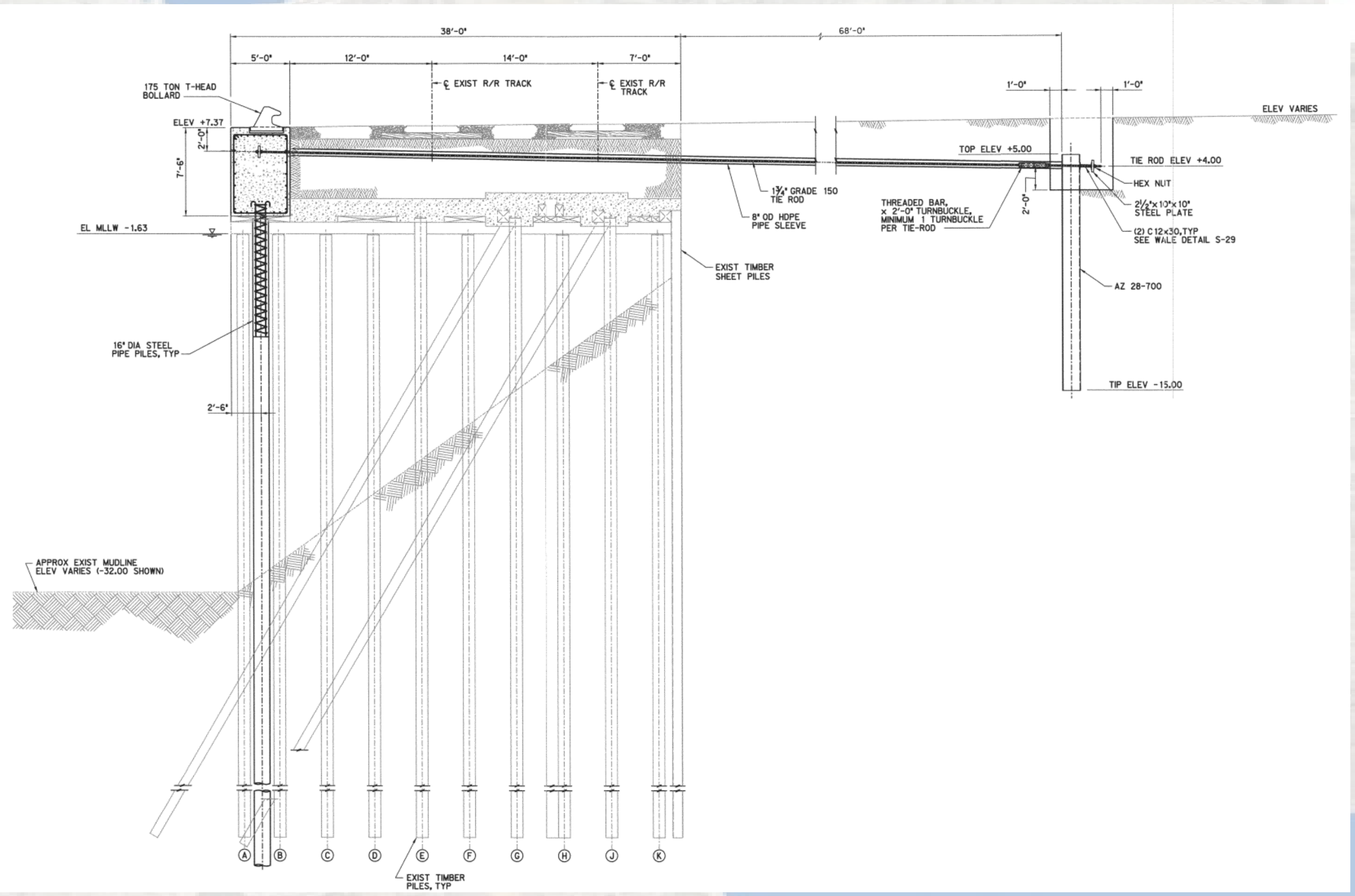
Timber Subdeck Replacement Targeted Reconstruction



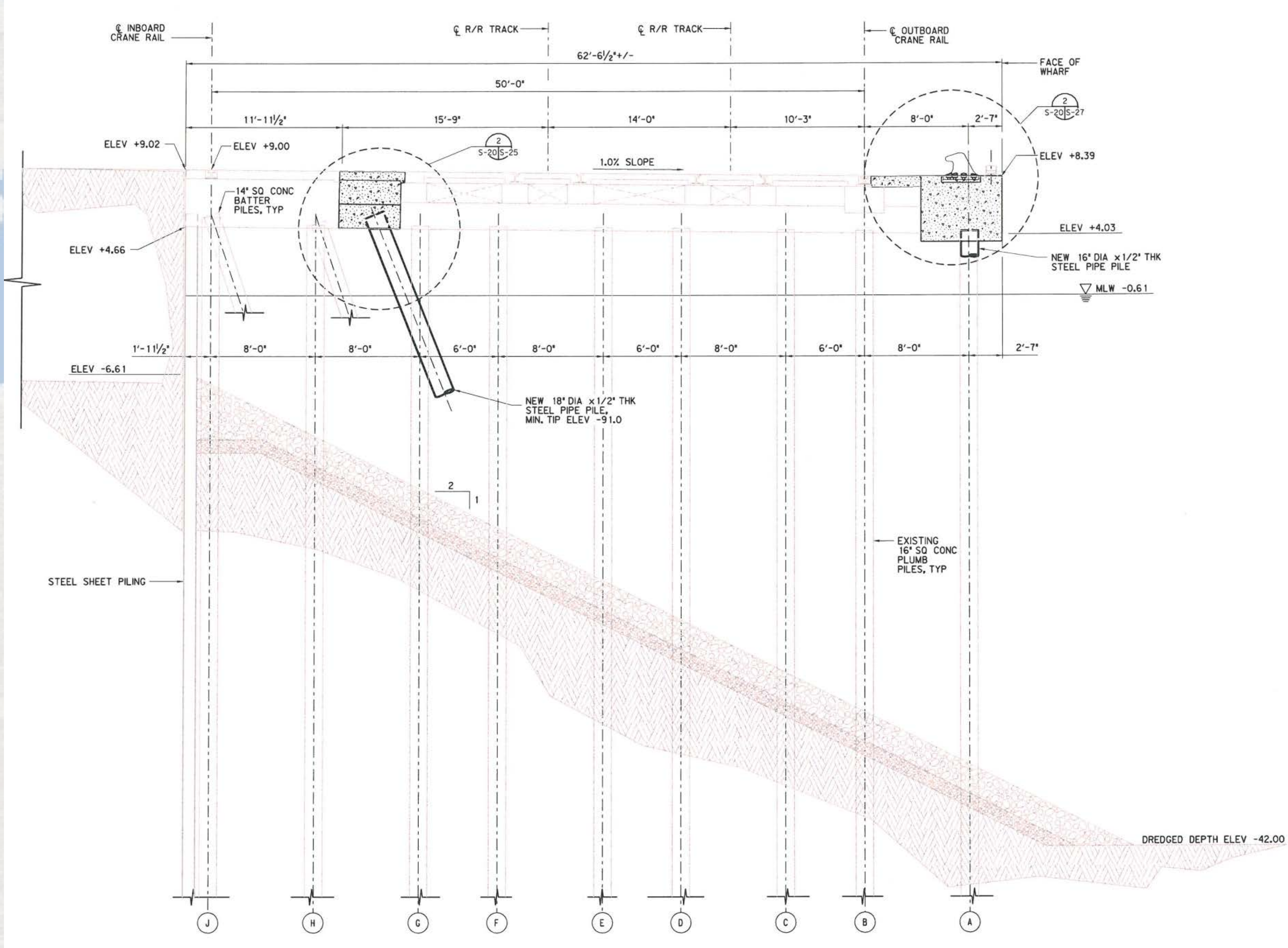
Partial Bulkhead Replacement - Targeted Reconstruction



