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virtual event

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Demonstrating the Value of Systems Engineering as the Professional Standard of Care

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www.incose.org/symp2021

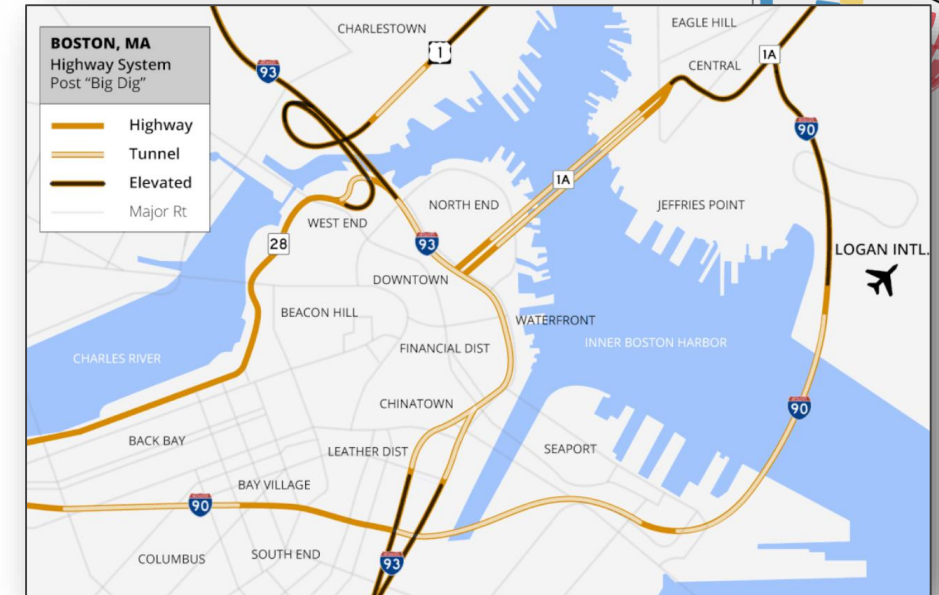


- ❖ **Problem Statement & Offered Solution**
 - Project Risk and Liability
 - SE as Liability Protection and Risk Mitigation Strategy
- ❖ **Background & Introduction**
- ❖ **Systems Engineering Challenges Faced**
- ❖ **Systems Engineering Objectives**
- ❖ **Systems Engineering Activities Performed**
- ❖ **Summary, Achieved Outcomes & Conclusion**

PROBLEM STATEMENT

EXAMPLE: THE “BIG DIG” PROJECT

- ❖ Central Artery/Tunnel Megaproject in Boston, MA
- ❖ Commonly known as the **Big-Dig** project
- ❖ Rerouted Interstate 93 (I-93) running through the heart of the city into a 1.5-mile tunnel
- ❖ Designed and built between 1982 and 2007
- ❖ Most expensive highway project in the US at the time (21.5 billion in 2020 US dollars)
- ❖ Plagued by thousands of water leaks, design flaws, charges of poor execution, use of substandard materials and other issues
- ❖ **Led to the death of a motorist and criminal arrests** when a 24-ton concrete ceiling panel collapsed onto a car



COLLAPSE OF 24-TON
CEILING CONCRETE PANEL



PROBLEM STATEMENT

EXAMPLE: THE “BIG DIG” PROJECT (CONT'D)



- ❖ **\$407 million in restitution** paid by the consortium managing the project
- ❖ Several smaller companies agreed to pay a combined sum of approximately **\$51 million**
- ❖ A **settlement agreement** included a statement of facts as the **basis for liability**
- ❖ The settlement addressed specifically areas of **construction management oversight failures**:
 - The use of **non-specified material**
 - The use of **substandard materials**
 - As well as **ignored observations of** failing epoxy bolt **load tests**
- ❖ The issues identified above are typically addressed in **construction specifications** describing in detail the scope of work, materials, installation, and quality of workmanship

OFFERED SOLUTION

SYSTEMS ENGINEERING AS THE **PROFESSIONAL STANDARD OF CARE**



- ❖ **Professional Standard of Care:** defined as the *systematic exercise of a reasonable level of care, diligence, and skill*
- ❖ Failure to adhere to the professional standard of care may result in company **risk** and **liability**
- ❖ **In the author's opinion**, the Big-Dig issues:
 - Describe a common requirements management and verification & validation challenge
 - Could have been avoided using a structured systems engineering approach
- ❖ **This presentation:**
 - Describes the application of SE principles to **construction specifications** in a large infrastructure project using a **case study** approach
 - Presents the application of systems engineering as the **systematic exercise of a reasonable level of care**
 - Demonstrates the **Value of Systems Engineering** as a **liability protection** and **risk mitigation strategy**



- ❖ **Problem Statement & Offered Solution**
- ❖ **Background & Introduction**
 - Construction Specifications
 - Case Study Project
- ❖ **Systems Engineering Challenges Faced**
- ❖ **Systems Engineering Objectives**
- ❖ **Systems Engineering Activities Performed**
- ❖ **Summary, Achieved Outcomes & Conclusion**

INTRODUCTION

CONSTRUCTION SPECIFICATIONS

- ❖ **Contract documents** that govern the construction of building and infrastructure projects (e.g. transportation, water, energy).
- ❖ Describe in detail the following **requirements**:
 - Scope of work,
 - Materials to be used,
 - Installation methods, and
 - Quality of workmanship (including inspection & testing)
- ❖ Essential component of the PS&E approach:
 - Plans (Drawings),
 - **(Construction) Specifications**, and
 - (Cost) Estimates.
- ❖ Governed by **Construction Specifications Institute (CSI)**
- ❖ **CSI MasterFormat Standard**: Standardized classification for Construction Specifications.

CSI MASTERFORMAT: **50 DIVISIONS**

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP:

- DIVISION 00 — PROCUREMENT AND CONTRACTING REQUIREMENTS

SPECIFICATIONS GROUP

GENERAL REQUIREMENTS SUBGROUP

- DIVISION 01 — GENERAL REQUIREMENTS

FACILITY CONSTRUCTION SUBGROUP

- DIVISION 02 — EXISTING CONDITIONS
- DIVISION 03 — CONCRETE
- DIVISION 04 — MASONRY
- DIVISION 05 — METALS
- DIVISION 06 — WOOD, PLASTIC, AND COMPOSITES
- DIVISION 07 — THERMAL AND ACoustical INSULATION
- DIVISION 08 — OPENINGS
- DIVISION 09 — FINISHES
- DIVISION 10 — SPECIALTIES
- DIVISION 11 — EQUIPMENT
- DIVISION 12 — FURNISHINGS
- DIVISION 13 — SPECIAL CONSTRUCTION
- DIVISION 14 — CONVEYING EQUIPMENT
- DIVISION 15 — RESERVED FOR FUTURE EXPANSION

FACILITY SERVICES SUBGROUP:

- DIVISION 20 — MECHANICAL SUPPORT
- DIVISION 21 — FIRE SUPPRESSION
- DIVISION 22 — PLUMBING
- DIVISION 23 — HEATING VENTILATING AND AIR CONDITIONING
- DIVISION 24 — RESERVED FOR FUTURE EXPANSION
- DIVISION 25 — INTEGRATED AUTOMATION
- DIVISION 26 — ELECTRICAL
- DIVISION 27 — COMMUNICATIONS
- DIVISION 28 — ELECTRONIC SAFETY AND SECURITY

SITE AND INFRASTRUCTURE SUBGROUP:

- DIVISION 30 — RESERVED FOR FUTURE EXPANSION
- DIVISION 31 — EARTHWORK
- DIVISION 32 — EXTERIOR IMPROVEMENTS
- DIVISION 33 — UTILITIES
- DIVISION 34 — TRANSPORTATION
- DIVISION 35 — WATERWAYS AND MARINE CONSTRUCTION

PROCESS EQUIPMENT SUBGROUP:

- DIVISION 40 — PROCESS INTERCONNECTIONS
- DIVISION 41 — MATERIAL PROCESSING AND HANDLING EQUIPMENT
- DIVISION 42 — PROCESS HEATING, COOLING, AND DRYING EQUIPMENT
- DIVISION 43 — PROCESS GAS AND LIQUID HANDLING, PURIFICATION AND STORAGE EQUIPMENT
- DIVISION 44 — POLLUTION CONTROL EQUIPMENT
- DIVISION 45 — INDUSTRY-SPECIFIC MANUFACTURING EQUIPMENT
- DIVISION 46 — WATER AND WASTEWATER EQUIPMENT
- DIVISION 47 — RESERVED FOR FUTURE EXPANSION
- DIVISION 48 — ELECTRICAL POWER GENERATION
- DIVISION 49 — RESERVED FOR FUTURE EXPANSION

INTRODUCTION

CONSTRUCTION SPECIFICATIONS

Part 1 – General: Describes managerial requirements such as applicability, work to be performed, codes and standards, definitions, **submittals**, quality management, etc.

Part 2 – Products: Describes the (performance) requirements, the acceptable (prescriptive or proprietary) products, **materials**, and sometimes even specific suppliers. **Big-Dig:** Would have contained the acceptable materials and material standards.

Part 3 – Execution: Describes the methods of installation and how to measure quality or effectiveness. **Big-Dig:** Would have identified the **inspections and tests** to be performed, including the bold load tests.

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP:

- DIVISION 00 — PROCUREMENT AND CONTRACTING REQUIREMENTS

SPECIFICATIONS GROUP

GENERAL REQUIREMENTS SUBGROUP

- DIVISION 01 — GENERAL REQUIREMENTS

FACILITY CONSTRUCTION SUBGROUP

- DIVISION 02 — EXISTING CONDITIONS
- DIVISION 03 — CONCRETE**
- DIVISION 04 — MASONRY

DIVISION 03 – CONCRETE

03 05 15	PORTLAND CEMENT CONCRETE
03 05 18	PRESTRESSED CONCRETE
03 11 00	CONCRETE FORMING
03 11 14	FALSEWORK
03 15 00	CONCRETE ACCESSORIES
03 15 13	WATERSTOPS
03 15 15	ELASTOMERIC BEARING PADS

SECTION 03 05 15

PORTLAND CEMENT CONCRETE

PART 1 - GENERAL

1.1 SECTION INCLUDES

1.6 SUBMITTALS

- A. Concrete Mix Designs: Include laboratory test minimum of 30 days prior
- B. Product Data: Submit manufacturer's data
- C. Aggregate Source: Submit manufacturer's data
- D. Affidavits/Certificates: Submit manufacturer's data

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Portland Cement: ASTM C150, Type I. High early strength concrete is a requirement.
- B. Aggregates:
 - 1. Coarse Aggregate: ASTM C33, Size No. 57). Deleterious materials in ASTM C33.

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

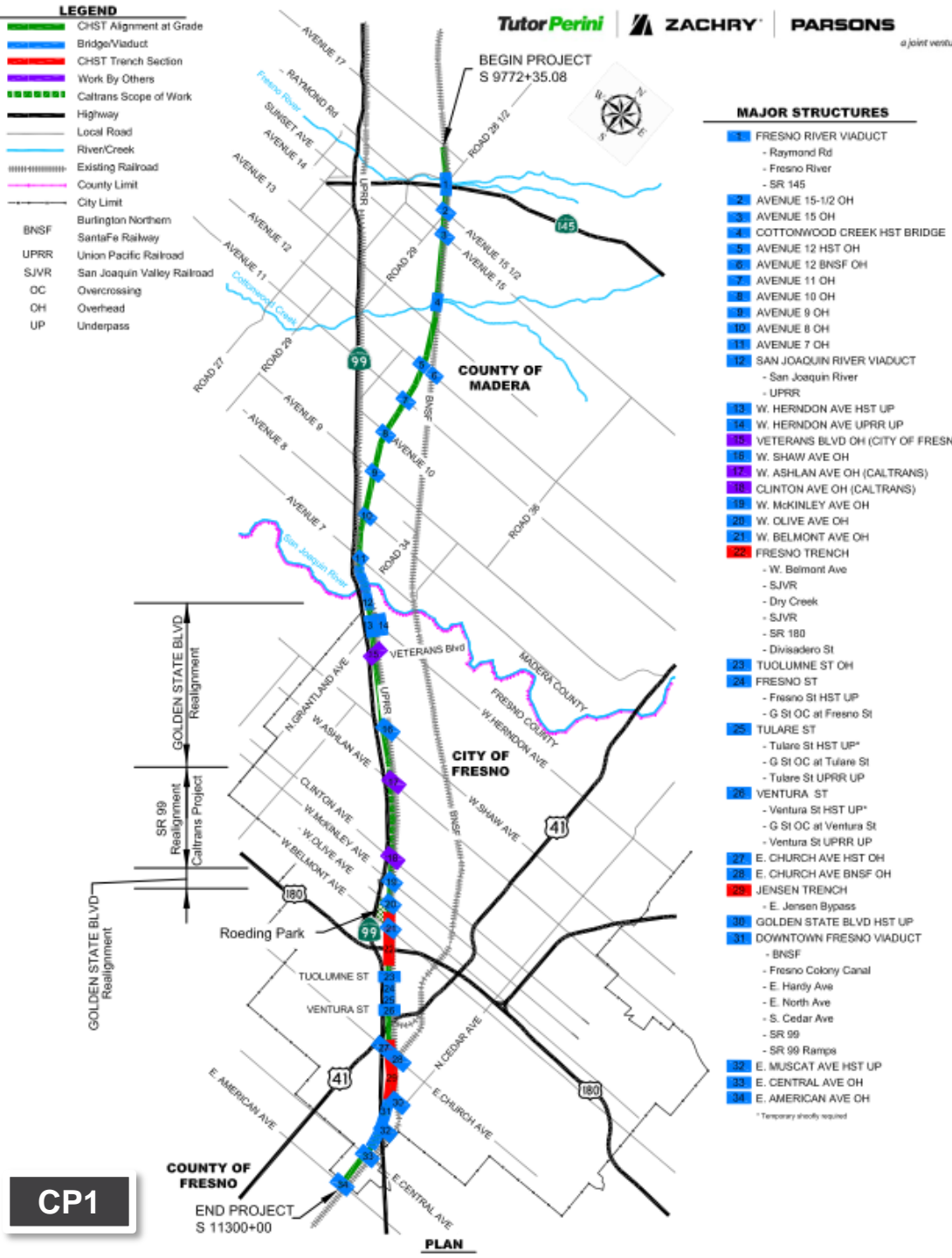
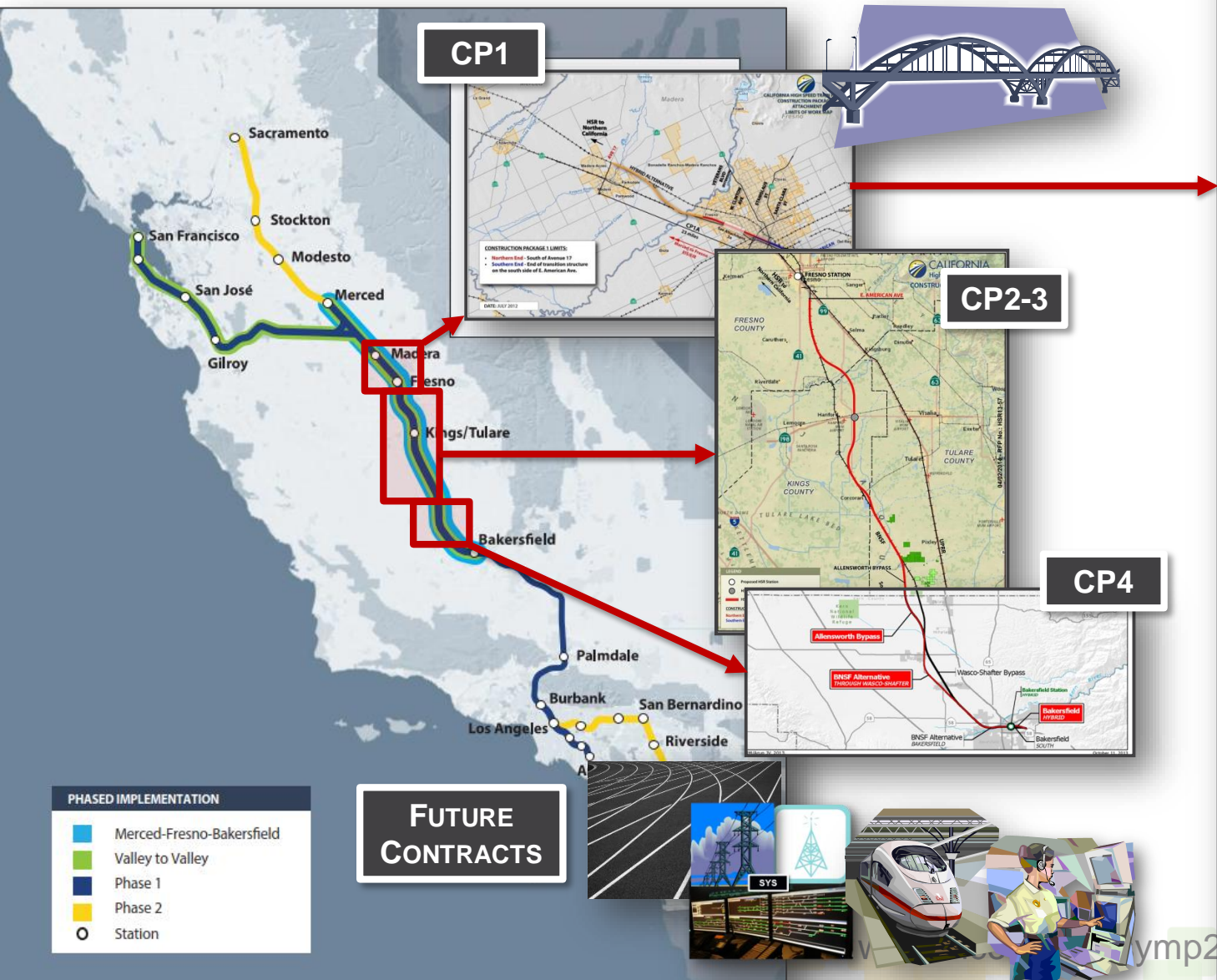
A. Inspection and Testing Services:

