

Engineering Standard

SAES-Q-001

30 April 2005

Criteria for Design and Construction of Concrete Structures

Civil Standards Committee Members

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Abu-Adas, H.A.

Abulhamayel, I.A.

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Kassam, E.M.

Saudi Aramco DeskTop Standards

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1 Scope

- 1.1 This Standard covers the minimum mandatory requirements governing the design, specification, and construction of all onshore structural and non-structural concrete.
- 1.2 This standard also covers the minimum mandatory requirements governing the design, specification, casting, and erection of all precast and prestressed concrete products.
- 1.3 This Standard does not include concrete for concrete masonry and refractory concrete. See [SAES-B-006](#) for additional information on use of concrete as fireproofing material.
- 1.4 This standard states the minimum requirement that need to be fulfilled for offshore and marine concrete.

Commentary Note:

This standard does not cover coating, protection and curing of non-structural concrete.

2 Conflicts and Deviations

- 2.1 Any conflicts between this Standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the company or buyer representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests to deviate from this Standard in writing to the company or buyer representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this Standard shall comply with the latest edition of the references listed below unless otherwise noted.

- 3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

[SAEP-302](#)

*Instructions for Obtaining a Waiver of a
Mandatory Saudi Aramco Engineering*

Requirement

Saudi Aramco Engineering Standards

<u>SAES-A-113</u>	<i>Geotechnical Engineering Requirements</i>
<u>SAES-B-006</u>	<i>Fireproofing for Plants</i>
<u>SAES-B-055</u>	<i>Plant Layout</i>
<u>SAES-H-101</u>	<i>Approved Protective Coating Systems</i>
<u>SAES-L-440</u>	<i>Anchor for Buried Pipelines</i>
<u>SAES-M-001</u>	<i>Structural Design Criteria for Non Buildings Structures</i>
<u>SAES-M-100</u>	<i>Saudi Aramco Building Code</i>
<u>SAES-O-100</u>	<i>General Requirements Safety and Security</i>
<u>SAES-P-104</u>	<i>Wiring Methods and Materials</i>
<u>SAES-Q-005</u>	<i>Concrete Foundations</i>
<u>SAES-Q-007</u>	<i>Foundations and Supporting Structure for Heavy Machinery</i>
<u>SAES-Q-009</u>	<i>Concrete Retaining Walls</i>
<u>SAES-S-020</u>	<i>Industrial Drainage and Sewers</i>
<u>SAES-T-911</u>	<i>Telecommunications Conduit System Design</i>
<u>SAES-X-800</u>	<i>Cathodic Protection for Existing Reinforced Concrete Structures</i>

Saudi Aramco Materials System Specifications

<u>09-SAMSS-075</u>	<i>Caulking Compound (Joint Sealant)</i>
<u>09-SAMSS-097</u>	<i>Ready-Mixed Portland Cement Concrete</i>
<u>09-SAMSS-106</u>	<i>Epoxy Coating of Steel Reinforcing Bars</i>
<u>12-SAMSS-007</u>	<i>Fabrication of Structural and Miscellaneous Steel</i>

Saudi Aramco Engineering Report

<u>SAER-5803</u>	<i>Concrete Repair Manual</i>
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Saudi Aramco Construction Safety Manual