Mooring Upgrade - Targeted Reconstruction



Mooring Upgrade - Targeted Reconstruction



Targeted Reconstruction Logistics

Adjacent cargo

Targeted Reconstruction Results

Abandon deteriorating and weak elements in place

Environmental Deterioration Factors for Concrete Structures

Physical

- Freeze/Thaw
- Scaling
- Supra Design Events
- Settlement
- Temperature

Chemical

- Corrosion
- Carbonation
- Sulfate Attack
- ASR
- DEF

Petrography– Crane Beam

ASR, high chlorides and corrosion of reinforcement

Loss of Section– Crane Beam

Depth of unsound concrete – 6+ inches

Design Factors for Concrete Structures

Mix Design
- Permeability
- Passivity
- Crack Resistance
- Workability
- Creep/Shrinkage

Design Philosophy
- Crack Control
- Reinforcement Material
- Joints

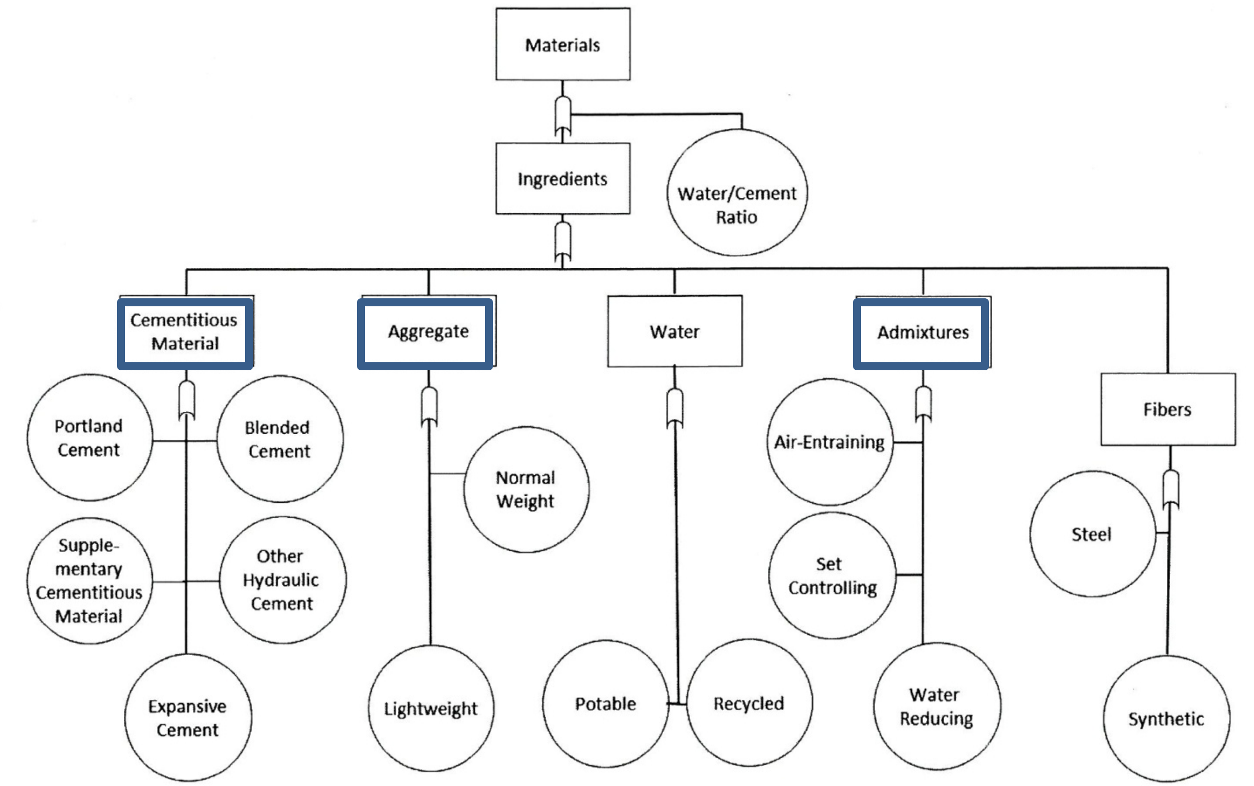


Figure 3.14. Materials fault tree.

Materials Fault Tree for Concrete

SHRB2 Renewal Project R19A, Design Guide for Service Life

Potential Deterioration Mode	Material Selection and Protective Measures Selection	Maintenance Modes	Life Cycle Costs: Initial	Life Cycle Costs: Long Term
Freeze and Thaw	Min. 6% Air Entrainment Sound Aggregates Strength > 3.5 ksi	None	Low	Low
	Proper Drainage and cover	None	Low	Low
	Membrane/Overlay	Continual Overlay Replacement every 20 years	Med	Med
ASR	Non-Reactive Aggregates	None	Med	Low
	Low Alkali Portland Cement	None	Med	Low
	Blended Aggregates Low Alkali Portland Cement SCMs (Fly Ash, Slag, etc.)	None	Med	Low
	Blended Aggregates Low Alkali Portland Cement Lithium Nitrate	None	Med	Low
	Proper Drainage	None	Low	Low
	Membrane/Overlay	Continual Overlay Replacement every 20 years	Med	Med
ACR	Non-Reactive Aggregates	None	Med	Low
	Blended Aggregates	None	Med	Low
	Proper Drainage	None	Low	Low
Sulfate Attack	Cement with low C3A content, early curing temperature <160°F	None	Low	Low
	Pozzolans, low w/cm, proper drainage	None	Low	Low
Delayed Ettringite Formation	Cement with low C3A content, early curing temperature <160°F	None	Low	Low
	Pozzolans, low w/cm, proper drainage	None	Low	Low

Concrete Durability Strategies

SHRB2 Renewal Project R19A, Design Guide for Service Life

Mix Design for Marine Concrete

PROPERTY	[6]Waterside Structures	Concrete Slab on Grade	[7]Utility Structures	[8]Miscellaneous Structures	Prestressed Concrete Piles	Precast Concrete Deck Panels	[11]Precast Concrete Utility Structures
28-Day Compressive Strength, ASTM C 39 (psi)	[1] 5,000	[1] 5,000	[1] 5,000	[1] 5,000	[1] 7,000	[1] 6,000	[1] 5,000
28-Day Flexural Strength, ASTM C 78 (psi)	--	700	--	--	--	--	--
Coarse Aggregate Size No. ASTM C 33	57 or 67	[5] Max 1-1/2”	57 or 67	57 or 67	67	57 or 67	57 or 67
Water-Cement Ratio (by weight)	0.40	0.45	0.45	0.50	0.40	0.40	0.40
Design Slump (inch)	[2] 4	[3] 2-3	[2] 4	[2] 2-5	[4] 4	[2] 4	[2] 4
Air Entrainment, % (ASTM C 231)	5±1.5	6.5 ±1.5	6.5 ±1.5	6.5 ±1.5	5±1.5	5±1.5	6±1.5
Calcium Nitrite Corrosion Inhibitor	YES	NO	NO	NO	YES	YES	NO
[9] Water Reducing Admixture Required	YES	YES	YES	NO	YES	YES	YES
[10]Anti-Washout Admixture	YES	NO	NO	NO	NO	NO	NO
STADIUM Life Expectancy (years)	50	50	50	50	75	75	50