B. Methods of Sampling and Testing:

1. **Sampling:** Representative composite samples shall be taken in accordance with ASTM C172. Each sample shall be obtained from a different batch of concrete.
2. **Slump Tests:** The above-specified Contractor employed testing laboratory shall perform slump tests of concrete during placing of concrete, as required, in accordance with ASTM C143. At least one test shall be performed at the delivery trucks for concrete delivered.
3. **Tests for Concrete Uniformity:** The same testing laboratory shall perform uniformity in accordance with ASTM C94, Annex A1. Each batch of concrete shall be tested as specified in ASTM C94, Annex A1.
4. **Tests for Concrete Temperature:** Freshly mixed concrete shall be tested when ambient temperature is below 40 degrees F and above 80 degrees F. When compression test cylinders are made. The concrete temperature shall be recorded when compression test cylinders made. Refer to Article entitled "Environmental Conditions" herein for hot and cold weather remedial requirements.
5. **Strength Tests:**
 - a. Prepare, cast, and deliver to the same independent testing laboratory laboratory-cured compression test samples. Cylinders shall be tested in accordance with ASTM C31. Cylinders shall be tested in accordance with ASTM C39.

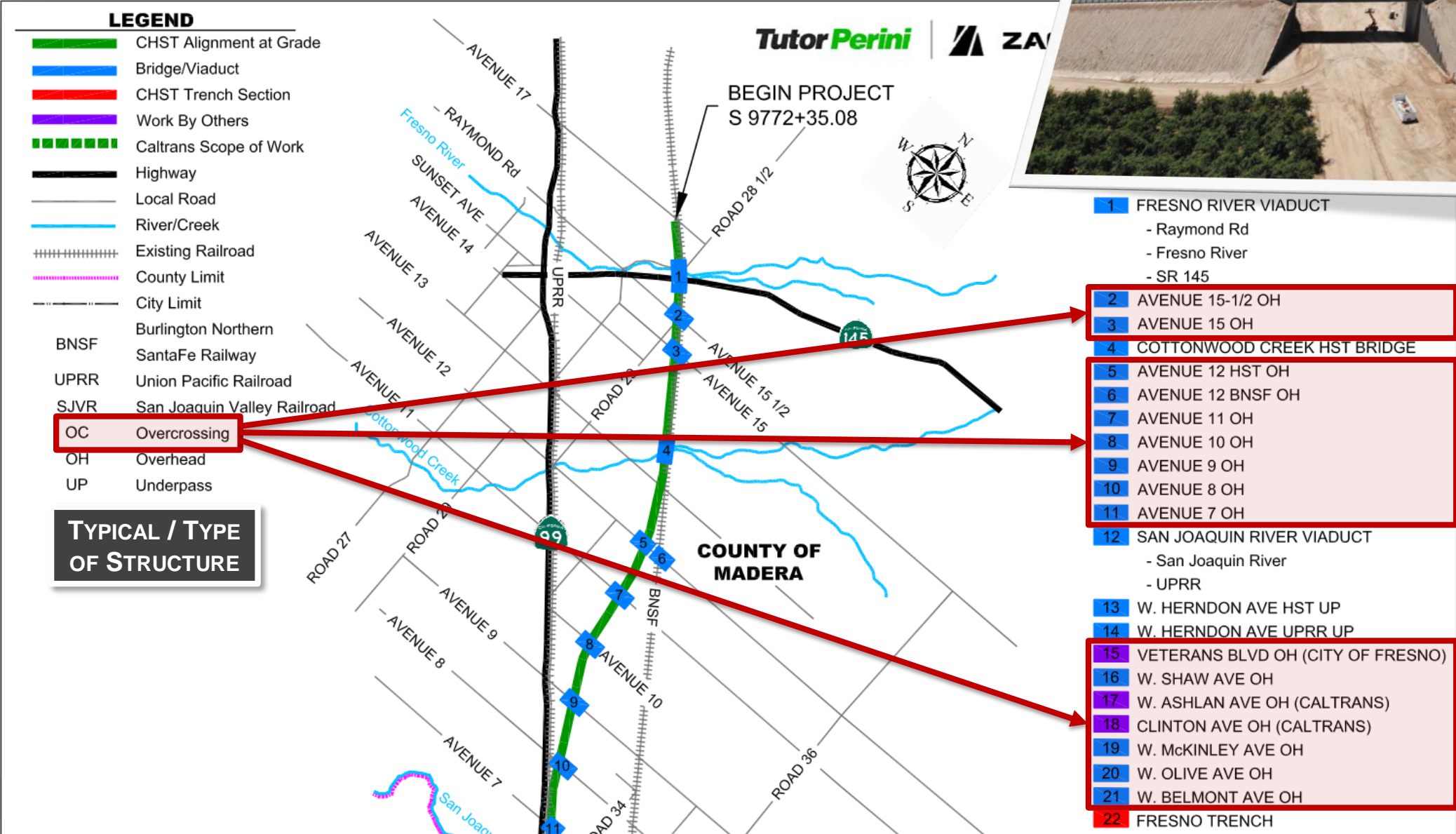
CASE STUDY PROJECT

CALIFORNIA HIGH-SPEED RAIL SYSTEM



CASE STUDY PROJECT

CALIFORNIA HIGH-SPEED RAIL SYSTEM (CONT'D)



AVE 10 OVERHEAD

- 1 FRESNO RIVER VIADUCT
 - Raymond Rd
 - Fresno River
 - SR 145
- 2 AVENUE 15-1/2 OH
- 3 AVENUE 15 OH
- 4 COTTONWOOD CREEK HST BRIDGE
- 5 AVENUE 12 HST OH
- 6 AVENUE 12 BNSF OH
- 7 AVENUE 11 OH
- 8 AVENUE 10 OH
- 9 AVENUE 9 OH
- 10 AVENUE 8 OH
- 11 AVENUE 7 OH
- 12 SAN JOAQUIN RIVER VIADUCT
 - San Joaquin River
 - UPRR
- 13 W. HERNDON AVE HST UP
- 14 W. HERNDON AVE UPRR UP
- 15 VETERANS BLVD OH (CITY OF FRESNO)
- 16 W. SHAW AVE OH
- 17 W. ASHLAN AVE OH (CALTRANS)
- 18 CLINTON AVE OH (CALTRANS)
- 19 W. MCKINLEY AVE OH
- 20 W. OLIVE AVE OH
- 21 W. BELMONT AVE OH
- 22 FRESNO TRENCH

ROADWAY OVERHEADS

CASE STUDY PROJECT

CALIFORNIA HIGH-SPEED RAIL SYSTEM (CONT'D)

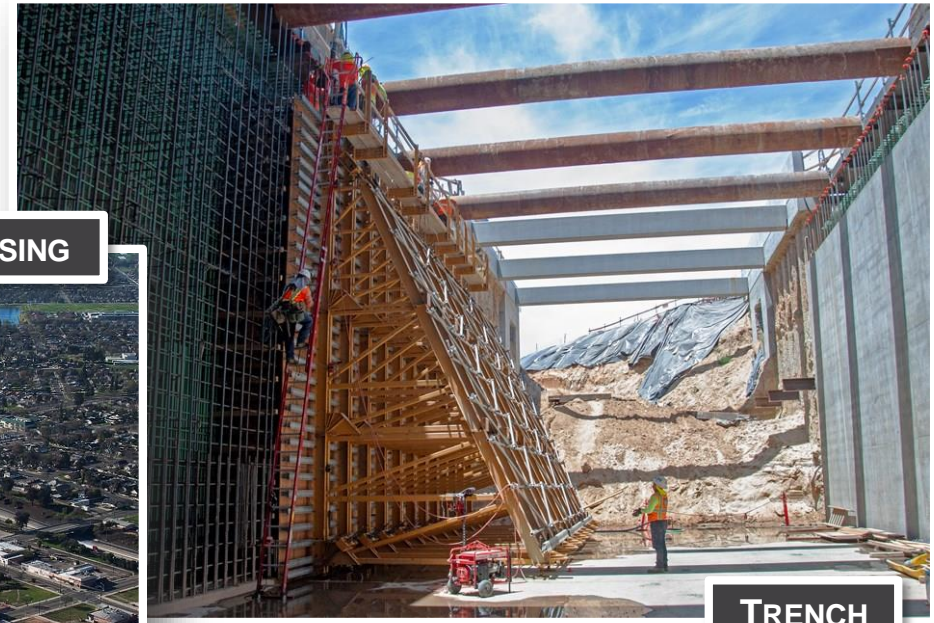
RIVER CROSSING



UNDERCROSSING



TRENCH



VIADUCTS



**225+ MAJOR STRUCTURES
(QUALITY MILESTONES)**

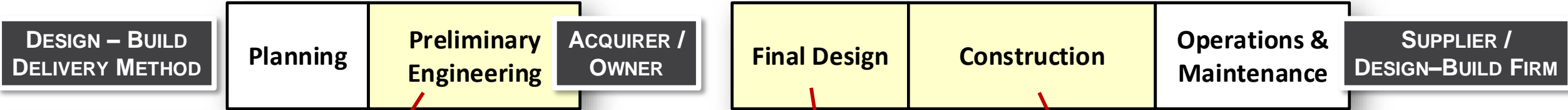




- ❖ **Problem Statement & Offered Solution**
- ❖ **Background & Introduction**
- ❖ **Systems Engineering Challenges Faced**
 - Typical Industry Approach to Managing Construction Specifications
 - Systems Engineering Challenges
- ❖ **Systems Engineering Objectives**
- ❖ **Systems Engineering Activities Performed**
- ❖ **Summary, Achieved Outcomes & Conclusion**

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

PROJECT DELIVERY METHODS & SPECIFICATION DEVELOPMENT



CALIFORNIA HIGH-SPEED TRAIN PROJECT - STANDARD SPECIFICATIONS

OWNERS STANDARDS (SPECIFICATIONS), PART OF RFP

PART 1 - GENERAL

1.1 SECTION INCLUDES

- A. Portland cement.
- B. Aggregates.
- C. Drying shrinkage of concrete.
- D. Concrete admixtures and cementitious materials.
- E. Tests and analysis of materials.
- F. Mix designs.
- G. Batching, mixing, and transporting.
- H. Inspection and Testing.

1.2 CLASSES OF CONCRETE

- A. Classes of concrete are designated by numerical symbol indicating the minimum 28-day compressive strength, in pounds per square inch as determined by ASTM C39, and the maximum permissible size of coarse aggregate.
- B. Each class of concrete may consist of one or more aggregate, cement factor, and types of admixtures or
- C. Each mix within a Class shall be considered a specific type requiring acceptance of the mix design.
- D. The various classes of

1.3 DEFINITIONS

- A. The word "concrete" indicates normal weight concrete having a compressive strength of 3,000 psi and a unit weight of 145 pounds per cubic foot.
- B. The term "lightweight concrete" indicates concrete having a compressive strength of 4,000 psi and a unit weight of 115 pounds per cubic foot.

CALIFORNIA HIGH-SPEED TRAIN PROJECT - CONSTRUCTION SPECIFICATIONS

Agreement No: HSR15-00

TAILORED CONSTRUCTION SPECIFICATIONS, PART OF FINAL DESIGN

- a. Preparation, handling, storage, and delivery of concrete test specimens.
- b. Suitable containers for the storage, curing, and delivery of concrete test specimens in accordance with ASTM C31 and ASTM C470.
- c. Suitable storage for a supply of test cylinder molds, test specimens to be cured at the jobsite, and other items required for sampling and testing.

Methods of Sampling and Testing:

1. Sampling: Representative composite samples shall be taken in accordance with ASTM C172. Each sample shall be obtained from a different batch of concrete on a random basis.
2. Slump Tests: The above-specified Contractor-employed testing laboratory shall perform slump tests of concrete during placing of concrete, as required, in accordance with ASTM C143. At least one test shall be performed at the delivery trucks for each 50 cubic yards of concrete delivered.
3. Tests for Concrete Uniformity: The same testing laboratory shall perform tests for concrete uniformity in accordance with ASTM C94, Annex A1. Each batch of concrete shall be tested as specified in ASTM C94, Annex A1.
4. Tests for Concrete Temperature: Freshly mixed concrete shall be tested hourly when the ambient temperature is below 40 degrees F and above 80 degrees F, and each time compression test cylinders are made. The concrete temperature shall be recorded on a compression test cylinders. Refer to Article titled Environmental Requirements herein for hot and cold weather remedial requirements.

Strength Tests:

- a. Prepare, cast, and deliver to the same independent testing laboratory, cylinders for laboratory-cured compression test samples. Cylinders shall be made and cured in accordance with ASTM C31. Cylinders shall be tested in accordance with

CONCRETE SAMPLING

CONCRETE STRENGTH TEST

Construction Specifications shall be prepared in accordance with the formats of CHSTP Standard Specifications, which are based on Construction Specifications Institute (CSI) MasterFormat™ 2011 edition and SectionFormat™ 2009 edition, and the following requirements: where Contractor has confirmed applicability of CHSTP Standard and Special Specifications sections, with or without modification, Contractor shall incorporate each applicable Standard and Special Specifications section into its Draft Construction Specifications.

MOORE TWINING ASSOCIATES, INC.