3.2 Industry Codes and Standards

American Concrete Institute

<i>ACI 117</i>	<i>Standard Specifications for Tolerances for Concrete Construction and Materials</i>	
<i>ACI 201.2R</i>	<i>Guide to Durable Concrete</i>	
<i>ACI 212.3R</i>	<i>Chemical Admixtures for Concrete</i>	
<i>ACI 301</i>	<i>Specifications for Structural Concrete</i>	
<i>ACI 302.1R</i>	<i>Guide for Concrete Floor and Slab Construction</i>	
<i>ACI 304R</i>	<i>Guide for Measuring, Mixing, Transporting and Placing Concrete</i>	
<i>ACI 304.2R</i>	<i>Placing Concrete by Pumping Methods</i>	
<i>ACI 305R</i>	<i>Hot Weather Concreting</i>	
<i>ACI 308</i>	<i>Standard Practice for Curing Concrete</i>	
<i>ACI 309R</i>	<i>Guide for Consolidation of Concrete</i>	
<i>ACI 318</i>	<i>Building Code Requirements for Structural Concrete</i>	
<i>ACI 347R</i>	<i>Guide to Formwork for Concrete</i>	
<i>ACI 350R</i>	<i>Design Consideration for Environmental Engineering Concrete Structures</i>	
<i>ACI 360R</i>	<i>Design of Slab on Grade</i>	
<i>ACI 504R</i>	<i>Guide to Sealing Joints in Concrete Structures</i>	
<i>ACI 515.1R</i>	<i>Guide to the use of Waterproofing, Dampproofing, Protective and Decorative Barrier Systems for Concrete</i>	
<i>ACI 517-2R</i>	<i>Accelerated Curing of Concrete at Atmospheric Pressure</i>	
<i>SP-66</i>	<i>ACI-Detailing Manual</i>	
American Society for Testing and Materials		
<i>ASTM A123</i>	<i>Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products</i>	
<i>ASTM A416</i>	<i>Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete</i>	
<i>ASTM A767</i>	<i>Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement</i>	

<i>ASTM A775</i>	<i>Standard Specification for Epoxy-Coated Reinforcing Bars</i>
<i>ASTM A884</i>	<i>Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement</i>
<i>ASTM C39</i>	<i>Compressive Strength of Cylindrical Concrete Specimens</i>
<i>ASTM C979</i>	<i>Standard Specification for Pigments for Integrally Colored Concrete</i>
<i>ASTM D1751</i>	<i>Standard Specification Preformed Expansion Joint Filler for Concrete Paving and Structural Construction</i>
<i>ASTM D1752</i>	<i>Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction</i>

Concrete Reinforcing Steel Institute (CRSI)

Field Handling Techniques for Epoxy Coated Rebar

Fabrication of Epoxy Coated Rebar

American Association of State Highway and Transportation Organization
"Standard Specification for Highway Bridges"

AASHTO T290 Standard Method of Test for Determining Water Soluble Sulfates Ion Content in Soil

AASHTO T291 Standard Method of Test for Determining Water Soluble Chloride Ion Content in Soil

3.3 Other References

Saudi Arabian Standards Organization

SASO SSA 2 Steel Bars for the Reinforcement of Concrete

SASO SSA 224 Steel Fabric for Reinforcement of Concrete

The Prestressed Concrete Institute - Design Handbook

4 Design

- 4.1 [SAES-B-055](#) "Plant Layout" shall be used for minimum horizontal and vertical spacing or clearance requirements of concrete structures.
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- 4.2 [SAES-L-440](#) "Anchor for Buried Pipelines" shall be used for the design of anchor blocks.
 - 4.3 [SAES-M-001](#) "Structural Design Criteria for Non-Building Structures" Section 4.2, Loading Requirements, shall be used for minimum design load requirements on concrete structures except buildings.
 - 4.4 [SAES-M-100](#) "Saudi Aramco Building Code" shall be used for the design of concrete buildings.
 - 4.5 [SAES-O-100](#) "General Requirements Safety and Security" shall be the basis for the design of all new Saudi Aramco industrial facilities designated as vital to the security of the Kingdom.
 - 4.6 [SAES-Q-005](#) "Concrete Foundations" shall be used to establish minimum design requirements for concrete footings and foundations, except foundations and supports for heavy machinery.
 - 4.7 [SAES-Q-007](#) "Foundations and Supporting structures for Heavy Machinery," shall be used to establish minimum design requirements for concrete foundations and elevated supports for heavy machinery.
 - 4.8 [SAES-Q-009](#) "Concrete Retaining Walls," shall be used to establish minimum design requirements for concrete retaining walls.
 - 4.9 ACI 301 "Specifications for Structural Concrete for Buildings", shall be used for all concrete structures except as modified by ACI 318M and this Standard.
 - 4.10 ACI 318M, "Building Code Requirements for Reinforced Concrete", shall be used for reinforced concrete structures.
 - 4.11 ACI 350R, "Design Considerations for Environmental Engineering Concrete Structures" shall be used for the design and construction of conventionally reinforced environmental engineering concrete structures.
 - 4.12 SP-66 "ACI-Detailing Manual" shall be used for detailing of reinforced concrete structures. Reinforcement cover requirements shall be in accordance with section 5 of this specification.
 - 4.13 ACI 201.2R "Guide to Durable Concrete," shall be used to specify special requirements for other exposures not covered by this standard.
 - 4.14 AASHTO "Standard Specification for Highway Bridges" shall be used for design of reinforced concrete bridges, culverts, pipeline crossing. Unless otherwise specified, the design shall be based on HS20 truck. Maintenance and construction crane loads shall also be considered.
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Commentary Note:

Ministry of Communication per SAES-Q-006 for the loads and Operation requirements should be satisfied in the design of reinforced concrete bridges, culverts, and pipecrossing.