Specifications for Marine Concrete

- B. All Cement: ASTM C 595, Type IS(MS) blended cement except as modified herein:
  - 1. The blended cement shall consist of a mixture of ASTM C 150 Type II cement and ground iron blast-furnace slag. Type I, Type III, and Type V cements shall not be accepted.
  - 2. Ground Iron Blast-Furnace Slag: ASTM C 989, Grade 120. Testing shall be performed no more than six months prior to submittal date.
  - 3. The ground iron blast-furnace slag shall comprise 25% by weight of total cementitious material.
  - 5. The tricalcium aluminate content of the blended cement shall be less than 8% by weight.
-
- C. For mass concrete and steam cured precast items; the following shall be met in addition to the requirements above:
  - 1. The maximum percent of sulfur reported as sulfate (SO3) in the blended cement shall be less than 3.0%.
  - 2. The alkali content of the blended cement shall be less than 0.7%
  - 3. The molar ratio of sulfate to tricalcium aluminate in the blended cement shall be less than 0.3.
-
- D. Aggregates
  - 3. Aggregates shall not contain any substance that may be deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of the concrete.
  - 5. Aggregates shall show expansions less than 0.10% at six months when tested in accordance with ASTM C 227 using cement with alkali content above 0.8% (expressed as sodium oxide). Aggregates showing expansion greater than 0.10% shall not be accepted. Where aggregates are deemed to possess properties or constituents that are known to have specific unfavorable effects in concrete, these aggregates shall not be accepted.
-
- E. Admixtures
  - 7. Corrosion Inhibiting:
    - h. Concentration of corrosion inhibitor shall be sufficient to produce the required life expectancy as predicted by the STADIUM analysis, but shall not be less than 5.1 pounds per cubic yard in the hardened concrete.

Mix Design for Marine Jacket Concrete

Location	f'c (Min. 28-Day Comp. Strength (psi)	ASTM C 33 Coarse Aggregate (Size No.)	Range of Slump (inches)	Water - Cement Ratio (by weight)	Anti-Washout Admixture Required
Pile Repair	5000	7	8-9.75	0.39	YES
Crane Beam Repair	5000	67	8-9.75	0.39	NO

D. Recommended Mix Design

1. The following mix design is specified for cementitious grout:

Cement, lb/cu yd	658
Silica fume, percent addition	6
Fly ash, percent addition	10
Cementitious materials, lb/cu yd	763
Fine aggregate, lb/cu yd	2028
Course aggregate, lb/cu yd	967
High range water reducer, fl oz/100# cement	14
[1]Anti-washout additive, percent cement weight	0.07

[1]Required for pile repairs only.

Service Life Issue	Solutions	Advantage	Disadvantage
Chemical reactions (ASR)	Non reactive siliceous aggregates	Reduce ASR	Hard to obtain in many areas
	Use of SCM	Reduce permeability, reduce ASR, limit alkalis from outside	Quality fly ash or slag missing in many areas
	Low w/cm	Reduce infiltration of solutions, limits alkalis from outside	Can produce high strength concrete that is brittle
	Chemical admixtures	Improved properties	Cost, incompatibility, side effects
	Lithium based admixtures	Inhibit ASR	Cost
	Limestone sweetening (blending with limestone)	Limit expansion	Reduced skid resistance
Chemical reactions (ACR)	Non reactive carbonate aggregates	Reduce ACR	Hard to obtain in some areas
	Reduce infiltration of solutions, limits alkalis from outside	Can produce high strength concrete that is brittle	Cracking
	Blend aggregate	Limit expansion	Hard to obtain in some areas
	Limit aggregate size to smallest practical	Limit expansion	Rich mixes with high paste content
Sulfate attack	Low C3A contents	Reduce sulfate attack	N/A
	Use of SCM	Reduce permeability, reduce sulfate attack, limit sulfates from outside	Quality fly ash or slag missing in many areas
	Low w/cm	Reduce infiltration of solutions, limits sulfates from outside	Can produce high strength concrete that is brittle

Durability Technologies

SHRB2 Renewal Project R19A, Design Guide for Service Life

Steam Curing Temperature Limitations and Monitoring Provisions

- c. Concrete Curing: Commence curing immediately following the initial set and completion of surface finishing. Provide curing procedures to keep the temperature of the concrete between 50 and 150 degrees F. Cure using one of the methods described below or by a method approved by the Engineer.
- d. Accelerated Steam Curing:
- (1) Immediately after each panel has been cast and finished, it shall be placed in a curing chamber, curing box, or under a tight enclosure which will protect the panel from wind and drafts. Such chambers and enclosures shall be sized to allow full circulation of steam around exposed surfaces of the panel.
- (2) Instrumentation:
- (a) Install exterior recording thermometers and interior temperature probes with enclosures and power source along with wiring. All thermometers and **probes shall record continuously and automatically.** Each 200 feet of length of fabrication bed shall be instrumented with both one exterior thermometer and one thermocouple interior probe. Exterior thermometers and interiors probes shall be installed in an alternating sequence. Parallel casting beds shall have the instrumentation placed in a staggered and alternating pattern along the panels. The thermometer and the probe shall be installed at 1/3 points along the 200 feet, close to the middle of the unit, and not closer than 5 feet and not farther than 10 feet from the orifice where the steam is introduced. The exterior thermometer shall be located at the side where the steam is introduced. The interior probe shall be located at center of panel thickness. Do not commence concrete placement until temperature recording devices have been checked to the satisfaction of the Q/C personnel. A uniform distribution of steam and curing temperature shall be maintained throughout the entire length of the panels. **Submit prints of the automatic readout daily if requested by Engineer.**
- (b) For the purpose of checking the Contractor's recording thermometer, the Engineer may install his own recorders. In this case, Contractor shall furnish the power source and wires at locations designated by the Engineer.
- (4) Commencing four hours after completion of concrete placement, the panels shall be subjected to the continuous action of steam. Care shall be exercised to see that heat is introduced gradually to avoid thermal shock to the concrete. During the heating, the temperature rise shall not exceed 25 to 35 degrees F per hour. The interior temperature of the panels shall be held at **a target temperature of 140 degrees F** with an upward **tolerance of 10 degrees F**. A single panel reaching an interior temperature of 150 degrees F may be accepted at the option of the Engineer. A run of several panels with an interior exceeding 150 degrees F will be rejected.
- (5) Cooling shall follow the steaming cycle. Care shall be exercised to protect the panels from rapid drops in temperature, mechanical injury, and other conditions likely to cause damage or loss of strength. During the cooling, the temperature drop shall not exceed 35 degrees F per hour. The cool down procedures shall be as follows:

STADIUM Results for Mix Designs

Element	Salinity (‰)	STADIUM® Analysis Graph ID	Reinforcement	Corrosion Inhibitor (gal/CY)	Cover (inches)	Time to Initiation + 10 years propagation (years)	Service Life (years)
Pile – Severe Exposure	30	A	Black	0	3.0	7 +10	17
	30	A	Black	0	3.25	9+10	19
	30	A	Black	0	3.5	10 + 10	20
	30	A	Black	3.5	3.0	65 + 10	75
Pile – Severe Exposure	18	B	Black	0	3.0	11 + 10	21
	18	B	Black	0	3.25	13+10	23
	18	B	Black	0	3.5	15+10	25
	18	B	Black	2.5	3.0	72+10	>75
Deck – Severe Exposure	30	C	Black	0	3.0	7+10	17
	30	C	Black	0	3.25	9+10	19
	30	C	Black	0	3.5	11+10	20
	30	C	Black	3.0	3.25	66+10	>75
	30	C2	Black	3.5	3.0	>75	>75
Deck – Severe Exposure	18	D	Black	0	3.0	12+10	22
	18	D	Black	0	3.5	14+10	24
	18	D	Black	0	4.0	17+10	27
	18	D	Black	2.0	3.5	70+10	>75
	18	D2	Black	2.5	3.0	>75	>75
Deck - Moderate Exposure	20	E	Black	0	3.0	21+10	31
	20	E	Black	0	3.25	24+10	34
	20	E	Black	0	3.5	29+10	39
	20	E	Black	2.0	3.0	29+10	>75
Deck - Moderate Exposure	12	F	Black	0	3.0	37+10	47
	12	F	Black	0	3.25	45+10	55
	12	F	Black	0	3.5	55+10	65
	12	F	Black	2.0	3.0	>75	>75

Workmanship Factors for Concrete Structures

Fabrication

- Mixing
- Consolidation
- Finishing
- Curing

Inspection

- Pile Driving

Driving Stresses for Prestressed Concrete Piles

- A new pile driving system, modifications to existing system, or new pile installation procedures shall be proposed by the Contractor if the pile installation stresses exceed the following maximum values:
  - Compression Stresses: 0.85(f'c) - fpe
  - Tension Stresses: 3 times the square root of f'c + fpe

- Reductions in allowable driving stresses appropriate for prestressed concrete piles in marine environments?