STR07 ITR3803 MTA Project No: G17201.01 Date: 11-19-18

CONCRETE SAMPLING DATA REPORT

Sample No.	Sample Type	Truck #	Ticket #	Batch Time	Time Truck Empty	Ambient Temp	Concrete Temp	Slump	Water Added Onsite	Unit Weight	Air Content	Sample Location
1	Concrete	80	50908	1:09	2:25	68*	73*	5.25"	4	NA	NA	

OBJECTIVE EVIDENCE, COLLECTED DURING CONSTRUCTION

2527 Fresno St
Fresno, CA 93721
(800) 268-7021

Report On: Concrete Compressive Strength Test Lab No: 38618-1
Report No: 38618-1
Page 1 of 3

Project: G17201.01 Acct ID: G172

Client: Tutor Perini Zackery Parsons, A Joint Venture
15901 Olden Street
Sylmar, CA 91342

Project: California High Speed Rail Construction Package #1

Contractor: Tutor Perini Zackery Parsons, A Joint Venture
Location: Fresno and Madera County HSR Route CP 1

Report Date: 03/23/2018
Sample Date: 02/23/2018
Sampled By: Becerra, Lupe
By Order Of: Scott Berger

Cylinder Marked	Age Tested (date : days)	Diameter (in)	Area (in²)	Maximum Load (lbs)	Break Type	Cure Loc	Compressive Strength (PSI)	Average Strength (PSI)
Set 1 Nbr 1	03/02/18 : 7	6.00	28.274	69,350	Type 2	Lab	2,450	2,450
Comments: The 7day strength didn't achieve 65% of the 28day fc. The strength may not achieve the 28day fc.								
1 2	03/23/18 : 28	6.00	28.274	131,820	Type 2	Lab	4,660	
1 3	03/23/18 : 28	6.00	28.274	146,210	Type 2	Lab	5,170	4,920

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

CONSTRUCTION QUALITY MANAGEMENT AND PROCEDURES



CQP B1.9 EXCERPT: INSPECTION & TESTING

1.7 QUALITY ASSURANCE/CONTROL

SPEC: 03 05 15 – PORTLAND CEMENT
CONCRETE – QA/QC REQUIREMENTS

- D. Contractor's Quality Management Plan shall ensure control and uniformity of materials, conformance with accepted mix designs, and prompt and proper delivery of concrete to the jobsite in accordance with applicable requirements of ASTM C94. Include in the plan all tests the Contractor will perform to verify compliance with Specification requirements, and the independent laboratory the Contractor intends to engage to perform the tests.

CQP No.	CONSTRUCTION QUALITY PROCEDURES (CQP)	Title	Revision Number	Revision or Issue Date
B1.1	Daily Inspection Reporting		2	03/30/16
B1.2	Materials Receiving Inspection and Acceptance		2	03/30/16
B1.3	Pre-Activity Meeting		2	03/30/16
B1.4	Control of Measuring and Test Equipment		2	03/30/16
B1.5	Material Storage, Identification and Traceability		2	03/30/16
B1.6	Material sampling and Testing		2	03/30/16
B1.7	Off-Site Inspection		2	03/30/16
B1.8	Management of Construction Subcontractors		2	03/30/16
B1.9	Inspection and Testing		2	03/30/16
B1.10	Request For Information		2	03/30/16
B1.11	Quality Hold Points		2	03/30/16
B1.12	Field Change Notice		2	03/30/16
B1.13	Quality Assurance Audit of Construction Activities		2	03/30/16
B1.14	Construction Surveying		2	03/30/16
B1.15	Construction Submittal Workflow Process		2	03/30/16

Receiving Material Inspection and Testing

- Incoming material or equipment shall be identified, inspected, and tested as required by applicable ITPs and CQP B1.2, Materials Receiving, Inspection, and Acceptance.
- Material or equipment manufactured in factories (systems components and equipment) will be subject to factory acceptance tests in accordance with the factory test items list and factory test schedule agreed between TPZP and vendors, as defined in CQP-B1.7, Off-site Inspection. Upon arrival to the project site storage facility, material and/or equipment will be checked visually against shipment documents to verify damage or short quantities.
- Incoming material or equipment will not be used until the required inspection and tests are completed or the necessary inspection and test reports are received and verified.
- Material or services not conforming to specified requirements will be identified and subsequent corrective action will be treated in accordance with CQP B1.2, Materials Receiving, Inspection, and Acceptance.

In-process Inspection and Testing

- During construction, inspection and testing will be carried out in accordance with the requirements of the ITP and Quality Inspection Schedule. Various elements will be checked for compliance with the Technical Contract Requirements established in DOORS. The requirements for each specific activity will be filtered and exported on an RVTM hard/electronic copy in Microsoft Word, Excel, and Adobe PDF format that will be verified by the inspection staff providing objective evidence that inspection and test plans and procedures meet Technical Contract Requirements (see Form CQP B1.9FB).
- Works subject to the requirements of the ITP and Quality Inspection Schedule. Inspections and tests are completed or necessary reports are received and verified.
- The inspection and tests specified in the ITP will be confirmed with the signature of the nominated personnel upon completion of the operation and prior to commencement of the next operation.
- Inspection checklists could be developed for certain activities. Checklists will show that the concerned parties have checked the required points.
- Non-conformances identified during an in-process inspection will be handled and recorded in accordance with CQP B1.2 - Materials Receiving, Inspection, and Acceptance.

CONSTRUCTION QUALITY FORMS (CQF)

Final Inspection and Testing.

Final inspection and testing shall take place as required by the Contract. This will include the review of inspection records to verify that the product or service has been inspected

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

CONSTRUCTION QUALITY FORMS



SECTION 03 05 15

PORTLAND CEMENT CONCRETE

CQP B1.9 FORM D: CONCRETE
PLACEMENT CHECKLIST (POUR CARD)

PART 1 - GENERAL

1.6 SUBMITTALS

- A. **Concrete Mix Designs:** Submit mix designs as herein specified. Include laboratory test reports of trial strength and shrinkage minimum of 30 days prior to batching or delivering concrete.
- B. Product Data: Submit manufacturer's product data for proposed concrete.
- C. Aggregate Source: Submit aggregate source.

PART 2 - PRODUCTS

2.3 MIX DESIGNS

- A. Selection of mix proportions shall conform to the applicable ACI 211.2. Concrete shall comply with ACI 301 and ACI 308. Mix designs will produce concrete suited for proper placement and curing. Mixes shall include recommended amounts of admixture and shall be tested for strength, shrinkage, and permeability.
- B. Mix design for subway structures and below-grade retaining walls shall include 15 percent replacement of the cement with fly ash, to provide a dense and impermeable concrete.
- C. Mix design for architectural concrete and formed concrete shall include a minimum 10 percent replacement of the cement with fly ash, along with a plasticizing admixture conforming with ASTM C1017, to provide a dense and impermeable concrete.

CONCRETE PLACEMENT CHECKLIST (POUR CARD)

Note: Once, it has been determined that the work meets the project requirements and all relevant items below have been accepted by the Construction Superintendent or designee and the TPZP QC Inspector will sign this Pour Card allowing concrete placement to proceed. The Pour Card shall be a Hold Point Release Report and kept with the quality records on Sharepoint.

Contractor:		Date:	
Milestone:		Structure Type:	
Project Documents Used For Inspection:			

Item #	Description	Production			N/A	QC	
		Verified	Initials	Date	Initials	Accepted	Initials
1	Access/Work Plans: Reviewed and approved						
2	Layout: Horizontal & vertical control verified.						
3	Concrete Mix Design: Submitted and approved for use						
4	Specifications: Confirmation of the governing agency specifications						
5	Layout: Checked for compliance with plans and details						

APPROVED
SUBMITTAL

symp2021

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

INSPECTION & TESTING PLANS (ITP)



**INSPECTION & TEST PLAN (ITP) FOR
PRODUCTION DILLED CONCRETE SHAFT**

SECTION 03 05 15

PORTLAND CEMENT CONCRETE

4.2.1 Concrete Sampling and Testing

[Source: Specifications Section 03 05 15 – Portland Cement Concrete, Section 3.1]

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

**INSPECTION
& TESTING**

B. Methods of Sampling and Testing:

1. **Sampling:** Representative composite samples shall be taken C172. Each sample shall be obtained from a different batch of
2. **Slump Tests:** The above-specified Contractor employed test slump tests of concrete during placing of concrete, as require C143. At least one test shall be performed at the delivery truck concrete delivered.
3. **Tests for Concrete Uniformity:** The same testing laboratory sh uniformity in accordance with ASTM C94, Annex A1. Eac tested as specified in ASTM C94, Annex A1
4. **Tests for Concrete Temperature:** Freshly mixed concrete sha ambient temperature is below 40 degrees F and above 80 compression test cylinders are made. The concrete temperat compression test cylinders made. Refer to Article entitled "E herein for hot and cold weather remedial requirements.
5. **Strength Tests:**
 - a. Prepare, cast, and deliver to the same independent tes laboratory-cured compression test samples. Cylinders accordance with ASTM C31. Cylinders shall be teste C39.

Test	Test Method	Sample Size	Sampling Location	QC Test Frequency	QA Test Frequency
Slump	ASTM C143	See test method	Concrete truck discharge chute	One test per each 50 CY of concrete delivered	One at FAI, or as determined by CQAM
Uniformity	ASTM C94, Annex A1	See test method	Concrete truck discharge chute	Each batch of concrete	One at FAI, or as determined by CQAM
Temperature				Test hourly when concrete temp is below 40 degrees F and above 80 degrees F, and each time compression test cylinders are made.	One at FAI, or as determined by CQAM
Compressive Strength	ASTM C31 ASTM C39	See test method	Concrete truck discharge	Four cylinders for each 100 cubic yards or fraction	One at FAI, or as determined by CQAM

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

QUALITY RECORDS



SUBCONTRACTOR'S DAILY REPORT

Subcontractor's Daily Report

Prime Contractor: [REDACTED]

Subcontractors: [REDACTED]

Job Name & Area: California High Speed Rail - CP1

Date: 11/10/2015

Location: AVE 11 OH MADERA COUNTY

Weather: Partly Cloudy

Description of Work and Location: STR 07 HR 2329 Compact STR 07 ITR 2344 Comp. S

NOTE: Please indicate, by category, the number of workers on site, and the hours, for the

CATEGORY	#	HOURS	CATEGORY	#	HOURS	CATEGORY	#	HOURS
Superintendents			Operating Eng.	1	8.0	Electrician		
Laborers			Surveyors			Prof. Cons		
Cement Finishers			Ironworkers					
Carpenters			Painters					
Truck Drivers			Carpenters					

CONCRETE MIX DESIGN

DATE: 07/10/2015 (revised 02/05/2017)
PROJECT: California High Speed Rail - CP1

USE: Drilled Shafts: Wet Hole Mix

TYPE: 7.6 sk, FA, 3/8", WR, SP, HS

CLASS: 4000 psi

MIX # 40HS

AGG 1: 1" x #4 Gravel BLEND 0 % 0% COARSE

AGG 2: 3/8" x #8 Pea Gravel BLEND 57 % 100.0% COARSE

AGG 3: Concrete Sand BLEND 43 % Source: Granite, Coaling

SIEVE	AGG 1:	AGG 2:	AGG 3:	COARSE	COMBINED
SIZE, mm	GRADING	GRADING	GRADING	GRADING	GRADING
1 1/2"		100	100	100	100
1"		100	100	100	100
3/4"		100	100	100	100
1/2"		100	100	100	100
3/8"		95	100	95	97
				14	50

CONCRETE TICKET

CUSTOMER ID	P.O. NUMBER / JOB NUMBER	TICKET NUMBER	DATE
RECON, INC.		28194	2016-03-07
DELIVER TO	DIRECTIONS		
TUOLUMNE ST. & "G" ST FRESNO	99 SOUTH TO PRESNO ST. LEFT TO "F" ST. LEFT TO MERCED ST. RIGHT TO "H" ST. LEFT TO JOB		
TIME DUE	TIME BATCHED	TIME ARRIVE	TIME START
11:44	10:49 AM	11:40	11:52
FINISH POUR	REV. COUNT		
12:20	127		
PLANT NO.	TRUCK	DRUM	SLUMP
	97		4.00
QUANTITY THIS LOAD	QUANTITY ORDERED	QUANTITY DELIVERED	PRODUCT CODE
0.50	57.00	19.00	40HSRWHFA
PRODUCT DESCRIPTION			
DRILLED SHAFTS WET HO YARD			
UNITS OF MEASURE	UNIT PRICE	EXTENDED PRICE	
YARD	0.00	0.00	
40HSRWH HSR WET HOLE MIX			
ZONE			
ZONE DELIVERY CHARGE			
0.00 0.00 0.00			

CONCRETE TRUCK LOG

(CONCRETE PLACEMENT STARTED) 10:10 AM
(COMPLETED) 2:14 PM

CONCRETE TRUCK LOG

Milestone: TAM

ACTIVITY NO. 030315

SPEC SECTION: 030315

LOCATION: TUOLUMNE

BATCH PLANT: [REDACTED]

INSPECTOR: [REDACTED]

ACTIVITY DESCRIPTION:

ABUTMENT #1-B, 1-10

1-12

MIX NO: 40HSRWHFA

TECHNICIAN: [REDACTED]

THEORETICAL CONCRETE VOLUME:

55

DATE: 3-7-16

CONCRETE CO: [REDACTED]

SLUMP: >7"

AIR: <4%

Tim Logan=Batch operator

Top of CMP Elev= 299.4

Cut off Elev= 279.14

Tip Elev= 225.0

No.	Ticket No.	Truck No.	Cubic Yards	Total Placed (yd3)	Time Batched	Finish Unload	Truck Arrival Time	Actual Minutes	Air Temp (F)	Water Added (gals)	Test Taken (y/n)	Concrete Temp (F)	Slump (in)	Revolutions	Comments
1	28192	80	9.5	9.5	1022	1150	1140	88	50	20	4	59	9	133	CYLINDERS TAKEN
2	28194	67	9.5	19	1049	1226	1140	87						127	LARGE CLUMPS (A FEW)
3	28195	88	9.5	28.5	1117	1250	1205	92		5				126	
4	28196	73	9.5	38	1142	130	1230	108						120	SMALL CLUMPS (A FEW)
5	28197	70	9.5	47.5	109	224	209	73						172	SMALL CLUMPS (A FEW)
6	28198	62	6.5	54.0	130	249	219	79							3rd CY WASTE ↑
7								0							
8								0							
9								0							
10								0							
11								0							
12								0							
13								0							
14								0							
15								0							
16								0							
17								0							
18								0							
19								0							
20								0							

CONCRETE PLACEMENT CHECKLIST

NT CHECKLIST (POUR CARD)

Milestone Name:	Tuolumne St Overhead	Drilled Shaft No.:	1-7 1-9 1-11
Pier/Bent/Abutment No.:	ABUTMENT #1	Subcontractor:	[REDACTED]
Project Documents Used:	Package Name, Drawing Numbers, , RFI/DCN/FCN, Spec. Sections		

Item #	Description	TPZP Production				TPZP QC				RVTM #	Comments
		Verified	Initials	Date	N/A	Verified /Accepted	Initials	Date	N/A		

Pre-Placement Concrete											
1	Concrete mix design approved?	✓	C2	3/7/16		✓	JB	3-7-16		PCC16, PCC69, PCC80, PCC95, PCC96, PCC171, PCC178, PCC181, PCC187, PCC196, PCC197, PCC198, PCC201	
2	Slurry mix design approved and used per plan?	✓			N/A	✓	JB	3-7-16		DCPS83	
3	Materials produced domestically and comply with GP 46.12.	✓	C2	3/7/16		✓	JB	3-7-16			
SHAFT EXCAVATION											
	Shaft dimensions, depth, alignment.									DCPS71, DCPS72, DCPS80	