4.15 The Prestressed Concrete Institute (PCI) Design Handbook shall be the basis for the analysis and design of precast, prestressed concrete structures and as modified below:

- a) Compressive Strength: The minimum 28 day design compressive strength shall be 28 MPa (4,000 psi) and the release strength for prestressed unit 24.1 MPa (3,500 psi).

Commentary Note:

More than 4,000 psi compressive strength can be used in the design of precast concrete.

- b) Prestressing tendons: Uncoated, 7-wire "low relaxation" strand per ASTM A416. Use Grade 250 unless Grade 270 is indicated.
- c) Strands: Epoxy coated strands shall not be used for prestressed concrete.
- d) Camber and deflection: Design flexural members with sufficient camber to properly offset deflection under superimposed dead loads.
- e) Cement content: The minimum cement content for precast concrete is 350 Kg/CM of concrete.

Commentary Note:

No maximum cement content is specified for precast concrete. It is usually common practice to specify cement content of more than 370 Kg/CM of concrete in the precast concrete industry.

4.16 Concrete shall be either structural or nonstructural, as follows:

- a) Structural Concrete: All reinforced concrete including concrete with minimum reinforcement for temperature and shrinkage control. The 28 day design compressive strength (ASTM C39) shall be 28 MPa (4000 psi).

Commentary Note:

More than 4000 psi design compressive strength can be used in the design of reinforced concrete structures provided that the crushing compressive strength will satisfy the requirement of chapter 5 of the ACI 318, the cement content will not exceed 400 kg/m³, and the water cement ratio will not exceed 0.4.

- b) Non-Structural Concrete: Unreinforced concrete of no significant structural value such as lean concrete for sub-slabs, concrete for duct banks etc. The minimum 28 day design compressive strength (ASTM C39) shall be 14 Mpa (2000 psi).
- 4.17 ACI 318M reinforcing specifications are based on ASTM metric standards. Design and specification variances from use of SSA 2 and SSA 224 metric Standard shall be considered and documented.
- 4.18 Concrete Paving shall be in accordance with [SAES-S-020](#) "Industrial Drainage and Sewers" and as follow:
- a) Areas subject to spills, wash water, firewater and sidewalk shall be paved with a minimum thickness of 100 mm of reinforced concrete with a minimum reinforcements of 150x150 MW9 x MW9 welded wire fabric. Areas subject to vehicular traffic shall be in accordance with paragraph 4.18b.

Commentary Note:

150x150 MW9xMW9: 150mm is the spacing between the reinforcement and MW9 (9 mm²) is the cross sectional area of the rebar.

- b) Paving slabs subject to vehicular traffic shall be a minimum thickness of 150 mm of reinforced concrete. The design load shall be as specified in paragraph 4.14 of this standard. The design of the paving shall be based on ACI 360R. Minimum reinforcement shall be 150x150 MW18.7 x MW18.7 welded wire fabric or equivalent.
- c) Paving slope to the catch basins or trenches shall not be less than 1:65 (1.5%). The maximum drop to catch basins from high point of paving shall be 200 mm.

Commentary Note:

Ensure that slope will not jeopardize the movement of traffic.

- d) Where foundations protrude through the paving, 12 mm diameter reinforcing bars, 800 mm long, shall be placed diagonally in the paving at all interior corners.
- e) Concrete paving shall have control or construction joints located at a maximum spacing of 6 meters on centers in both directions.
- f) Expansion joints shall be used in paving adjacent to all poured in place concrete members.