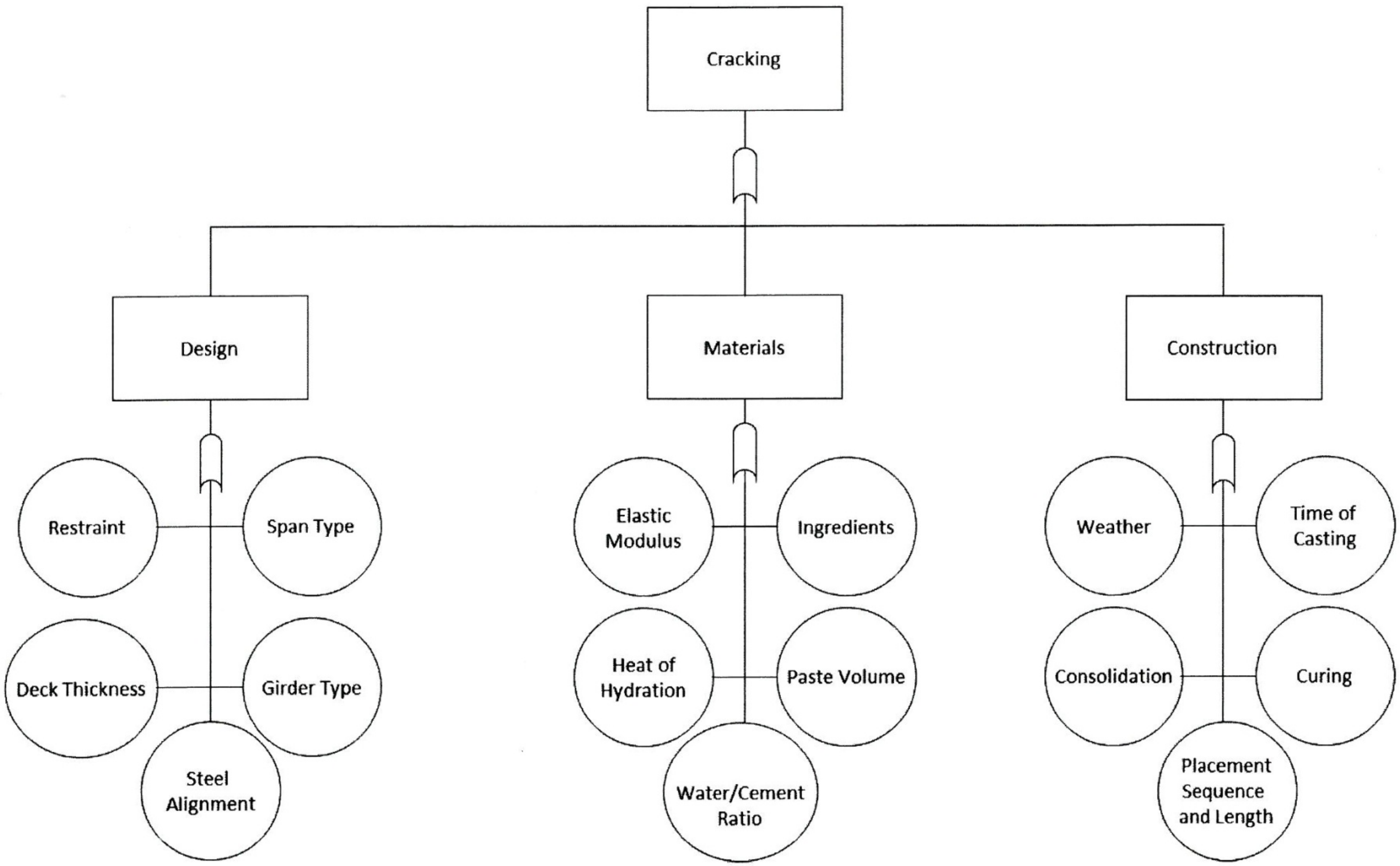
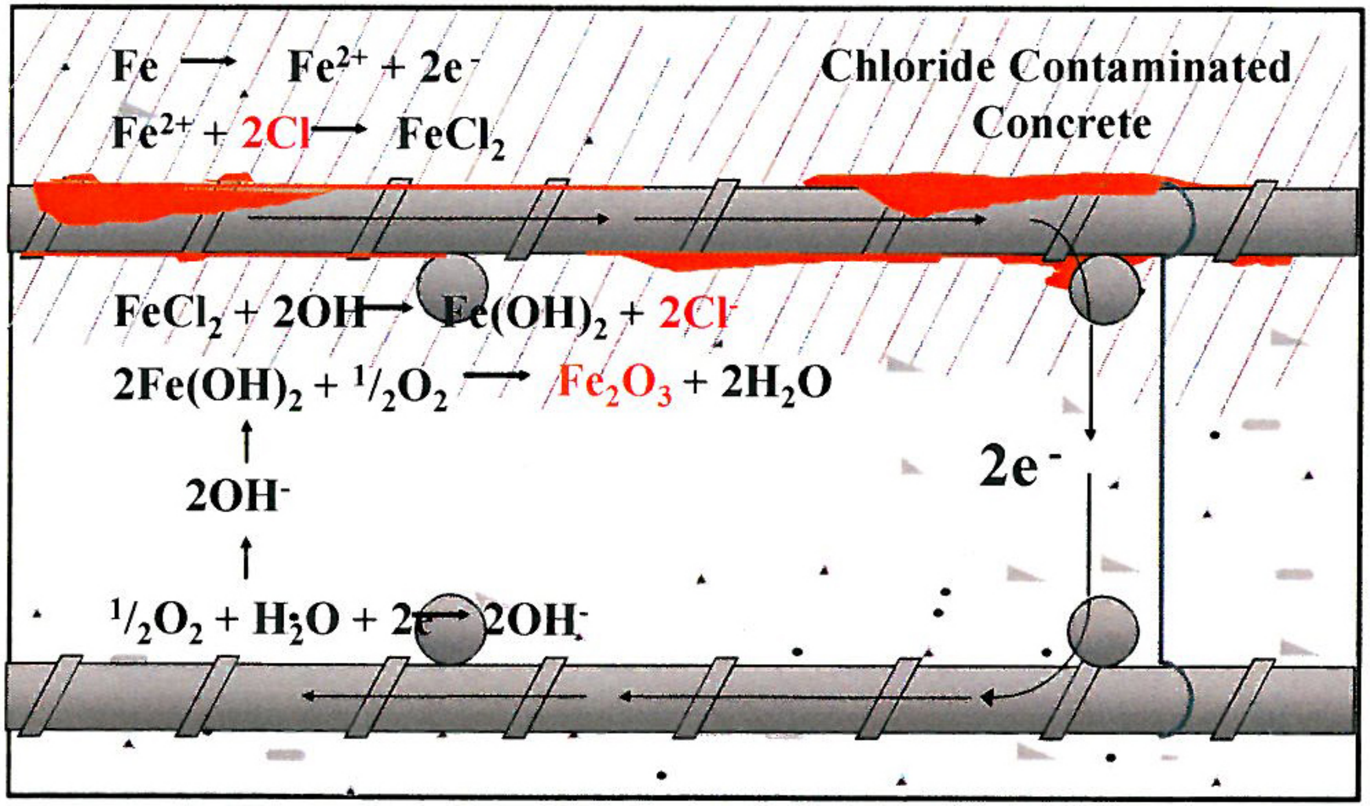


Figure 3.19. Cracking fault tree.