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

ADDITIONAL CHSRS VERIFICATION & VALIDATION REQUIREMENTS



Doc. ID	Document Section	Requirements Specification Assigned to Avenue 11 Overhead	Allocation	Quality Record	Reference Folder
Portland Cement Concrete 03 05 15	3.1B.1 Field Quality Control	Sampling: Representative composite samples shall be taken in accordance with ASTM C172. Each sample shall be obtained from a different batch of concrete on a random basis.	CIDH Abutment Retaining Walls Wing Walls Deck	QR-CON2	8.1 Construction Quality Records https://egnyte.com/Sin20QA_QC_NCRs/7.01%20-%20Mil20OH/8.0%20Quality/8.1%20Cons
Portland Cement Concrete 03 05 15	3.1B.2 Field Quality Control	Slump Tests: ACI-certified personnel shall perform slump tests of concrete during placing of concrete, as required, in accordance with ASTM C143. At least one test shall be performed at the delivery trucks for each 100 cubic yards of concrete delivered	CIDH Abutment Retaining Walls Wing Walls Deck	QR-CON2	8.1 Construction Quality Records
Portland Cement Concrete 03 05 15	3.1B.3 Field Quality Control	Tests for Concrete Uniformity: The same testing laboratory shall perform tests for concrete uniformity in accordance with ASTM C94, Annex A1. Each batch of concrete shall be tested as specified in ASTM C94, Annex A1	CIDH Abutment Retaining Walls Wing Walls Deck	QR-CON2	8.1 Construction Quality Records https://egnyte.com/Sin20QA_QC_NCRs/7.01%20-%20Mil20OH/8.0%20Quality/8.1%20Cons
Portland Cement Concrete 03 05 15	3.1B.4 Field Quality Control	Tests for Concrete Temperature: Freshly mixed concrete shall be tested hourly when the ambient temperature is below 40 degrees F and above 80 degrees F, and each time compression test cylinders are made. The concrete temperature shall be recorded on all compression test cylinders.	CIDH Abutment Retaining Walls Wing Walls Deck	QR-CON2	8.1 Construction Quality Records https://egnyte.com/Sin20QA_QC_NCRs/7.01%20-%20Mil20OH/8.0%20Quality/8.1%20Cons
Portland Cement Concrete 03 05 15	3.1B.5 Field Quality Control	Strength Tests: a. Prepare, cast, and deliver to the same independent testing laboratory, cylinders for laboratory-cured compression test samples. Cylinders shall be made and cured in accordance with ASTM C31. Cylinders shall be tested in accordance with ASTM C39.	CIDH Abutment Retaining Walls Wing Walls	QR-CON3	8.1 Construction Quality Records https://egnyte.com/Sin20QA_QC_NCRs/7.01%20-%20Mil20OH/8.0%20Quality/8.1%20Cons

REFERENCES & TRACES TO OBJECTIVE EVIDENCE (QUALITY RECORDS)

REQUIREMENTS VERIFICATION TRACEABILITY MATRIX (RVTM)



- ❖ Problem Statement & Offered Solution
- ❖ Background & Introduction
- ❖ **Systems Engineering Challenges Faced**
 - Typical Industry Approach to Managing Construction Specifications
 - **Systems Engineering Challenges**
- ❖ Systems Engineering Objectives
- ❖ Systems Engineering Activities Performed
- ❖ Summary, Achieved Outcomes & Conclusion

SYSTEMS ENGINEERING CHALLENGES

OVERVIEW



Selected Challenges:

- ❖ Large Number of Contract Documents and **Requirements**
- ❖ Specification and Requirements **Applicability**
- ❖ Different Implementation by each Contractor
- ❖ Submittal Fragmentation and Submittal Log
- ❖ Availability of Construction Phase Submittals
- ❖ **Organization** of Quality Records
- ❖ **Traceability** to Objective Evidence

SYSTEMS ENGINEERING CHALLENGES

LARGE # OF CONTRACT REQUIREMENTS, SPEC & REQ. APPLICABILITY



CONSTRUCTION PACKAGE 1 (HSR 13-06)

GENERAL PROVISIONS

234 PAGES, 1,334 SHALL STATEMENTS

CONTRACT AGREEMENT: HSR 13-06

- Pt A - Subpart 1 – Signature Document
- B2 - Pt A - Subpart 2 – Special Provisions
- B2 - Pt B – General Provisions**
- B2 - Pt C - Subpart 1 – Scope of Work**
- B2 - Pt D - Subpart 1 – Community Benefits Agreement
- B3 - Pt A - Subpart 1 – Basis of Design
- B3 - Pt A - Subpart 2 – Organizational Conflict of Interest Policy
- B3 - Pt A - Subpart 3 – Revised Small and Disadvantaged Business Enterprise Program
- B3 - Pt B - Subpart 1 – Verification, Validation and Self-Certification
- B3 - Pt B - Subpart 2 – Reliability, Availability and Maintainability
- B3 - Pt B - Subpart 5 – Design Variance Request Process
- B3 - Pt B - Subpart 6 – Safety and Security Management Plan
- B3 - Pt B - Subpart 7 – Aesthetic Guidelines for Non-Station Structures
- B3 - Pt B - Subpart 8 – Cost and Scheduling Controls Program
- B3 - Pt B - Subpart 9 – Payment Milestone Data Pack Specifications
- B3 - Pt C - Subpart 1 – Design Criteria**
- B3 - Pt C - Subpart 2 – CADD Manual
- B3 - Pt C - Subpart 3 – Plan Preparation Manual
- B3 - Pt D - Subpart 1 – Third Party Entities Master and Cooperative Agreement Updates**
- B3 - Pt D - Subpart 2 – Approach for Obtaining ICS Environmental Approvals/Permits
- Pt D - Subpart 4 – Mitigation, Monitoring and Reporting Program
- Pt D - Subpart 5 – Design Variance Report
- Pt D - Subpart 6 – CP01 Transportation Mitigation
- B3 - Pt D - Subpart 7 – Draft Engineering and Construction UPRR Agreement
- B3 - Pt D - Subpart 7 – Caltrans and Railroad Agreements Caltrans SR99
- B3 - Pt D - Subpart 8 – City Fresno Design Guidelines Clarifications
- Pt E - Subpart 1 – Directive Drawings
- Pt E - Subpart 2 – Preliminary Ground Motion Data
- Pt E - Subpart 3 – Record of Survey and Control Monument Data
- Pt E - Subpart 4 – Right-of-Way Acquisition Plan
- B3 - Pt E - Subpart 5 – Geotechnical Baseline Report American Avenue
- B3 - Pt E - Subpart 5 – Geotechnical Baseline Report

SCOPE OF WORK

97 PAGES, 447 SHALL STATEMENTS

DESIGN CRITERIA MANUAL

1,279 PAGES, 7,951 SHALL STATEMENTS

THIRD PARTY AGREEMENTS

551 PAGES, 1,819 SHALL STATEMENTS

STANDARD SPECIFICATIONS

434 PAGES, 2,274 SHALL STATEMENTS

Table of Contents

DIVISION 02 – TECHNICAL GENERAL REQUIREMENTS AND EXISTING CONDITIONS
02 01 00 STANDARD SPECIFICATIONS GENERAL STATEMENTS
02 01 56.39 TEMPORARY TREE AND PLANT PROTECTION
02 21 13 SITE SURVEYS
02 21 23 FIELD ENGINEERING
02 21 33 PHOTOGRAPHIC DOCUMENTATION
02 22 00 EXISTING CONDITIONS ASSESSMENT
02 41 00 DEMOLITION

DIVISION 03 – CONCRETE
03 05 15 PORTLAND CEMENT CONCRETE
03 05 18 PRESTRESSED CONCRETE
03 11 00 CONCRETE FORMING
03 11 14 FALSEWORK
03 15 00 CONCRETE ACCESSORIES
03 15 13 WATERSTOPS
03 15 15 ELASTOMERIC BEARING PADS
03 15 23 CONCRETE ANCHORS
03 20 00 CONCRETE REINFORCING
03 30 00 CAST-IN-PLACE CONCRETE
03 35 00 CONCRETE FINISHING
03 37 13 SHOTCRETE
03 40 00 PRECAST CONCRETE
03 43 00 PRECAST CONCRETE SEGMENTAL CONSTRUCTION
03 62 00 NON-SHRINK GROUTING
03 70 00 MASS CONCRETE

DIVISION 05 – METAL
05 05 22 METAL WELDING
05 12 00 STRUCTURAL STEEL FRAMING
05 50 00 METAL FABRICATIONS
05 51 00 METAL STAIRS

DIVISION 07 – THERMAL AND MOISTURE PROTECTION
07 95 63 BRIDGE FLOOR SLABS
07 95 66 BRIDGE FLOOR SLABS
07 95 73 TUNNEL LININGS

DIVISION 09 – FINISHES
09 96 00 HIGH-PERFORMANCE COATINGS

DIVISION 31 – EARTHWORK
31 05 00 COMMON WORK RESULTS FOR EARTHWORK
31 09 13 GEOTECHNICAL INSTRUMENTATION AND MONITORING
31 11 00 CLEARING AND GRUBBING
31 23 19 DEWATERING
31 23 26 AGGREGATE DRAINAGE LAYER
31 35 00 SLOPE PROTECTION
31 35 33 TURF AND HYDROSEED SLOPE PROTECTION
31 38 13 REINFORCED SLOPES AND EARTH STRUCTURES
31 39 13 GROUND ANCHORS
31 50 13 TEMPORARY EXCAVATION SUPPORT AND PROTECTION
31 62 00 DRIVEN PILES
31 63 29 DRILLED CONCRETE PIERS AND SHAFTS

DIVISION 32 – EXTERIOR IMPROVEMENTS
32 11 23 AGGREGATE BASE COURSES
32 31 13 CHAIN LINK FENCES AND GATES
32 90 00 PLANTING

DIVISION 33 – UTILITIES
33 05 16 UTILITY STRUCTURES
33 05 25 SUPPORT AND PROTECTION OF UTILITIES
33 05 28 TRENCHING AND BACKFILLING FOR UTILITIES
33 05 33 RELOCATION OF EXISTING UTILITIES

Which of the 1,000s of Requirements apply to Ave 10 Overhead?



SYSTEMS ENGINEERING CHALLENGES

CONSTRUCTION PHASE SUBMITTALS & SUBMITTAL LOG



Construction Phase submittals are those submittals that are required by the Construction Specifications and do not require submittal to the Authority unless otherwise stated in the Contract. The Contractor shall provide access to the Authority for the review and audit of these submittals. The Contractor shall provide copies of these submittals to the Authority upon request.

INCLUDING INSPECTIONS & TESTS / QUALITY RECORDS

SECTION 03 05 15

PORTLAND CEMENT CONCRETE

PART 1 - GENERAL

1.6 SUBMITTALS

- A. **Concrete Mix Designs:** Submit mix designs as herein specified in Article entitled "Mix Designs". Include laboratory test reports of trial strength and shrinkage tests. Submit mix designs a minimum of 30 days prior to batching or delivering concrete.
- B. **Product Data:** Submit manufacturer's product data for proposed concrete.
- C. **Aggregate Source:** Submit aggregate source.
- D. **Affidavits/Certificates:** For each shipment of materials, submit evidence of compliance with Specification requirements for cement, aggregate, supplementary cementitious materials, and admixtures. Mill tests and manufacturers' certification of compliance with ASTM Specifications may be accepted in lieu of testing of cement and analysis of aggregates. Certificates of Compliance shall be signed by the materials manufacturer and the Contractor.
- E. **Batch Tickets:** Submit a delivery ticket with each batch of concrete delivered to the site in accordance with the requirements of ASTM C94.

Which Concrete Mix Design(s) apply to Ave 10 Overhead?

SUBMITTAL LOG

Title	SubmittalType	LatestReviewCycle
... 4000ps Concrete Mix Dsgn #53T1G01C	INFO	000
... 4000ps Concrete Mix Design #60T1G01	INFO	000
... Project Wide 5000 ps Concrete Mix	INFO	000
... Road 27 OH- 8500ps Concrete Mix	INFO	000
15362 ... OM 5000 ps Concrete Mix #60F1G03B	INFO	000
15063 ... PW Concrete Mix Design #73T1G05F	INFO	001
14675 ... UPRR Concrete Mix Dsgn for NON-UPRR	INFO	000
14371 ... SR180 5000ps Concrete Mix Design	INFO	000
13729 ... UPRR 4000ps Concrete Mix Design	INFO	000
13480 ... COF- Asphalt Concrete Mix Design	INFO	000
12987 ... Project Wide-CIDH Concrete Mix Dsgn	INFO	000
12970 ... Project Wide CIDH Concrete Mix Dsgn	APPROVAL	000
... Tuolumne OH - MSE Wall Concrete Mix	INFO	000
... Tuolumne OH-MSE Wall Concrete Mix	INFO	000
12281 ... Project Wide 6000 ps Concrete Mix	INFO	000
11363 ... 5000ps Concrete Mix Dsgn #50B1G03	INFO	000
10919 ... 6000ps Concrete Mix Design #60F1G12	INFO	000
10918 ... 6000 ps Concrete Mix Design	INFO	000
10917 ... 4000 PS Concrete Mix #40F1G03	INFO	000
10916 ... 5000ps Concrete Mix Design #60F1G03	INFO	000

SYSTEMS ENGINEERING CHALLENGES

TRACING, LOCATING, AND VERIFYING TO OBJECTIVE EVIDENCE



Doc. ID	Document Section	Requirements Specification Assigned to Avenue 11 Overhead	Allocation	Quality Record	Reference Folder
Portland Cement Concrete 03 05 15	3.1B.2 Field Quality Control	Slump Tests: ACI-certified personnel shall perform slump tests of concrete during placing of concrete, as required, in accordance with ASTM C143. At least one test shall be performed at the delivery trucks for each 100 cubic yards of concrete delivered	CIDH Abutment Retaining W Wing Walls Deck	QR-CON2	8.1 Construction Quality Records https://egnyte.com/Sin 200A QC NCRs/7.01%20-%20Mil 200H/8.0%20Quality/8.1%20Cons

OBJECTIVE
EVIDENCE

QUALITY MILESTONE
DATA PACK (QMDP)

- 1.0 Executive Summary
- 2.0 Environmental Compliance
- 3.0 Verification, Validation, and Self Certification
- 4.0 Third Party Requirements
- 5.0 Milestones Photographic Evidence
- 6.0 Operations and Maintenance Requirements
- 7.0 Disposition of Comments
- 8.0 Quality
- 9.0 Drawings, Documents, and Records

8.1 Construction Quality Records 1,250+ Quality Records? 1,256 Files

- CC-REBR-STR07-110617_Ave_11_Abut_1_2_CIDH_Piles_Rebar_MRIR.pdf
- CC-STR07-Drilled Shaft Certificate of Conformance Abutment 1 Signed
- CL-CON1-STR07-111417_Ave_11_Abut_1_CIDH_Piles_Pour_Card.pdf
- CL-CON1-STR07-111517_Ave_11_Abut_1_2_CIDH_Piles_Pour_Card.pdf
- CL-GBO1-STR07-032619_AVE_11_Grounding_Bonding_QC_Checklist_Fisk.p
- QR-CON1-Mix 40F5G07_PW_Wet_Hole_Drilled_Shaft_Concrete_MD_Stamped
- QR-CON2-STR07-111417_ITR2344_Abut_1_CIDH_Pile_PCC_DIR_35691_1.pdf
- QR-CON2-STR07-111517_ITR2344_CIDH_Piles_PCC_DIR_35764_1.pdf

Tutor Perini ZACHRY PARSONS, A Joint Venture

Subcontractor's Daily Report DUE by 9AM following day

Prime Contractor: Tutor Perini/ Zachry/ Parsons, JV Subcontractors: Moore Twining Assoc. Inc.

Job Name & Area: California High Speed Rail - CP1 Date: 11-14-17

Location: Ave 11 OH MADERA COUNTY Weather: PARTLY CLOUDY 67°

Description of Work and Location: STR 07 ITR 2329 COMPACTION
STR 07 ITR 2344 CONC. SAMPLE

Tutor Perini ZACHRY PARSONS, A Joint Venture

Subcontractor's Daily Report DUE by 9AM following day

Prime Contractor: Tutor Perini/ Zachry/ Parsons, JV Subcontractors: Moore Twining Assoc. Inc.

Job Name & Area: California High Speed Rail - CP1 Date: 11-15-17

Location: Ave 11 OH MADERA COUNTY Weather: PARTLY CLOUDY 70°

Description of Work and Location: ITR 2329 STR 01 COMPACTION
ITR 2344 STR 07 CONCRETE

NOTE: Please indicate, by category, the number of workers on site, and the hours, for the above date.