- 4.19 Concrete Repair, SAEP-5803 "Concrete Repair Manual" should be the basis for the repair of deteriorated concrete structures, and [SAES-X-800](#) "Cathodic Protection for Existing Reinforced Concrete Structures" should be used if Cathodic Protection is considered for the repair of existing deteriorated concrete structures.

5 Concrete Materials

The concrete materials shall be in accordance with [09-SAMSS-097](#) "Ready-Mixed Portland Cement Concrete" and as follows:

5.1 Portland Cement/Reinforcements

Portland cement and reinforcing rebars shall be as follows:

Table 1 – Exposures Types

Exposure	Cement Type	Steel	Description
I	I	FBE	Concrete members exposed to negligible sulfate SO_4 (less than 0.1% by weight of soil and less than 150 ppm in ground water) ¹ and any of the following: <ul style="list-style-type: none"> • Water with total dissolved solid more than 1000 PPM. • Chemicals. • Within 5 km from the shore lines. • Where water table is less than one meter below the bottom of the foundation. • Sewage treatment plant.
II	V	FBE	Sulfate content is more than or equals 0.1% by weight of soil or more than or equals 150 ppm in the ground water and the chloride content is less than what is specified in exposure III. ²
III	I+Silica Fume ³	FBE	<ul style="list-style-type: none"> • Water soluble sulfate content more than 0.1% and water soluble chloride more than 0.5% by weight of soil. • Sulfate more than 1500 ppm and chloride more than 10000 ppm in the ground water.
IV	I+Silica Fume	Uncoated	Sulfur pits
V	I	Uncoated	With negligible sulfates and chlorides (less than 0.1% each) by weight of surrounding environment and not classified under any of the above exposures. See commentary notes.

Notes:

- 1 Sulfates and Chlorides shall be determined in accordance with AASHTO T290 and AASHTO T291 respectively or equivalent test methods.
- 2 If the sulfate content is less than 1500 ppm and the chloride is more than 500 ppm, then Type I cement and FBE coated rebars shall be used.

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- 3 Surrounding environment could be air, soil or water. Interior roof slabs can be classified as exposure V. ||
- 4 Plant paving, sidewalks, erosion protection paving and slabs reinforced with welded wire fabric are exempted from the use of silica fume.

Commentary Notes:

The use of the Silica Fume cement is limited to the structural concrete members.

Table 1 is based on performance of geotechnical investigation as required by [SAES-A-113](#) or availability of prior reports showing soil chemical composition. In the absence of geotechnical investigation reports/soil chemical analysis, it is recommended to use epoxy coated reinforcement and type V cement.

- 5.2 Reinforcing steel bars shall conform to SASO SSA 2, hot-rolled, high tensile, deformed steel. These bars shall be acceptable under the ACI 318M specified limitation of 422 Mpa (60.0 ksi). For design variances, see section 4.18 of this specification.
- 5.3 Welded wire fabric shall conform to SASO SSA 224, (cold drawn) wire with a minimum yield strength of 240 MPa (34.8 ksi).
- 5.4 Galvanized welded wire fabric shall conform to ASTM A767 and shall be acceptable reinforcement in lieu of epoxy coated welded wire fabric coated in accordance to ASTM A884.
- 5.5 Coated reinforcements shall be Fusion Bonded Epoxy in accordance with [09-SAMSS-106](#).
- 5.6 Manufacture, fabrication, handling, placement and storage of reinforcement shall be in accordance with chapter 7 of ACI 318. Handling and fabrication of the Epoxy coated reinforcement shall be in accordance with ASTM A775 Appendix, and Concrete Reinforcing Steel Institute (CRSI).

Commentary Note:

Care should be taken to avoid any damage to the coated rebars during shipment, handling, fabrication and placement of the coated rebars. The extent of the damage and repair of the coating shall be in accordance with [09-SAMSS-106](#).

- 5.7 Fabrication tolerance shall conform to ACI 117.
- 5.8 Table 2 defines the minimum concrete cover measured from outer most rebar (tie bar), that shall be provided for reinforcement of cast-in-place concrete structures.