Cracking Fault Tree

SHRB2 Renewal Project R19A, Design Guide for Service Life



Corrosion Macrocell

SHRB2 Renewal Project R19A, Design Guide for Service Life

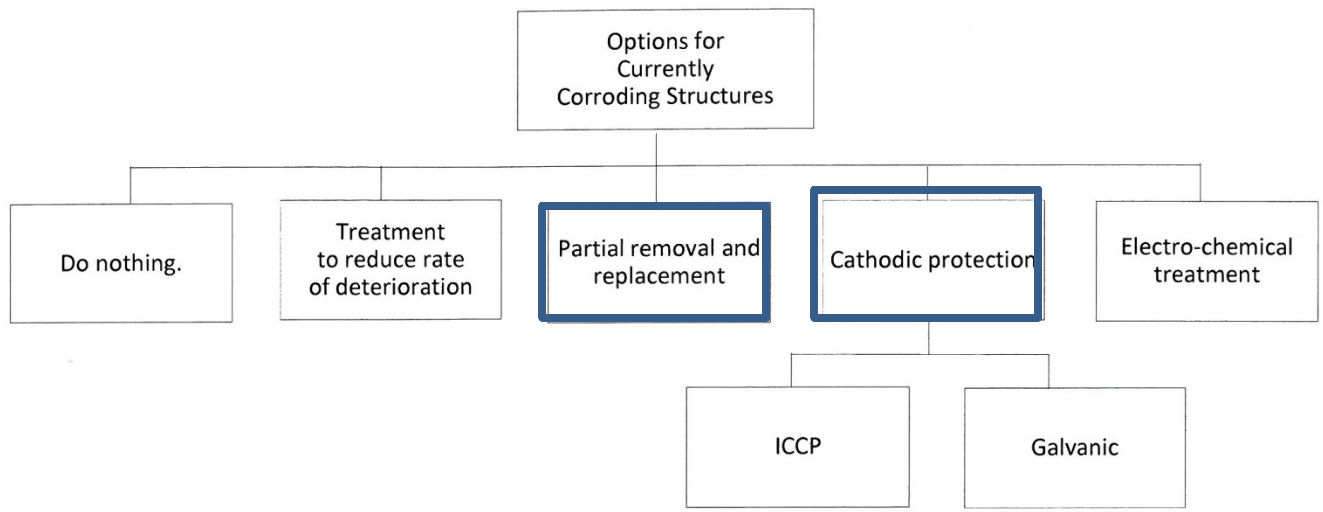


Figure 5.13. Options for corroding structures.

Strategies for Corroding Structures

SHRB2 Renewal Project R19A, Design Guide for Service Life

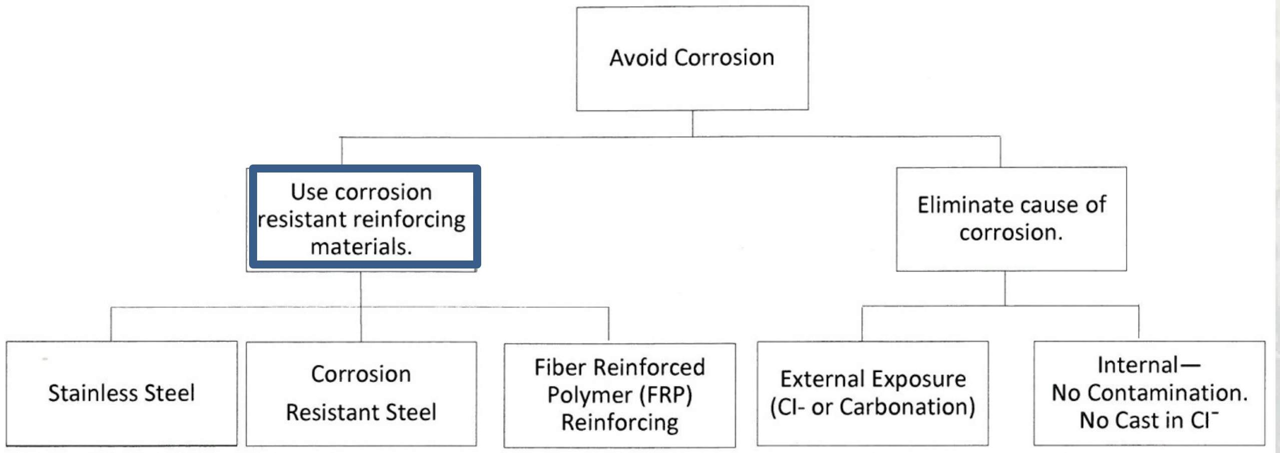


Figure 5.9. Options for avoiding corrosion.

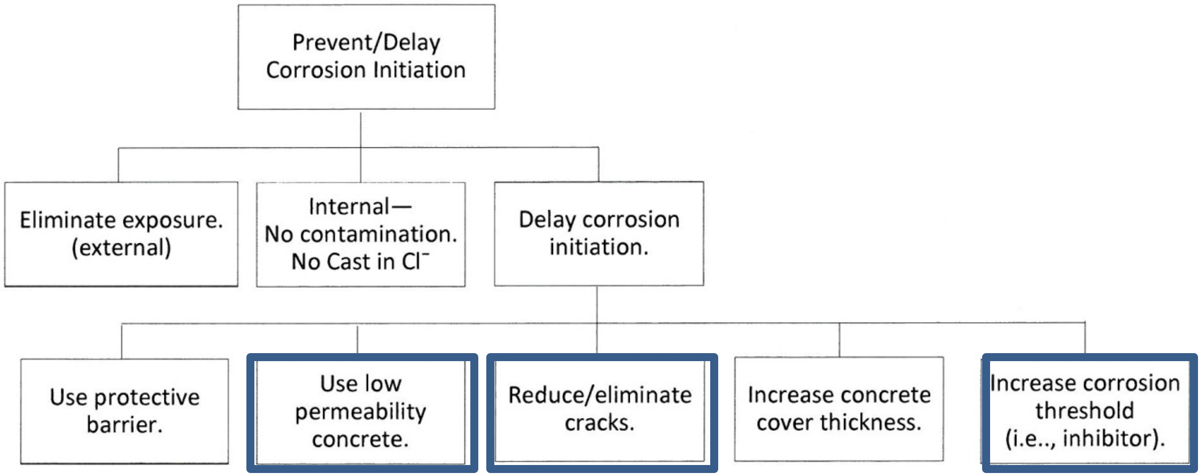


Figure 5.10. Options for preventing or delaying corrosion initiation.