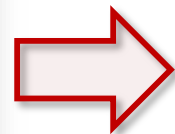
CATEGORY	#	HOURS	CATEGORY	#	HOURS
Superintendents			Operating Eng.	1	8
Surveyors			Electricians		
Laborers			Prof. Consult.		
Cement Finishers			Ironworkers		
Carpenters			Painters		
Truck Drivers			Carpenters		
Plumbers					

Total Work Force:

Injuries / Accidents / Incidents (circle one, if yes see attached incident report): YES ☐ NO ☒

Make / Model Equipment # / License Plate GAS DIESEL Hour Meter / Mileage (Start) Hour Meter / Mileage (Finish)

Slump Tests?





- ❖ **Problem Statement & Offered Solution**
- ❖ **Background & Introduction**
- ❖ **Systems Engineering Challenges Faced**
- ❖ **Systems Engineering Objectives**
 - Objectives
 - Constraints & Considerations
 - Envisioned Solution
- ❖ **Systems Engineering Activities Performed**
- ❖ **Summary, Achieved Outcomes & Conclusion**

SYSTEMS ENGINEERING OBJECTIVES

OBJECTIVES



1. Address the Systems Engineering Challenges described above

- Determine governing construction specifications and requirements
- Analyze and allocate applicable requirements to individual HSR milestones and HSR milestone elements (e.g. foundations, columns, deck, etc.)
- Create a structured quality record storage system suitable for the large amount of records
- Provide effective traceability between requirements and objective evidence

2. Demonstrate the Professional Standard of Care

- Systematically exercise a reasonable level of care, diligence, and skill

3. Avoid the cautionary tale of the Big-Dig scenario

- Provide a requirement-based approach demonstrating the correct use of specified materials and the successful execution of all specified inspections and tests

4. Deliver the successful HSR milestones Acceptance and Certification

- Handed over / input into the next HSR track and systems contractor

SYSTEMS ENGINEERING OBJECTIVES

CONSTRAINTS & CONSIDERATIONS



1. Construction Industry

- Used to plans, specifications, and estimates (PS&E) approach, CSI MasterFormat
- Average annual gross domestic product (GDP) of more than \$636B, 7.2 million employees
- Consider continued use of the **construction specifications**

2. Quality Management vs. Systems Engineering

- Systems engineering (incl. Verification & Validation) widely unknown in construction industry
- Consider integration of the **quality management system** including plans, procedures, forms, inspection and test plans and procedures, and resulting quality records

3. Contract Management

- Any change to an executed contract has the potential to result in contractor claims
- Consider re-use of construction specifications, quality documents, submittal log, ITPs, QMDP, etc.

4. Contractor Deliverables

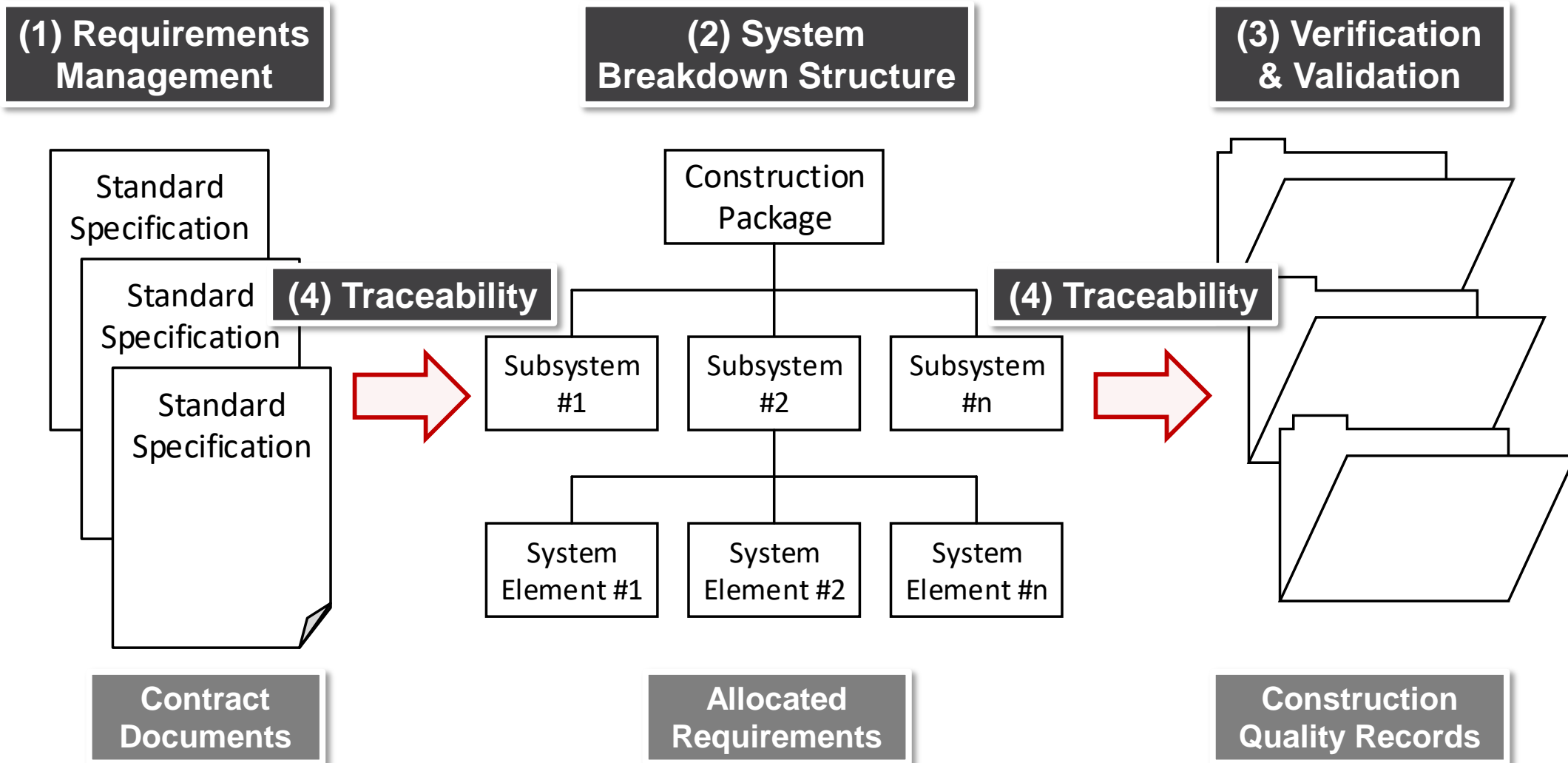
- Consider re-using existing specifications, requirements analysis, breakdown structures, etc.

5. Human Aspect

- Consider resistance to change, adding value through improved, more effective / efficient processes

SYSTEMS ENGINEERING OBJECTIVES

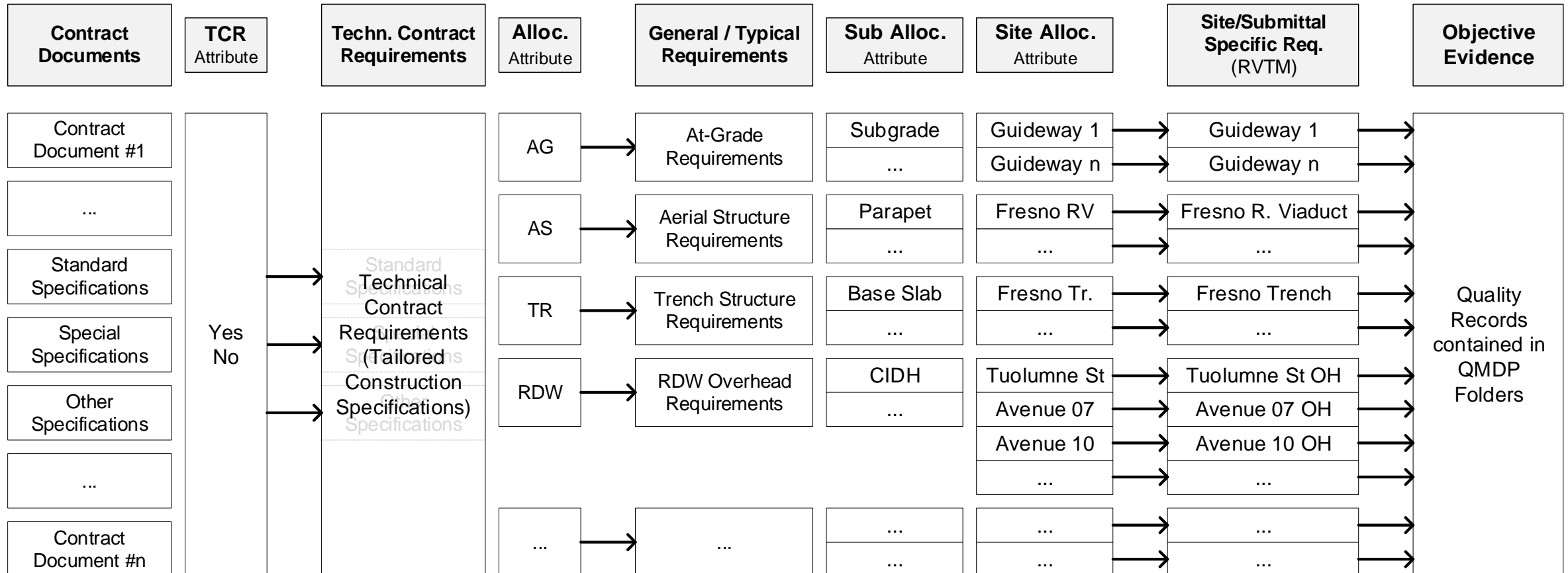
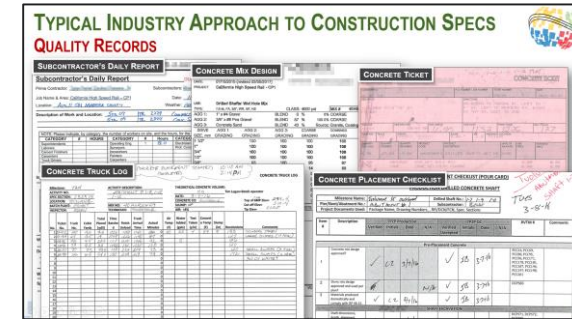
ENVISIONED SOLUTION: FOUR (4) STEP APPROACH





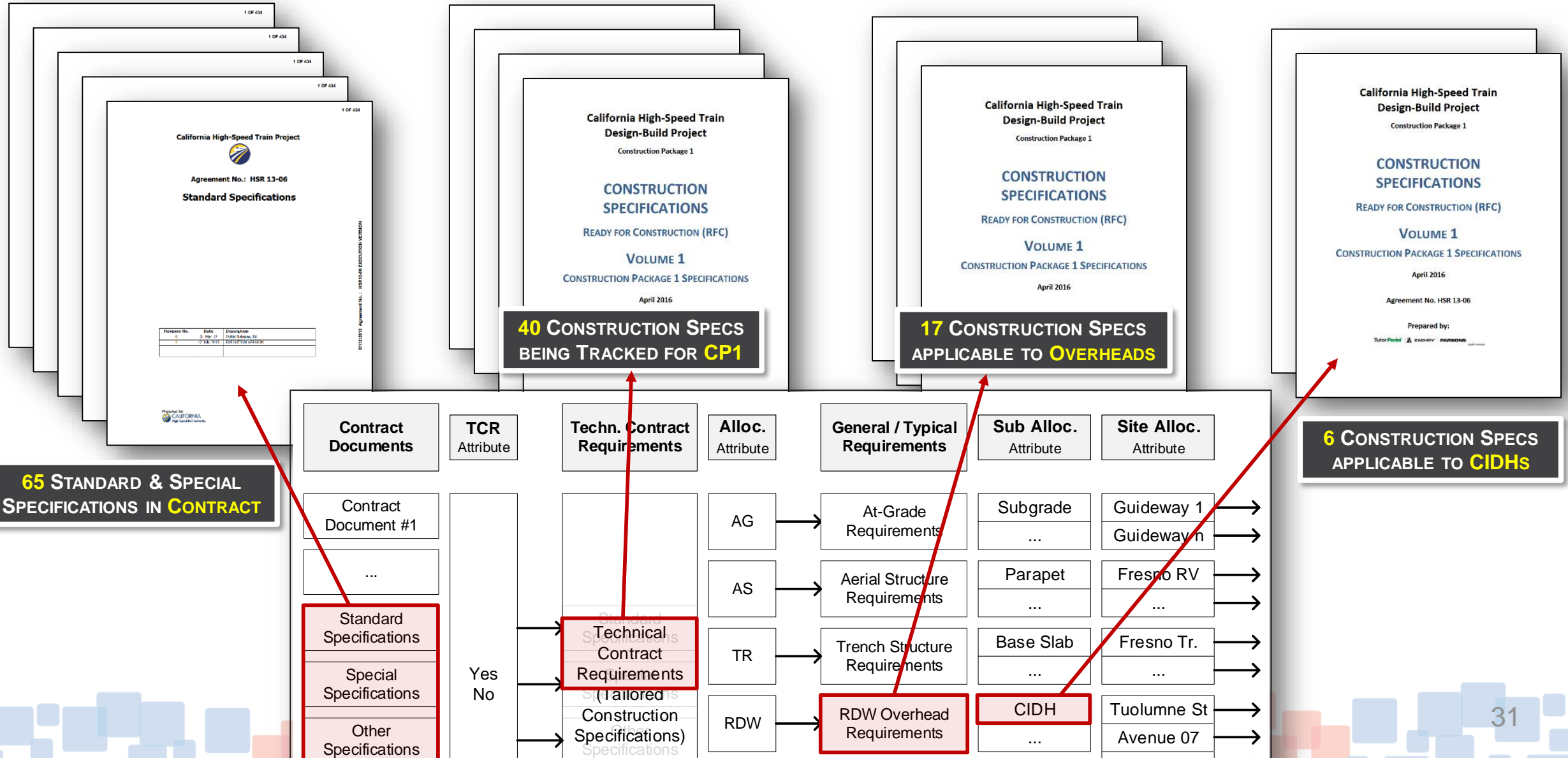
- ❖ **Problem Statement & Offered Solution**
- ❖ **Background & Introduction**
- ❖ **Systems Engineering Challenges Faced**
- ❖ **Systems Engineering Objectives**
- ❖ **Systems Engineering Activities Performed**
 1. Requirements Management
 2. System Breakdown Structure
 3. Verification and Validation
 4. Traceability
- ❖ **Summary, Achieved Outcomes & Conclusion**

STRUCTION SPECS



SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 1: REQUIREMENTS MANAGEMENT – ANALYSIS & ALLOCATION



SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 1: REQUIREMENTS MANAGEMENT – **APPLICABLE SPECIFICATIONS**



California High-Speed Train Project

Construction Package 1



**INSPECTION AND TEST PLAN
FOR
PRODUCTION DRILLED CONCRETE SHAFT**

Revision 1

July, 2016

CP1 INSPECTION & TEST PLAN

Prepared by:

1.2 Reference Documents

The referenced documents are considered mandatory as determined applicable by TPZP and for those sections or portion thereof identified in this ITP. The list may be updated to conform to the CP 1 Project Construction Specifications.

- CHSTP Standard Specifications, Executed Version, Rev 1 – July 12, 2013
- General Provisions, Executed Version, Rev 7 – July 30, 2013
- Scope of Work, Executed Version, Rev 9 – July 31, 2013
- CP 1 Construction Specifications Ready for Construction (RFC), Volume 1
 - 03 05 15 – Portland Cement Concrete
 - 03 11 00 – Concrete Forming
 - 03 20 00 – Concrete Reinforcing
 - 03 30 00 – Cast-In-Place Concrete
 - 31 63 29 – Drilled Concrete Piers and Shafts
 - 26 05 26 Grounding and Bonding
- Approved RFC or Early Start of Construction (ESOC) Plans
- Approved Shop Drawings
- Quality Management Plan (QMP), Rev 1 – April, 2016
- 2010 Standard Specifications & Special Amendments – State of California

**6 CONSTRUCTION SPECS
APPLICABLE TO CIDHS**

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 1: RM – APPLICABLE REQ. & V&V METHODS

1.2 Reference Documents

The referenced documents are considered mandatory as sections or portion thereof identified in this ITP. The list may be subject to change during the construction process.