Table 2 – Minimum Concrete Cover

Concrete Structure	Minimum Cover (mm)
Concrete cast against and permanently exposed to earth (including foundations over a sub-slab)	75
Formed concrete exposed to earth or weather	
Supporting Process Equipment	75
Buildings, walkway platforms, stairs, AC pads	50
Concrete not exposed to weather nor in contact with ground (which can be inspected from all sides):	
Beams, columns	50
Slabs, walls, joists	25
Concrete exposed to sea water, raw water or sewage	75
Between reinforcement and anchor flange/pipe within pipeline anchor blocks	100
Concrete slab over 50 mm sub-slab	50
Sidewalks, walkways, etc.	50

6 Embedded Items

- 6.1 All sleeves, inserts, anchor bolts, waterstops and other embedded items shall be installed in accordance with the design drawings and supported against displacement.
- 6.2 The design of anchor bolts shall be in accordance to [SAES-Q-005](#) and the materials shall be in accordance to [12-SAMSS-007](#).
- 6.3 Projecting steel items (such as grating angles, slide plates, unistrut, steel plates, etc.) which are attached to the formwork and cast at the concrete surface shall be hot dip galvanized in accordance with ASTM A123 or coated with the zinc rich epoxy primer in APCS-1C of [SAES-H-101](#). Additionally, the steel attachment, which anchors these items to the concrete, shall be similarly galvanized or coated.
- 6.4 Reinforcing steel bars, anchor bolts or other steel embedments shall not be used as the means for grounding electrical equipment and shall not be tied to grounding neutral conductors, or any part of the lightning protection system.
- 6.5 Conduits, pipes and other items made from aluminum shall not be embedded in structural concrete unless effectively coated to prevent aluminum-concrete reaction.

7 Placing Concrete

- 7.1 Concrete shall be placed in accordance with ACI 301, Chapter 8, ACI 304R and this specification. For Hot Weather Concreting requirements, see Section 13.
- 7.2 Equipment made of aluminum alloys shall not be used for pump lines, tremies, or chutes used to discharge concrete from a truck mixer.
- 7.3 Concrete shall not be placed prior to a recorded pre-placement inspection and authorization to proceed by Saudi Aramco.
- 7.4 Raking shall not be used for movement of concrete after placement.
- 7.5 Vibrators shall not be used to move concrete inside forms.
- 7.6 Retempering of concrete after placement is prohibited.
- 7.7 Concrete shall not be dropped freely where reinforcing will cause segregation nor shall it be dropped freely more than 1 m.
- 7.8 Concrete shall be deposited as near as possible in its final position to avoid segregation due to re-handling or flowing.
- 7.9 Placed concrete shall be consolidated by mechanical vibrating equipment supplemented by hand spading, rodding or tamping. Equipment and procedure for consolidation of concrete shall be in accordance with ACI 309R.
- 7.10 Concrete shall be placed on a clean surface. Standing water shall be removed prior to placement of concrete.
- 7.11 The use of precast concrete or mortar blocks as bar supports and spacers discussed in paragraph 5.7.3.1 of ACI 301, shall be prohibited.

8 Formwork

The design and construction of the formwork shall be in accordance with ACI 347R, Saudi Aramco Construction Safety Manual, and shall be the responsibility of the contractor.

9 Finishing

The finishing of concrete shall be in accordance with ACI 301, Chapters 11.7, and ACI 302.1R unless otherwise specified in the construction drawings or job specification.

10 Curing

- 10.1 Structural concrete shall be continuously water cured in accordance with recommendations of ACI 305R, ACI 308 and as modified below.

Commentary Note:

To avoid self desiccation of the concrete mix, only water curing method shall be used to cure the structural concrete. Please refer to section 1.3.2 of ACI308 R.

- 10.2 Maximum total dissolved solids in water used for curing shall not exceed 1000 parts per million.
- 10.3 Water curing shall be continuous until the compressive strength has reached 70% of the specified strength, but not less than 7 days after placement.
- 10.4 The saturated burlaps shall be covered with a plasticized sheet vapor barrier, minimum 0.15 mm (6 mils) in thickness.
- 10.5 Steam curing can be used for precast concrete. It should be in accordance with ACI 517-2R.