Corrosion Delay and Avoidance Strategies

SHRB2 Renewal Project R19A, Design Guide for Service Life

Service Life Issue	Solutions	Advantage	Disadvantage
Corrosion of reinforcement	Low permeability	Reduce infiltration of aggressive solutions	Can produce high strength concrete that is brittle
	membranes and coatings	Reduce infiltration of aggressive solutions	Difficult to apply in the field, wear of traffic
	Sealers for pore lining and blocking	Reduce infiltration of aggressive solutions	Difficult to apply in the field, concrete may be difficult to penetrate
	Use of low w/cm	High strength, low permeability	Excessive cracking, shrinkage
	Low shrinkage	Minimize cracking	Low water content may adversely affect workability
	Low modulus of elasticity	High deformation, minimize deck cracking	Reduce stiffness
	Use of SCM	Reduce permeability	Quality fly ash or slag missing in many areas
	Large max aggregate size	Less surface area, loess water, cement, and paste	Less bond
	Well graded aggregates	Less paste	Problem when good shape is missing
	Chemical admixtures	Reduced permeability	Cost, incompatibility, side effects
	Cover	More resistance to penetration of solutions	Wider cracks, extra weight and cost
	Overlays	Create a low permeability protective layer over the conventional concrete.	Difficult to place, expensive, and is prone to cracking, proper curing is critical.
	Corrosion Inhibitors	Stable protective layer on the steel	Cost

Corrosion Technologies

SHRB2 Renewal Project R19A, Design Guide for Service Life

Service Life Issue	Solutions	Advantage	Disadvantage
Corrosion of reinforcement	Electrochemical chloride extraction	Extract chlorides from the concrete, or use in new structures to increase corrosion threshold	Extraction depends on the depth and location, risk of embrittlement (prestressed), difficult to predict service life
	Cathodic protection	Prevent corrosion from initiating, advantage as a repair method	High cost involved in maintaining the power source and sacrificial mesh anode. Embrittlement of strand and softening of concrete (prestressed structures)
	Sealers	Prevent solutions from penetrating the concrete, easy to apply either during or after construction	Difficult to ensure adequate coverage. Varying performance and cost. Short service life. Abrasion, sunlight and environment affect the sealer's efficiency
	Membrane	Prevent moisture infiltration	Varying performance. Difficult to install on curved or rough decks and to maintain quality and thickness during field installation.
Corrosion of reinforcement	Stay in place metal form for marines structures	Prevent infiltration of aggressive solutions	Cost
	Stainless steel	High resistance to corrosion	Initial cost
	FRP	High resistance to corrosion	FRP prone to degradation from environmental factors
	Z bars (galvanizing over epoxy coating)	High resistance to corrosion	
	Epoxy coated steel	Create protective layer over the steel and increase the electrical resistance	Epoxy coating can be damaged during handling, shipping and storage corrosion can initiate under the coating
	Low carbon chromium steel	High resistance to corrosion	High strength, no yield point
	Drainage design	Minimize saturation	Continuous maintenance
	Post Tension	Puts the concrete in compression minimizing cracks that facilitate the penetration of chlorides	Post tensioning ducts and grout are concerns in resisting corrosion

Reinforcement Corrosion Technologies

SHRB2 Renewal Project R19A, Design Guide for Service Life

Research
Corrosion Resistant Reinforcing Steel

- FHWA In House, SK Lee and Paul Virmani: chloride threshold and corrosion time for 12 varieties

- UKansas, Matt O'Reilly: Rapid microcell and cracked beam tests to establish corrosion rates for BB ECR and SS varieties

- FHWA/Florida DOT, Mario Paredes and William H. Hartt: chloride threshold and corrosion time for BB and SS varieties in support of Florida DOT's policy to implement alloys that will not corrode even if concrete is cracked, poorly consolidated and/or with zero concrete cover.

Hot Dip Galvanized Reinforcement

- GALVANIZED REINFORCING STEEL
- A. Under Bid Alternate B, all reinforcing steel within the superstructure shall be galvanized.
-
- B. All galvanized reinforcing steel shall be deformed billet-steel and shall conform to **ASTM A 706**, Grade 60.
-
- C. Galvanized reinforcing bars shall be galvanized in accordance with ASTM A 767, Class 1.
- 1. Prior to galvanizing, steel bars shall have all grease, dirt, mortar, scale, injurious rust, or any other foreign substance removed.
- 2. **Prior to galvanizing, all bars shall be bent and fabricated**.
- 3. The average coating thickness, of a minimum of 3 tests, shall be **3.5 ounces per square foot or 6 mils**.
- 4. All bars shall be inspected after galvanizing. If cracking/and or loss of the coating is observed, repair coating as described in ASTM A 767.
-
- D. All galvanized mild steel spirals located within the superstructure shall conform to ASTM A 82.
-
- E. All galvanized welded wire fabric shall conform to ASTM A 1060.
-
- F. Welding of galvanized bars is not permitted without the approval of the Engineer.
- 1. When permitted, welding of galvanized reinforcing shall conform to AWS D1.4 and AWS WZC. Welds shall only be made on the steel free of zinc adjacent to the weld. The zinc coating shall be removed at least one inch from either side of the intended weld zone, and on all sides of the bar by grinding or alternate approved method. After weld is completed, the zinc coating in the area of the weld shall be repaired using procedures conforming to ASTM A 780.

Under Bid Alternate B**, all steel wire ties, supports, standees, and all other reinforcing accessories** comprised of steel, and in direct contact with reinforcing, shall be galvanized. Reinforcing accessories in direct contact with reinforcing shall not introduce dissimilar metals or coatings within the concrete.

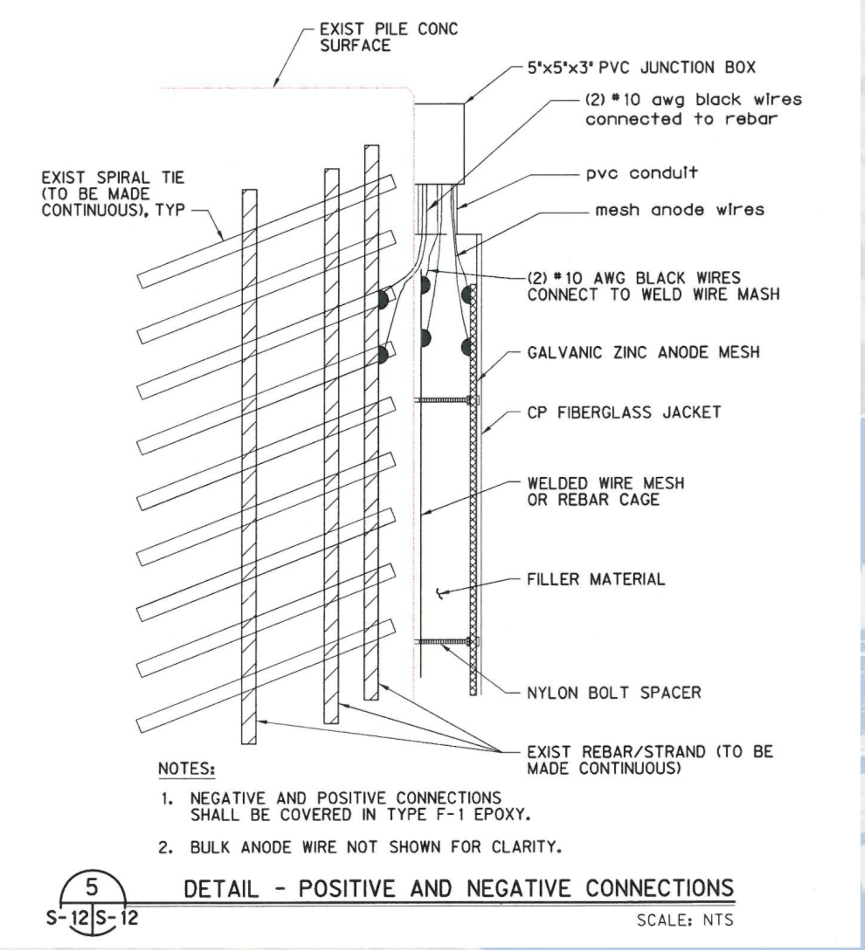
Hot Dip Galvanized Reinforcement

- **DMT4 Reconstruction Base Bid: $19.8M**
- **Base Bid BB: 739T**
- **HDG Alternate: 942T for additional $872K (4.4%)**
- **Unit price BB: $2283/ton**
- **Unit price HDG: $2717/ton**