- CHSTP Standard Specifications, Executed Version, Rev 7 – July 30, 2013
- General Provisions, Executed Version, Rev 7 – July 30, 2013
- Scope of Work, Executed Version, Rev 9 – July 31, 2013
- CP 1 Construction Specifications Ready for Construction
 - 03 05 15 – Portland Cement Concrete
 - 03 11 00 – Concrete Forming
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- Approved RFC or Early Start of Construction (ESOC) Plan
- Approved Shop Drawings
- Quality Management Plan (QMP), Rev 1 – April, 2016
- 2010 Standard Specifications & Special Amendments

CP1 INSPECTION & TEST PLAN

03 05 15 Portland Cement Concrete DL - 191 Executed

1 GENERAL

1.6 SUBMITTALS

A. Concrete Mix Designs: Submit mix designs as herein required. Include laboratory test reports of trial strength and shrinkage test results a minimum of 30 days prior to batching or delivering concrete.

2 PRODUCTS

2.1 MATERIALS

A. Portland Cement: ASTM C150, Type II, low alkali. Where high early strength concrete is a requirement a minimum of 30 days prior to batching or delivering concrete.

3 EXECUTION

3.1 FIELD QUALITY CONTROL

B. Methods of Sampling and Testing:
1. Sampling: Representative composite samples shall be obtained from a minimum of three different batches. Each sample shall be obtained from a different batch.

5. Strength Tests:

a. Prepare, cast, and deliver to the same independent laboratory-cured compression test samples. Cylinders shall be tested in accordance with ASTM C31. Cylinders shall be tested at 28 days in accordance with ASTM C39. If the cylinder shall be discarded.

b. The minimum number of test cylinders to be tested each placement shall be four cylinders for each placement. Additional sets of test cylinders are required beyond the minimum, each set shall consist of a minimum of two cylinders.

c. All cylinders in a set shall be marked with a unique number on the record of concrete placed. All cylinders shall be tested at an independent testing laboratory.

d. From each set of cylinders cast, one cylinder shall be discarded at 28 days in accordance with ASTM C39. If the cylinder shall be discarded.

FOCUS ON REQUIREMENTS:

- SUBMITTALS
- PRODUCTS / MATERIALS
- QUALITY (INSP. & TESTING)

1.6_SUB-A-Concrete_Mix_Designs.pdf

1.6_SUB-B-Product_Data.pdf

1.6_SUB-C-Aggregate_Source.pdf

1.6_SUB-D-Certificates.pdf

1.6_SUB-E-Batch_Tickets.pdf

1.7_QAC-A-Qualified_Concrete_Supplier.pdf

1.7_QAC-B-Concrete_Supplier.pdf

1.7_QAC-C-Mix_Designs.pdf

1.7_QAC-D-Contractor's_Quality_Management_Plan.pdf

1.7_QAC-E-Cement_and_Aggregates.pdf

1.8_ENV-A-Hot_Weather_Concreting.pdf

1.8_ENV-B-Cold_Weather_Concreting.pdf

2.1_MAT-A-Portland_Cement.pdf

2.1_MAT-B-Aggregates.pdf

2.1_MAT-C-Special_Aggregates_for_Reducing_Shrinkage&Creep.pdf

2.1_MAT-D-Concrete_Admixtures_and_Cementitious_Materials.pdf

2.1_MAT-E-Water.pdf

2.1_MAT-F-Reinforcement_Fibers.pdf

2.2_MAT-A-Tests_and_Records
2.2_MAT-B-Samples

2.3_MAT-Mix_Designs.pdf

3.1_FQC-A-Inspection&Test_Services.pdf

3.1_FQC-B.1_Methods_of_Sampling&Testing-Sampling.pdf

3.1_FQC-B.2_Methods_of_Sampling&Testing-Slump_Tests.pdf

3.1_FQC-B.3_Methods_of_Sampling&Testing-Concrete_Uniformity.pdf

3.1_FQC-B.4_Methods_of_Sampling&Testing-Temperature.pdf

3.1_FQC-B.5_Methods_of_Sampling&Testing-Strength_Tests.pdf

3.1_FQC-B.6_Methods_of_Sampling&Testing-Contractor's_Benefit.pdf

CORRESPONDING "TEST CASES"
(EXPECTED OBJECTIVE EVIDENCE)

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 2: SYSTEM BREAKDOWN STRUCTURE (SBS)

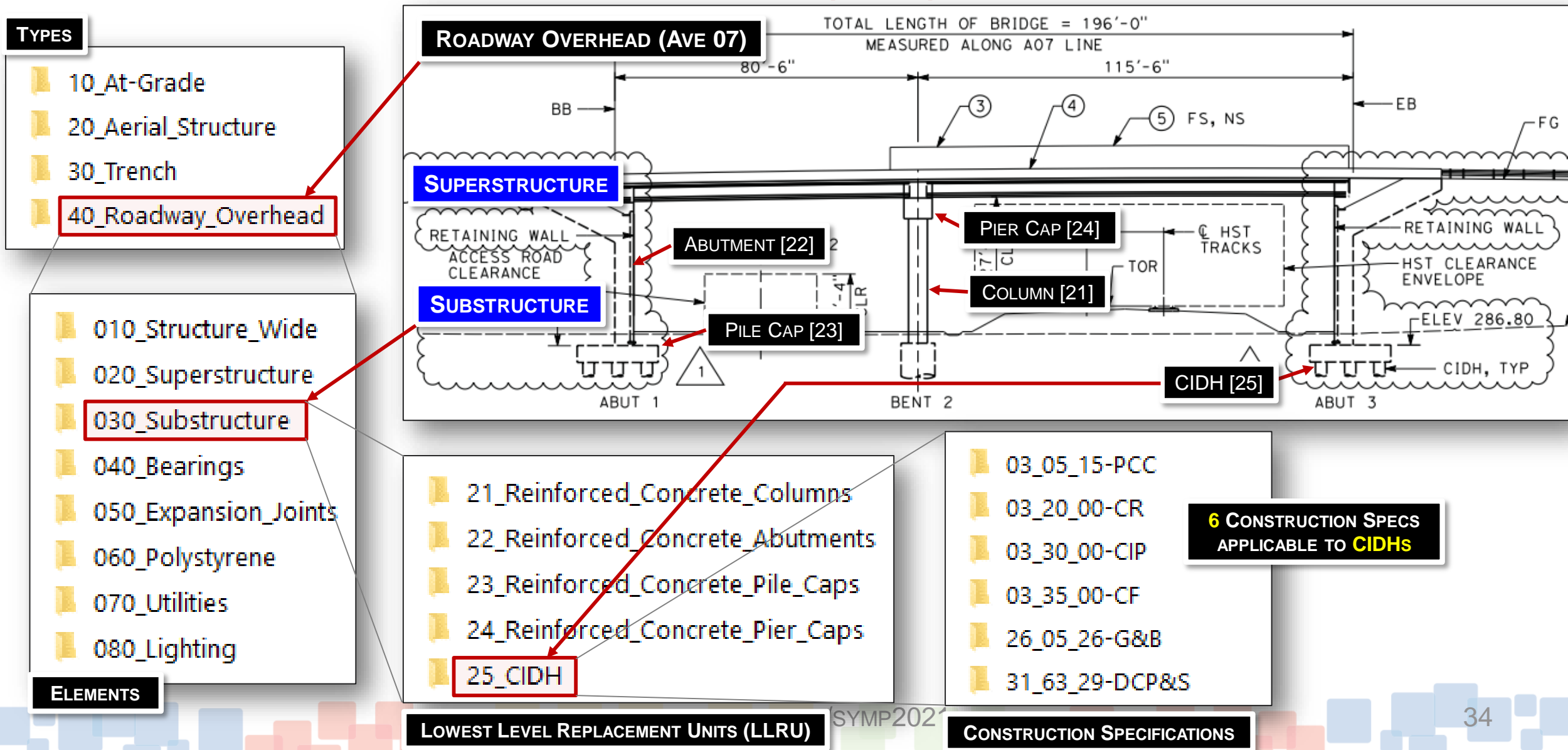


Table 1 - RAM Allocation Matrix

CP1 RAM ALLOCATION REPORT (RAR)

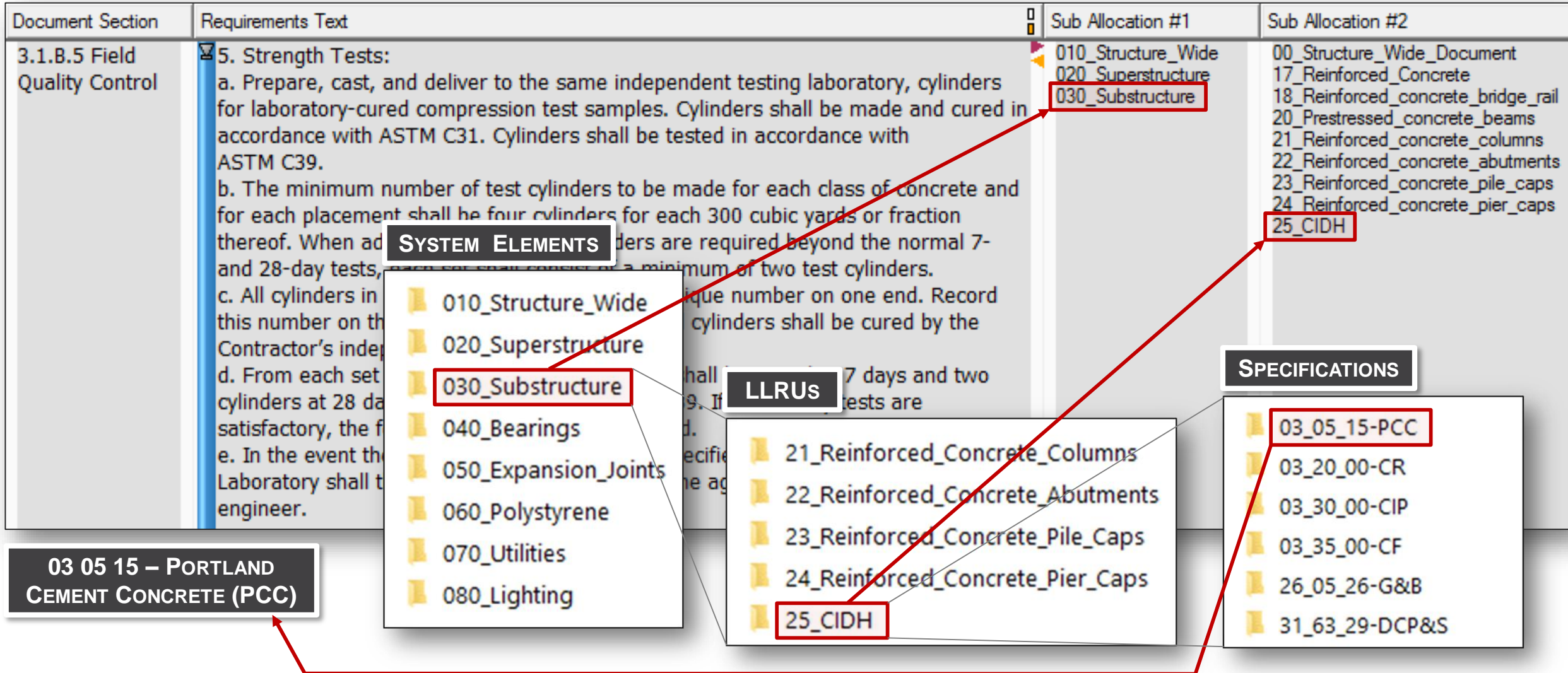
Work Elements (Attachment 4 -Scope Elements Matrix)						RAM Attributes										
Item	RAM ID #	Discipline	Category	Item	Major category	Element	Lowest Level Replacement Unit	Design Life/Reliability	Maintainability	Accessibility	Maintenance Window	MTTR (5 hours window or not)	Discipline Allocation	Subcontractor/Supplier Name	Subcontractor/Supplier Cut Sheet/Product Data	Historical Data/Similar Element Reference
18	RAM 18	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure	Reinforced concrete bridge rail	100 years	Yes, from the bridge deck.	This is always accessible from top of the bridge.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
19	RAM 19	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure	Metal fencing	100 years	Yes, from the bridge deck.	This is always accessible from the bridge deck.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
20	RAM 20	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure				This is always accessible from underneath by boom trucks, ladders, etc.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
21	RAM 21	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure				This is always accessible from underneath by boom trucks, ladders, etc.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
22	RAM 22	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure				This is always accessible from underneath by boom trucks, ladders, etc.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
23	RAM 23	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure				This is always accessible from underneath by boom trucks, ladders, etc.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
24	RAM 24	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure	Reinforced concrete pier caps	100 years	Yes, from adjacent ground.	This is always accessible from underneath by boom trucks, ladders, etc.	Between 12:01 am and 05:00 am daily	Less than 5 hours	Structures	TBD	TBD	TBD
25	RAM 25	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure	CIDH	100 years	No	This is buried and essentially inaccessible. Element is designed as	N/A	N/A	Structures	TBD	TBD	TBD

- 010_Structure_Wide
- 020_Superstructure
- 030_Substructure
- 040_Bearings
- 050_Expansion_Joints
- 060_Polystyrene
- 070_Utilities
- 080_Lighting

- 21_Reinforced_Concrete_Columns
- 22_Reinforced_Concrete_Abutments
- 23_Reinforced_Concrete_Pile_Caps
- 24_Reinforced_Concrete_Pier_Caps
- 25_CIDH

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 2: USING SBS FOR REQUIREMENTS ALLOCATION



SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 2: USING SBS FOR QMDP FOLDER STRUCTURE

1.0 Executive Summary

2.0 Environmental Compliance

3.0 Verification, Validation, and Self Certification

4.0 Third Party Requirements

5.0 Milestones Photographic Evidence

6.0 Operations and Maintenance Requirements

7.0 Disposition of Comments

8.0 Quality

9.0 Drawings, Documents, and Records

QMDP FOLDER STRUCTURE

8.1 Construction Quality Records

010_Structure_Wide

020_Superstructure

030_Substructure

21_Reinforced_Concrete_Columns

22_Reinforced_Concrete_Abutments

23_Reinforced_Concrete_Pile_Caps

24_Reinforced_Concrete_Pier_Caps

25_CIDH

03_05_15-PCC

03_20_00-CR

03_30_00-CIP

03_35_00-CF

26_05_26-G&B

31_63_29-DCP&S

040_Bearings

050_Expansion_Joints

060_Polystyrene

070_Uilities

080_Lighting

PORTLAND CEMENT
CONCRETE SPECIFICATION

1.6_SUB-A-Concrete_Mix_Designs.pdf

1.6_SUB-B-Product_Data.pdf

1.6_SUB-C-Aggregate_Source.pdf

1.6_SUB-D-Certificates.pdf

1.6_SUB-E-Batch_Tickets.pdf

1.7_QAC-A-Qualitied_Concrete_Supplier.pdf

1.7_QAC-B-Concrete_Supplier.pdf

1.7_QAC-C-Mix_Designs.pdf

1.7_QAC-D-Contractor's_Quality_Management_Plan.pdf

1.7_QAC-E-Cement_and_Aggregates.pdf

1.8_ENV-A-Hot_Weather_Concreting.pdf

1.8_ENV-B-Cold_Weather_Concreting.pdf

2.1_MAT-A-Portland_Cement.pdf

2.1_MAT-B-Aggregates.pdf

2.1_MAT-C-Special_Aggregates_for_Reducing_Shrinkage&Creep.pdf

2.1_MAT-D-Concrete_Admixtures_and_Cementitious_Materials.pdf

2.1_MAT-E-Water.pdf

2.1_MAT-F-Reinforcement_Fibers.pdf

2.2_MAT-A-Tests_and_Sample_Analyses.pdf

2.2_MAT-B-Samples.pdf

2.3_MAT-Mix_Designs.pdf

3.1_FQC-A-Inspection&Test_Services.pdf

3.1_FQC-B.1_Methods_of_Sampling&Testing-Sampling.pdf

3.1_FQC-B.2_Methods_of_Sampling&Testing-Slump_Tests.pdf

3.1_FQC-B.3_Methods_

3.1_FQC-B.4_Methods_

3.1_FQC-B.5_Methods_of_Sampling&Testing-Strength_Tests.pdf

3.1_FQC-B.6_Methods_of_Sampling&Testing-Contractor's_Benefit.pdf

CORRESPONDING "TEST CASES"
(EXPECTED OBJECTIVE EVIDENCE)

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 3: VERIFICATION & VALIDATION – LOCATING THE QUALITY RECORDS



03 05 15 Portland Cement Concrete DL - 191 Executed

1 GENERAL

1.6 SUBMITTALS

A. Concrete Mix Designs: Submit mix designs as herein specified in Article entitled "Mix Designs." Include laboratory test reports of trial strength and shrinkage tests. Submit mix designs a minimum of 30 days prior to batching.