11 Coating and Protection

- 11.1 A plasticized sheet vapor barrier, minimum 0.15 mm (6 mils) in thickness, shall be placed beneath slabs on grade. Outdoor sidewalks are exempted from this requirement.
- 11.2 A plasticized sheet vapor barrier, minimum 0.15 mm (6 mils) in thickness or a 50 mm sub-slab (lean concrete) shall be placed beneath concrete foundations.
- 11.3 A plasticized sheet vapor barrier shall be placed below and around the sides of concrete that is placed directly into excavation without the use of formwork, where coal tar or bitumen coating cannot be applied.
- 11.4 All concrete surfaces in direct contact with earth shall be coated with two coats of coal tar or bitumen coating that conforms to APCS-3 or APCS-10 of [SAES-H-101](#).

Commentary Note:

APCS-10 shall not be used where soil is contaminated with hydrocarbons.

- 11.5 Where concrete surface protection is required it shall be in accordance with ACI 515.1R.

12 Pumped Concrete

- 12.1 Placing concrete by pumping methods shall also conform to the requirements of ACI 304.2R.
- 12.2 Slump and cylinder test samples shall be taken from the end of the mixture truck chute or at the discharge point of the concrete placement hose when concrete pumps are used.

13 Hot Weather Concreting

When hot weather conditions exist, contractor shall place concrete in compliance with ACI 305R.

14 Joints

- 14.1 Joints not specified on the design drawings, shall be in accordance with ACI 301, Chapter 6 and Chapter 11, Section 11.5.
- 14.2 Paving or slab construction joints not specified on the drawings shall be located at column centerlines and intermediate intervals. ||
- 14.3 Waterstops shall be provided in joints where watertight construction is required. Waterstop type shall be specified and shown on the drawings and shall satisfy the function and operation of the structure

Commentary Note:

Waterstops at sulfur pit should be suitable for the operation of sulfur pit. ||

- 14. ACI 504R, "Guide to Joint Sealants for Concrete Structures" shall be used to prepare and select proper material for all installations.
- 14.5 Joint filler strips for expansion joints shall conform to ASTM D1751 or ASTM D1752. Type shall be as noted on the design drawings.
- 14.6 Joints sealer shall conform to [09-SAMSS-075](#).

15 Concrete for Underground Ducts

- 15.1 Concrete for underground duct envelopes shall be colored in accordance with [SAES-T-911](#) and [SAES-P-104](#) for communication and electrical ducts respectively.
 - 15.2 Coloring admixtures shall be in accordance with ACI 212.3R section 6.6 and ASTM C979.
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16 Testing and Inspection

The contractor shall employ an independent Saudi Aramco approved testing agency to perform field and laboratory testing which shall include compressive tests of molded concrete cylinders, test for slump, unit weight, air content (where air-entrainment is required) and fresh concrete temperature. All testing shall be in accordance with [09-SAMSS-097](#) "Ready-Mix Portland Cement Concrete".

17 Offshore Concrete Structures

- 17.1 A full environmental Evaluation for concrete marine structures shall be performed. The evaluation shall include identification of marine organisms including rock boring mollusks and sponges that would pose a threat to the concrete structure and its integrity. Specific susceptibility of the concrete structure to attack by boring organisms in the Arabian Gulf has been associated with the use of calcareous (i.e., limestone) aggregate in the concrete.
- 17.2 No offshore concrete (below highest astronomical tide) structure shall be contracted for construction, fabrication or installation (in a marine environment) without the following provisions being satisfied:
- a) All marine design parameters shall be specified.
 - b) All special concreting provisions for fabrication and installation shall be specified. The proposed concrete materials and/or protection means shall be supported with literature and case studies. The extent and resistance of the protection means shall be based on full evaluation of the local environmental conditions.
 - c) The environmental evaluation, marine design specification and concrete specification shall be presented for review and approval to the Manager, Consulting Services Department.

Commentary Notes:

Saudi Aramco experienced serious concrete deterioration at Ju'aymah trestle concrete piles as a result of rock boring (marine) organisms attack to the concrete ingredients in particular calcareous aggregates. The concrete cover in this structure was penetrated by the rock borers within five years from the time of construction. As a result of this attack, the reinforcing steel was exposed to the sea water, which created further concrete deterioration.

It is very important for the concrete protection system to be designed for the local conditions, and the design life of the structure. This includes ultra violet radiation, corrosive environment, the life of the concrete protection material, and the rate per year at which these organisms will penetrate through the protection material/s.

Revision Summary

30 April 2005

Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.