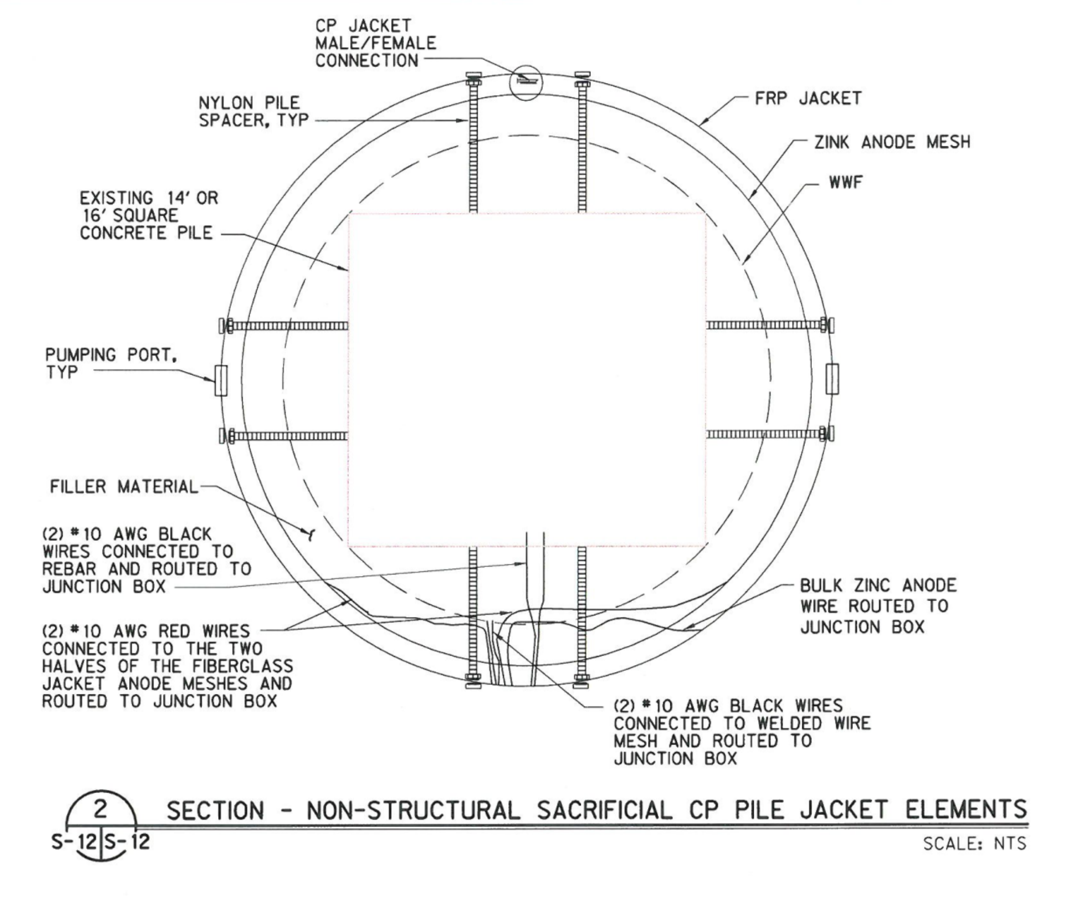
Hi Strength, Low Carbon Chromium Reinforcement

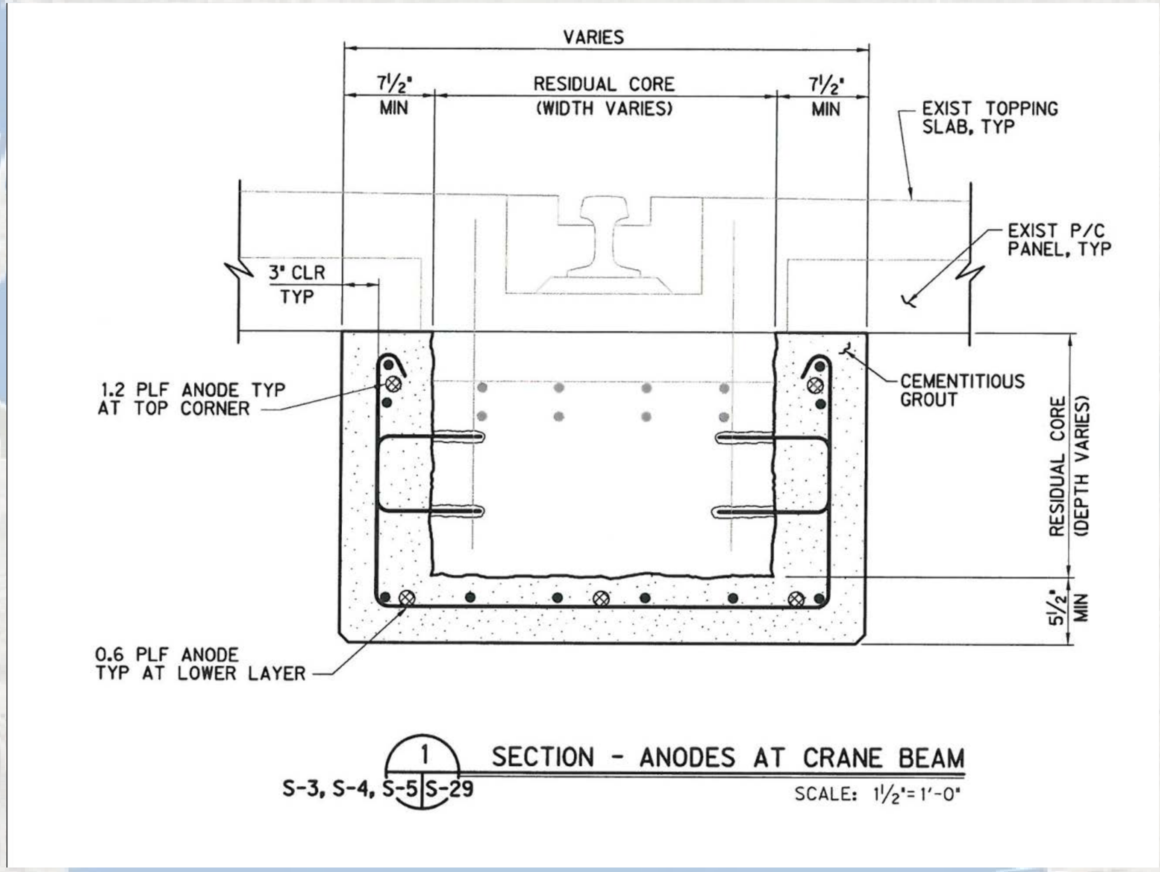
- A. A Value Engineering Change Proposal (VECP) to provide an equivalent reinforced concrete superstructure design using high-strength, low carbon, corrosion-resistant chromium reinforcing steel may be submitted to the Administration. All submitted VECP design documents shall be sealed by a Professional Engineer licensed in the state of Maryland.
-
- 4. All aspects of the proposed VECP design shall be supported by a complete set of calculations sealed by a Professional Engineer licensed in the state of Maryland. The complete set of sealed calculations shall be included within the VECP submittal. Only VECP submittals that include a complete set of sealed calculations will be accepted for review by the Administration. The submitted set of design computations shall be considered “complete” if the following aspects of design are supported in accordance with the code criteria and standards denoted herein:
-
- a. The design of all proposed framing cross sections provide equivalent or greater strength than the current design denoted in Contract Documents.
-
- b. The design of all proposed framing cross sections provide equivalent or better crack width control than the current design denoted in the Contract Documents.
-
- 5. The proposed VECP superstructure design shall use Low Carbon, Chromium Reinforcing Steel conforming to ASTM A 1035, Grade 100. Grade 120 will not be considered. Fabrication and detailing, including but not limited to hooks, bends, splices, development, anchorage, tolerances, bar terminators, connectors, and associated considerations and appurtenances shall conform to the more stringent of code requirements and/or manufacturer recommendations.