2 PRODUCTS

2.1 MATERIALS

A. Portland Cement: ASTM C150, Type I, where high early strength concrete is required.

3 EXECUTION

3.1 FIELD QUALITY CONTROL

B. Methods of Sampling and Testing:

1. Sampling: Representative composite samples of each placement shall be obtained from a minimum of 10 locations.

5. Strength Tests:

a. Prepare, cast, and deliver to the laboratory-cured compression test cylinders in accordance with ASTM C31. Cylinders shall be 16 inches in diameter and 36 inches high.

b. The minimum number of test cylinders for each placement shall be four cylinders. In addition, one set of test cylinders shall be cast for each placement. Each set shall consist of a minimum of three cylinders. All cylinders in a set shall be tested in the record of concrete independent testing laboratory.

c. From each set of cylinders cast at 28 days in accordance with ASTM C31, one cylinder shall be discarded.

d. In the event the 28-day tests are not completed, the Laboratory shall then test the four cylinders at 56 days.

03 05 15 – PORTLAND CEMENT CONCRETE (PCC)

Contractor's Benefit
The Contractor's benefit
The Contractor's quality control

CORRESPONDING "TEST CASES"
(EXPECTED OBJECTIVE EVIDENCE)

8.0 Quality

8.1 Construction Quality Records

> 010_Structure_Wide

> 020_Superstructure

> 030_Substructure

> 21_Reinforced_Concrete_Columns

> 22_Reinforced_Concrete_Abutment

> 23_Reinforced_Concrete_Pile_Caps

> 24_Reinforced_Concrete_Pier_Caps

> 25_CIDH

> 03_05_15-PCC

> 03_20_00-CR

> 03_30_00-CIP

> 03_35_00-CF

> 26_05_26-G&B

> 31_63_29-DCP&S

> 040_Bearings

> 050_Expansion_Joints

> 060_Polystyrene

> 070_Uilities

1.6_SUB-A-Concrete_Mix_Designs.pdf

1.6_SUB-B-Product_Data.pdf

1.6_SUB-C-Aggregate_Source.pdf

1.6_SUB-D-Certificates.pdf

1.6_SUB-E-Batch_Tickets.pdf

1.7_QAC-A-Qualified_Concrete_Supplier.pdf

1.7_QAC-B-Concrete_Supplier.pdf

1.7_QAC-C-Mix_Designs.pdf

1.7_QAC-D-Contractor's_Quality_Management

1.7_QAC-E-Cement_and_Aggregates.pdf

1.8_ENV-A-Hot_Weather_Concreting.pdf

1.8_ENV-B-Cold_Weather_Concreting.pdf

2.1_MAT-A-Portland_Cement.pdf

2.1_MAT-B-Aggregates.pdf

2.1_MAT-C-Special_Aggregates_for_Reducing_S

2.1_MAT-D-Concrete_Admixtures_and_Cementin

2.1_MAT-E-Water.pdf

2.1_MAT-F-Reinforcement_Fibers.pdf

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3.1_FQC-B.2_Methods_of_Sampling&Testing-Slump_Tests.p

3.1_FQC-B.3_Methods_of_Sampling&Testing-Concrete_Uniformity.pai

3.1_FQC-B.4_Methods_of_Sampling&Testing-Temperature.pdf

3.1_FQC-B.5_Methods_of_Sampling&Testing-Strength_Tests.pdf

3.1_FQC-B.6_Methods_of_Sampling&Testing-Contractor's_Benefit.pdf

3.1_FQC-C-Evaluation_and_Acceptance_of_Tests.pdf

3.1_FQC-D-Acceptance_of_Structure_(Completed_Concrete_Work).pdf

Concrete Mix Design

PROJECT: California High Speed Rail

USE: 7.00 cu yd, 30" PA, W10, 1" x 1" Gravel

AGG 1: 3/4" x 1/4" Gravel

AGG 2: 3/4" x 1/4" Gravel

AGG 3: 3/4" x 1/4" Gravel

SIEVE: 100, 200, 40, 60, 100, 200, 40, 60, 100, 200

GRADING: 100, 200, 40, 60, 100, 200, 40, 60, 100, 200

Signatures: [Signature] [Signature]

Stamp: SMOA #91-10-003

SUBMITTAL: CONCRETE MIX DESIGN

2.1 MAT - A - Portland Cement

CEMENT TEST REPORT

Cement: Permanent Type I (V), Low Alkali, ASTM C 150 30

Production Period: Permanent August 2017

Report Date: 9/7/2017

STANDARD CHEMICAL REQUIREMENTS	TEST RESULTS	ASTM C 150 IS SPECIFICATIONS	TYPE II	TYPE V
Fineness (Blaine), %	28.8	28.0	—	—
Specific Gravity (G ₁)	3.15	3.15	—	—
Soundness (ASTM C 150), %	0.0	0.0	—	—
Free Chloride (ASTM C 150), %	0.00	0.00	—	—
Chloride (ASTM C 150), %	0.00	0.00	—	—
Sulfate (ASTM C 150), %	0.00	0.00	—	—
Chloride (ASTM C 150), %	0.00	0.00	—	—
Sulfate (ASTM C 150), %	0.00	0.00	—	—
Chloride (ASTM C 150), %	0.00	0.00	—	—
Sulfate (ASTM C 150), %	0.00	0.00	—	—

MATERIAL: PORTLAND CEMENT

3.1 FQC - B.5 Methods of Sampling & Testing

Report On: Concrete Compressive

Project: G17201.01 Acct ID: G172

Client: [Redacted]

Project: California High Speed Rail Construction Package #1

Report Date: 09/16/2019

Location: Fresno and Madera County HSR Route CP 1

Sample Date: 08/16/2019

Sampled By: [Redacted]

By Order Of: [Redacted]

Cylinder Marked	Age Tested (days)	Diameter (in)	Area (sq in)	Max Load (lb)	Break Type	Cure	Compressive Strength (psi)	Average Strength (psi)	Tested By
1	08/23/19: 7	6.00	28.274	129,020	Type 2	Lab	4,560	4,620	[Redacted]
2	08/23/19: 7	6.00	28.274	132,050	Type 2	Lab	4,670	4,620	[Redacted]
3	08/13/19: 28	6.00	28.274	188,120	Type 2	Lab	4,660	4,620	[Redacted]
4	09/13/19: 28	6.00	28.274	193,460	Type 2	Lab	6,840	6,750	[Redacted]
5	HOLD								
6	HOLD								

Comments: FQC (D)

Meets Reference Value

Quantity Represented: 4,000 psi @ 28 days

Placement Location: Abutments 1 & 2 CIDH plus Ave 10 gateway

Sample Location: STR06 ITR4457

Test Method (As Applicable): Compressive strength tests per ASTM C39

Respectfully Submitted, [Signature]

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 3: VERIFICATION & VALIDATION – PERFORMING THE ACTUAL REVIEW



03 05 15 Portland Cement Concrete DL - 191 Executed		TCR
1 GENERAL		
1.6 SUBMITTALS		
A. Concrete Mix Designs:	Submit mix designs as herein specified in Article entitled "Mix Designs". Include laboratory test reports of trial strength and shrinkage tests. Submit mix designs a minimum of 30 days prior to batching or delivering concrete.	Yes
2 PRODUCTS		
2.1 MATERIALS		
A. Portland Cement:	ASTM C150, Type II, low alkali. Type III Portland cement may be used where high early strength concrete is a requirement as approved by the Contractor's engineer.	Yes
3 EXECUTION		
3.1 FIELD QUALITY CONTROL		
B. Methods of Sampling and Testing:		Yes
1. Sampling:	Representative composite samples shall be taken in accordance with ASTM C172. Each sample shall be obtained from a different batch of concrete on a random basis.	Yes
5. Strength Tests:		Yes
a.	Prepare, cast, and deliver to the same independent testing laboratory, cylinders for laboratory-cured compression test samples. Cylinders shall be made and cured in accordance with ASTM C31. Cylinders shall be tested in accordance with ASTM C39.	
b.	The minimum number of test cylinders to be made for each class of concrete and for each placement shall be four cylinders for each 100 cubic yards or fraction thereof. When additional sets of test cylinders are required beyond the normal 7- and 28-day tests, each set shall consist of a minimum of two test cylinders.	
c.	All cylinders in a set shall be marked with a unique number on one end. Record this number on the record of concrete placed. All cylinders shall be cured by the Contractor's independent testing laboratory.	
d.	From each set of cylinders cast, one cylinder shall be tested at 7 days and two cylinders at 28 days in accordance with ASTM C39. If the 28-day tests are satisfactory, the fourth cylinder shall be discarded.	
e.	In the event the 28-day tests are below the specified strength requirements, the Laboratory shall then test the fourth cylinder at the age selected by the Contractor's	

03 05 15 – PORTLAND CEMENT CONCRETE (PCC)

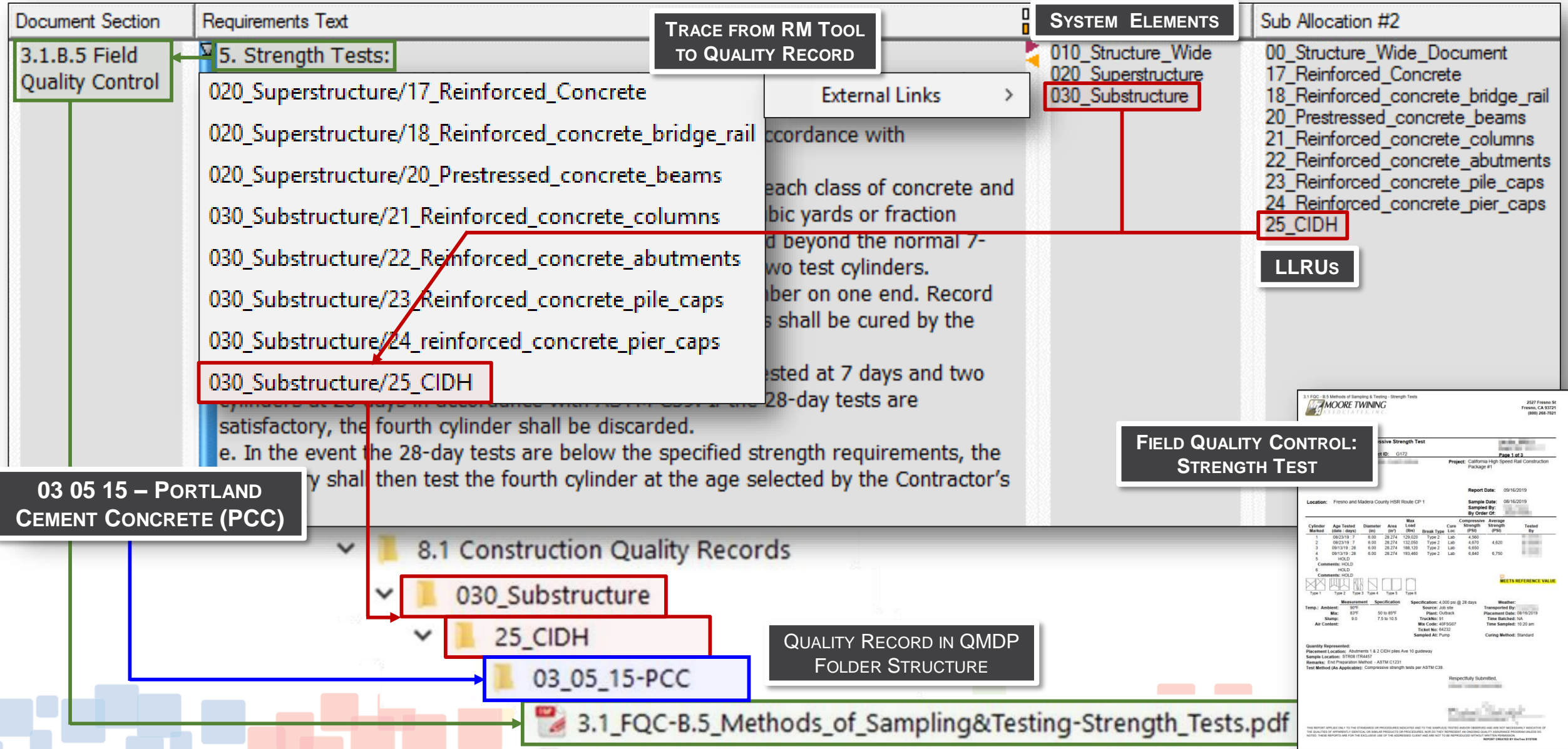
Contractor's Benefit: Tests required to verify early form removal, or other the Contractor's benefit, shall be performed at Contractor's expense as part of r's quality control program.

**SUBMITTAL:
CONCRETE MIX DESIGN**

Concrete Mix Design
PROJECT: California High Speed Rail
USE: 7.00 inch, 30" PA, W10
AGG 1: 3/4" Gravel
AGG 2: 3/4" x 1/8" Pass Gravel
AGG 3: Concrete Sand
SIEVE AGG 1: AGG 2: AGG 3: AGG 4: AGG 5: AGG 6: AGG 7: AGG 8: AGG 9: AGG 10: AGG 11: AGG 12: AGG 13: AGG 14: AGG 15: AGG 16: AGG 17: AGG 18: AGG 19: AGG 20: AGG 21: AGG 22: AGG 23: AGG 24: AGG 25: AGG 26: AGG 27: AGG 28: AGG 29: AGG 30: AGG 31: AGG 32: AGG 33: AGG 34: AGG 35: AGG 36: AGG 37: AGG 38: AGG 39: AGG 40: AGG 41: AGG 42: AGG 43: AGG 44: AGG 45: AGG 46: AGG 47: AGG 48: AGG 49: AGG 50: AGG 51: AGG 52: AGG 53: AGG 54: AGG 55: AGG 56: AGG 57: AGG 58: AGG 59: AGG 60: AGG 61: AGG 62: AGG 63: AGG 64: AGG 65: AGG 66: AGG 67: AGG 68: AGG 69: AGG 70: AGG 71: AGG 72: AGG 73: AGG 74: AGG 75: AGG 76: AGG 77: AGG 78: AGG 79: AGG 80: AGG 81: AGG 82: AGG 83: AGG 84: AGG 85: AGG 86: AGG 87: AGG 88: AGG 89: AGG 90: AGG 91: AGG 92: AGG 93: AGG 94: AGG 95: AGG 96: AGG 97: AGG 98: AGG 99: AGG 100: AGG 101: AGG 102: AGG 103: AGG 104: AGG 105: AGG 106: AGG 107: AGG 108: AGG 109: AGG 110: AGG 111: AGG 112: AGG 113: AGG 114: AGG 115: AGG 116: AGG 117: AGG 118: AGG 119: AGG 120: AGG 121: AGG 122: AGG 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567: AGG 568: AGG 569: AGG 570: AGG 571: AGG 572: AGG 573: AGG 574: AGG 575: AGG 576: AGG 577: AGG 578: AGG 579: AGG 580: AGG 581: AGG 582: AGG 583: AGG 584: AGG 585: AGG 586: AGG 587: AGG 588: AGG 589: AGG 590: AGG 591: AGG 592: AGG 593: AGG 594: AGG 595: AGG 596: AGG 597: AGG 598: AGG 599: AGG 600: AGG 601: AGG 602: AGG 603: AGG 604: AGG 605: AGG 606: AGG 607: AGG 608: AGG 609: AGG 610: AGG 611: AGG 612: AGG 613: AGG 614: AGG 615: AGG 616: AGG 617: AGG 618: AGG 619: AGG 620: AGG 621: AGG 622: AGG 623: AGG 624: AGG 625: AGG 626: AGG 627: AGG 628: AGG 629: AGG 630: AGG 631: AGG 632: AGG 633: AGG 634: AGG 635: AGG 636: AGG 637: AGG 638: AGG 639: AGG 640: AGG 641: AGG 642: AGG 643: AGG 644: AGG 645: AGG 646: AGG 647: AGG 648: AGG 649: AGG 650: AGG 651: AGG 652: AGG 653: AGG 654: AGG 655: AGG 656: AGG 657: AGG 658: AGG 659: AGG 660: AGG 661: AGG 662: AGG 663: AGG 664: AGG 665: AGG 666: AGG 667: AGG 668: AGG 669: AGG 670: AGG 671: AGG 672: AGG 673: AGG 674: AGG 675: AGG 676: AGG 677: AGG 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SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 4: TRACEABILITY – USING REQ. MGMT. TOOL (AUTOMATED TRACING)



SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 4: TRACEABILITY – INHERENT TRACEABILITY



03 05 15 Portland Cement Concrete DL - 191 Executed

1 GENERAL

1.6 SUBMITTALS

A. Concrete Mix Designs: Submit mix designs as herein specified in Article entitled "Mix Designs." Include laboratory test reports of trial strength and shrinkage tests. Submit mix designs a minimum of 30 days prior to batching.