Jacketed Concrete Pile
Zinc Mesh CP Wiring Schematic



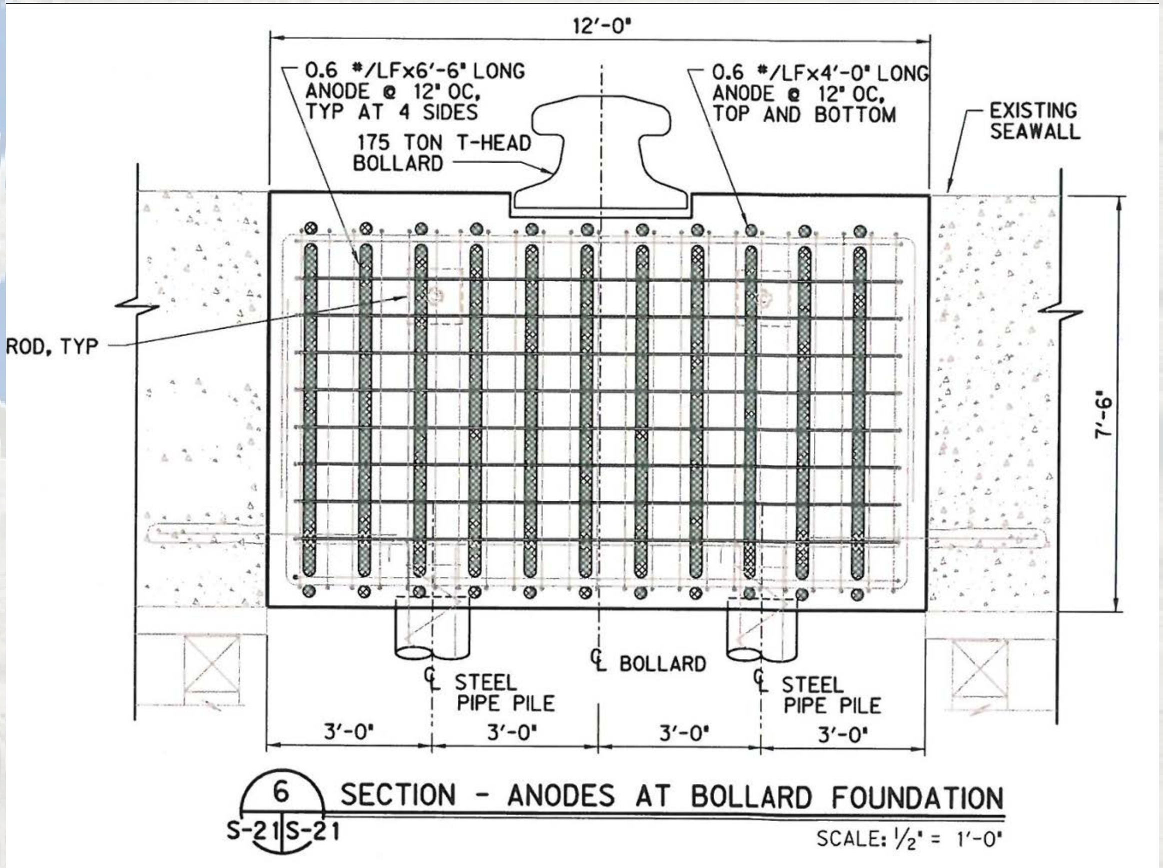
Jacketed Concrete Pile
Zinc Mesh CP Wiring Schematic





Jacketed Crane Beam

Sacrificial Anode Placement



Jacketed Bollard Cap

Sacrificial Anode Placement

Targeted Reconstruction – Pile Cap

Galvanic Reinforcement Anodes

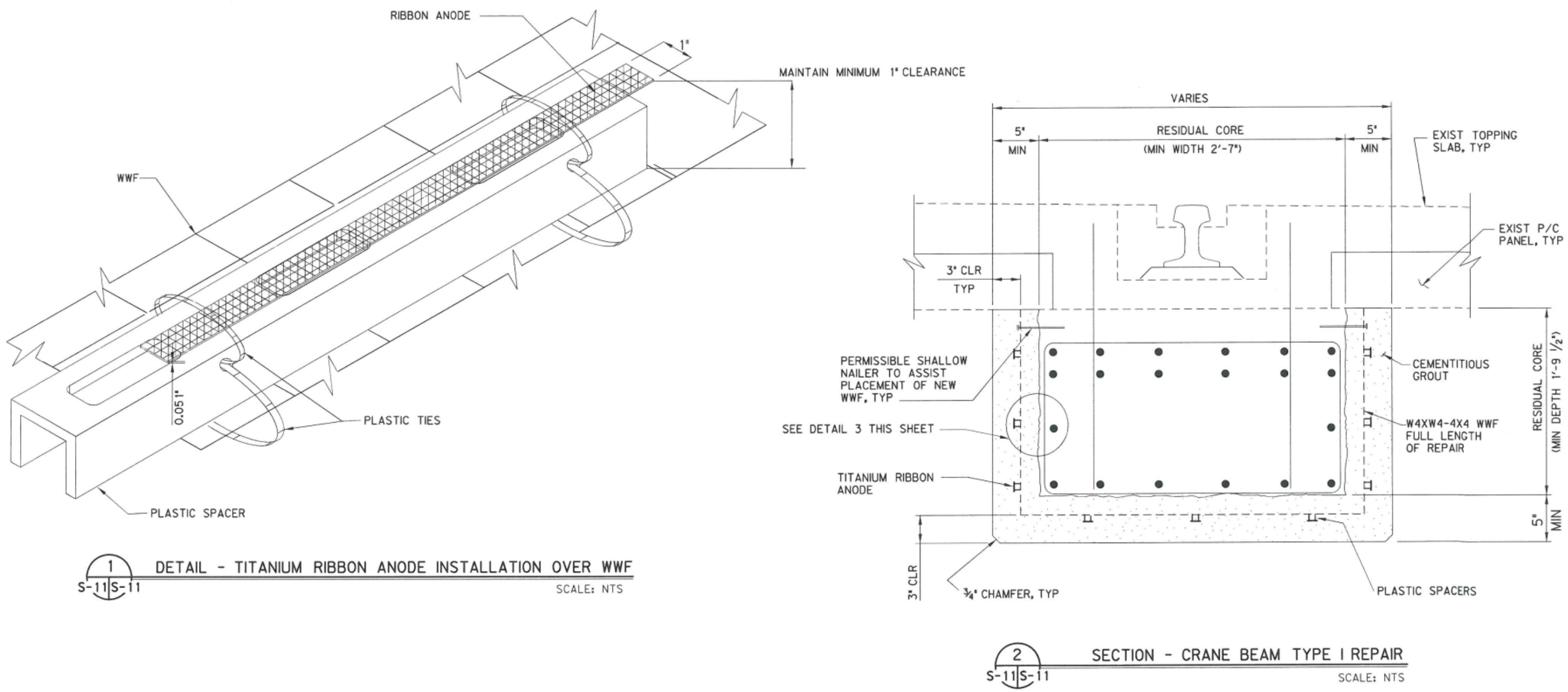
Targeted Reconstruction – Pile Cap

Galvanic Reinforcement Anodes

Targeted Reconstruction – Timber Subdeck

Galvanic Reinforcement Anodes

Crane Beam – Jacketed Repair of Concrete Corrosion Impressed Current CP System



Crane Beam – Jacketed Repair of Concrete Corrosion Impressed Current CP System