2 PRODUCTS

2.1 MATERIALS

A. Portland Cement: ASTM C150, Type I, where high early strength concrete is required.

3 EXECUTION

3.1 FIELD QUALITY CONTROL

B. Methods of Sampling and Testing:

1. Sampling: Representative composite samples of each placement shall be obtained from a minimum of 10 locations.

5. Strength Tests:

a. Prepare, cast, and deliver to the laboratory-cured compression test specimens in accordance with ASTM C31. Cylinders shall be 6 in. diameter by 12 in. high.

b. The minimum number of test specimens for each placement shall be four cylinders. In addition, one set of test cylinders shall be cast for each placement, each set shall consist of a minimum of four cylinders. All cylinders in a set shall be tested in the record of concrete independent testing laboratory.

c. From each set of cylinders cast at 28 days in accordance with ASTM C31, one cylinder shall be discarded.

d. In the event the 28-day tests are not completed, the Laboratory shall then test the remaining cylinders.

03 05 15 – PORTLAND CEMENT CONCRETE (PCC)

Contractor's Benefit: The Contractor's benefit, shall be performed at Contractor's expense in the Contractor's quality control program.

8.0 Quality

8.1 Construction Quality Records

> 010_Structure_Wide

> 020_Superstructure

> 030_Substructure

> 21_Reinforced_Concrete_Columns

> 22_Reinforced_Concrete_Abutment

> 23_Reinforced_Concrete_Pile_Caps

> 24_Reinforced_Concrete_Pier_Caps

> 25_CIDH

> 03_05_15-PCC

> 03_20_00-CR

> 03_30_00-CIP

> 03_35_00-CF

> 26_05_26-G&B

> 31_63_29-DCP&S

> 040_Bearings

> 050_Expansion_Joints

> 060_Polystyrene

> 070_Utillities

> 080_Lighting

1.6 SUB-A-Concrete_Mix_Designs.pdf

1.6 SUB-B-Product_Data.pdf

1.6 SUB-C-Aggregate_Source.pdf

1.6 SUB-D-Certificates.pdf

1.6 SUB-E-Batch_Tickets.pdf

1.7 QAC-A-Qualified_Concrete_Supplier.pdf

1.7 QAC-B-Concrete_Supplier.pdf

1.7 QAC-C-Mix_Designs.pdf

1.7 QAC-D-Contractor's_Quality_Management

1.7 QAC-E-Cement_and_Aggregates.pdf

1.8 ENV-A-Hot_Weather_Concreting.pdf

1.8 ENV-B-Cold_Weather_Concreting.pdf

2.1 MAT-A-Portland_Cement.pdf

2.1 MAT-B-Aggregates.pdf

2.1 MAT-C-Special_Aggregates_for_Reducing_S

2.1 MAT-D-Concrete_Admixtures_and_Cementin

2.1 MAT-E-Water.pdf

2.1 MAT-F-Reinforcement_Fibers.pdf

2.2 MAT-A-Tests_and_Sample_Analyses.pdf

2.2 MAT-B-Samples.pdf

2.3 MAT-Mix_Designs.pdf

3.1 FQC-A-Inspection&Test_Services.pdf

3.1 FQC-B.1_Methods_of_Sampling&Testing-Sampling.pdf

3.1 FQC-B.2_Methods_of_Sampling&Testing-Slump_Tests.p

3.1 FQC-B.3_Methods_of_Sampling&Testing-Concrete_Uniformity.pai

3.1 FQC-B.4_Methods_of_Sampling&Testing-Temperature.pdf

3.1 FQC-B.5_Methods_of_Sampling&Testing-Strength_Tests.pdf

3.1 FQC-B.6_Methods_of_Sampling&Testing-Contractor's_Benefit.pdf

3.1 FQC-C-Evaluation_and_Acceptance_of_Tests.pdf

3.1 FQC-D-Acceptance_of_Structure_(Completed_Concrete_Work).pdf

Concrete Mix Design

PROJECT: California High Speed Rail

USE: Drilled Shafts, Wet Mix

AGG 1: 1" x 1/4" Gravel

AGG 2: 3/4" x 1/8" Pass Gravel

AGG 3: Concrete Sand

SIEVE: 100, 200, 40, 60, 100, 200

SIZE: 100, 200, 40, 60, 100, 200

GRADING: 100, 200, 40, 60, 100, 200

Signatures: [Signature]

SUBMITTAL: CONCRETE MIX DESIGN

2.1 MAT - A - Portland Cement

CEMENT TEST REPORT

Cement: Permanent Type I (V), Low Alkali, ASTM C 150 30

Production Period: Permanent August 2017

Report Date: 9/7/2017

STANDARD CHEMICAL REQUIREMENTS	TEST RESULTS	ASTM C 150 14 SPECIFICATIONS
ASTM C 150 14	28.8	TYPE I
ASTM C 150 14	1.2	TYPE V

MATERIAL: PORTLAND CEMENT

3.1 FQC - B.5 Methods of Sampling & Testing

Report On: Concrete Compressive

Project: G17201.01 Acct ID: G172

Client: [Redacted]

Project: California High Speed Rail Construction Package #1

Report Date: 09/16/2019

Location: Fresno and Madera County HSR Route CP 1

Sample Date: 08/16/2019

Sampled By: [Redacted]

By Order Of: [Redacted]

Cylinder Marked	Age Tested (days)	Diameter (in)	Area (sq in)	Max Load (lb)	Break Type	Cure	Compressive Strength (psi)	Average Strength (psi)	Tested By
1	08/23/19 - 7	6.00	28.274	129,020	Type 2	Lab	4,560		
2	08/23/19 - 7	6.00	28.274	132,050	Type 2	Lab	4,670	4,620	
3	08/13/19 - 28	6.00	28.274	188,120	Type 2	Lab	4,660		
4	09/13/19 - 28	6.00	28.274	193,460	Type 2	Lab	6,840	6,750	
5	HOLD								
6	HOLD								

Comments: FQC (D)

MEETS REFERENCE VALUE

Specification: 4,000 psi @ 28 days

Weather: [Redacted]

Temp.: Ambient: 80°F

Mix: 62°F

Slump: 9.0

Air Content: 7.5 to 10.5

Source: Job site

Plant: Caltrans

TruckNo: 91

Mix Code: 401 562/7

Batched: NA

Time Sampled: 10:30 am

Sampled At: Pump

Curing Method: Standard

Quantity Represented: [Redacted]

Placement Location: Abutments 1 & 2 CIDH plus Ave 10 gateway

Sample Location: STR04 ITR4457

Remarks: End Proprietary Method ASTM C1231

Test Method (As Applicable): Compressive strength tests per ASTM C39

Respectfully Submitted, [Signature]



- ❖ **Problem Statement & Offered Solution**
- ❖ **Background & Introduction**
- ❖ **Systems Engineering Challenges Faced**
- ❖ **Systems Engineering Objectives**
- ❖ **Systems Engineering Activities Performed**
- ❖ **Summary, Achieved Outcomes & Conclusion**

SUMMARY

PROBLEM STATEMENT

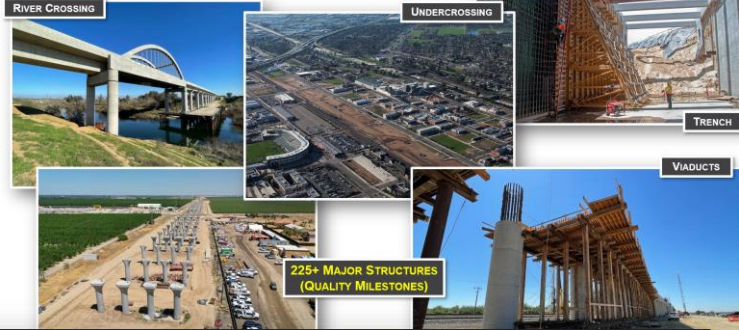
EXAMPLE: THE "BIG DIG" PROJECT

- ❖ Central Artery/Tunnel Megaproject in Boston, MA that rerouted Interstate 93 (I-93) running through the heart of the city into a 1.5-mile tunnel
- ❖ Commonly known as the **Big-Dig** project
- ❖ Designed and built between 1982 and 2007
- ❖ Most expensive highway project in the US at the time (21.5 billion in 2020 US dollars)
- ❖ Plagued by thousands of water leaks, design flaws, charges of poor execution, use of substandard materials and other issues
- ❖ **Led to the death of a motorist and criminal arrests** when a 24-ton concrete ceiling panel collapsed onto a car



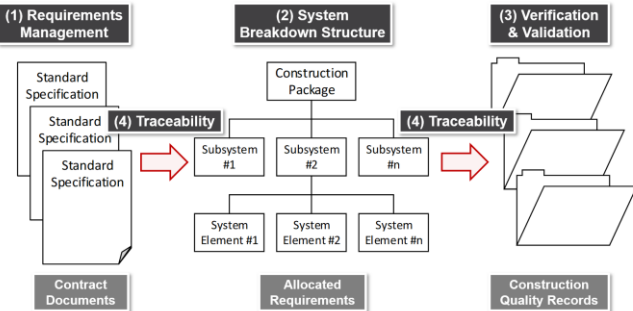
CASE STUDY PROJECT

CALIFORNIA HIGH-SPEED RAIL SYSTEM (CONT'D)



SYSTEMS ENGINEERING OBJECTIVES

ENVISIONED SOLUTION: FOUR (4) STEP APPROACH



www.incoose.org/symp2021

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OFFERED SOLUTION

SYSTEMS ENGINEERING AS THE PROFESSIONAL STANDARD OF CARE

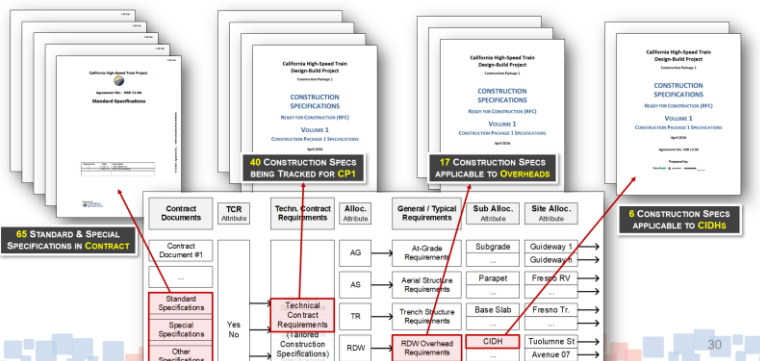
- ❖ **Professional Standard of Care:** defined as the *systematic exercise of a reasonable level of care, diligence, and skill*
- ❖ Failure to adhere to the professional standard of care may result in company **risk and liability**
- ❖ **In the author's opinion**, the Big-Dig issues:
 - Describe a common requirements management and verification & validation challenge
 - Could have been avoided using a structured systems engineering approach
- ❖ **This presentation:**
 - Describes the application of SE principles to **construction specifications** in a large infrastructure project using a **case study** approach
 - Presents the application of systems engineering as the **systematic exercise of a reasonable level of care**
 - Demonstrates the **Value of Systems Engineering** as a **liability protection** and

TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS

CONSTRUCTION QUALITY MANAGEMENT AND PROCEDURES

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 1: REQUIREMENTS MANAGEMENT – ANALYSIS & ALLOCATION



30

INTRODUCTION

CONSTRUCTION SPECIFICATIONS

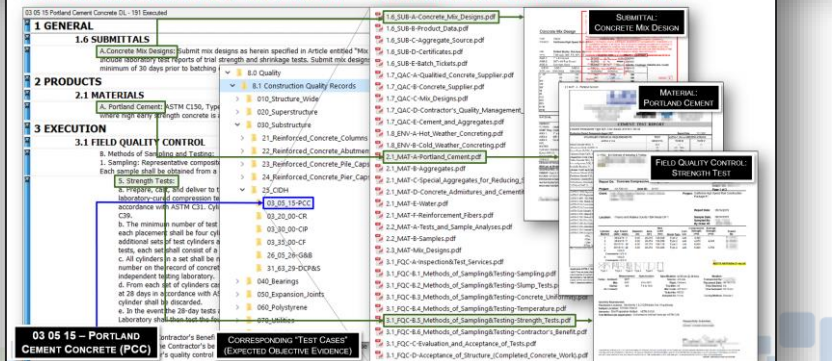
- Part 1 – General:** Describes managerial requirements such as applicability, work to be performed, codes and standards, definitions, submittals, quality management, etc.
- Part 2 – Products:** Describes the (performance) requirements, the acceptable (prescriptive or proprietary) products, materials, and sometimes even specific suppliers. **Big-Dig:** Would have contained the acceptable materials and material standards.
- Part 3 – Execution:** Describes the methods of installation and how to measure quality or effectiveness. **Big-Dig:** Would have identified the **inspections and tests** to be performed,

SYSTEMS ENGINEERING CHALLENGES

TRACING, LOCATING, AND VERIFYING TO OBJECTIVE EVIDENCE

SYSTEMS ENGINEERING ACTIVITIES PERFORMED

STEP 3: VERIFICATION & VALIDATION – LOCATING THE QUALITY RECORDS



ACHIEVED OUTCOMES & CONCLUSION



- ❖ **Addresses the Systems Engineering Challenges**
 - Implemented pilot project for Ave 10 Roadway Overhead as proof of concept
 - Enabled reviewers to efficiently and effectively identify relevant quality records
 - Produced excellent review comments against construction specification requirements
- ❖ **Avoids the cautionary tale of the Big-Dig scenario**
 - Provides a requirement-based approach demonstrating the correct use of **specified materials** and the successful execution of all specified **inspections and tests**
- ❖ **Will Deliver the successful HSR Milestones Acceptance and Certification**
 - Offers the assurance that the infrastructure HSR milestones have been built in accordance with the construction specifications
 - Will lead to successful acceptance, certification, and handover to the next HSR track and systems contractors, thereby reducing performance, schedule, and cost risk to the Authority and the public
- ❖ **Demonstrates the Professional Standard of Care**
 - Structured & systematic application of systems engineering principles to construction specifications illustrates the **systematic exercise of a reasonable level of care, diligence, and skill**, referred to as the professional standard of care, thereby demonstrating the **Value of Systems Engineering** as a **successful liability protection and risk mitigation strategy**



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