31st Annual INCOSE international symposium

virtual event

July 17 - 22, 2021

July 20, 2021: 04:45-05:30 AM Hawaiian Standard Time (Track 5, Session 4.5.2)

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

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www.incose.org/symp2021

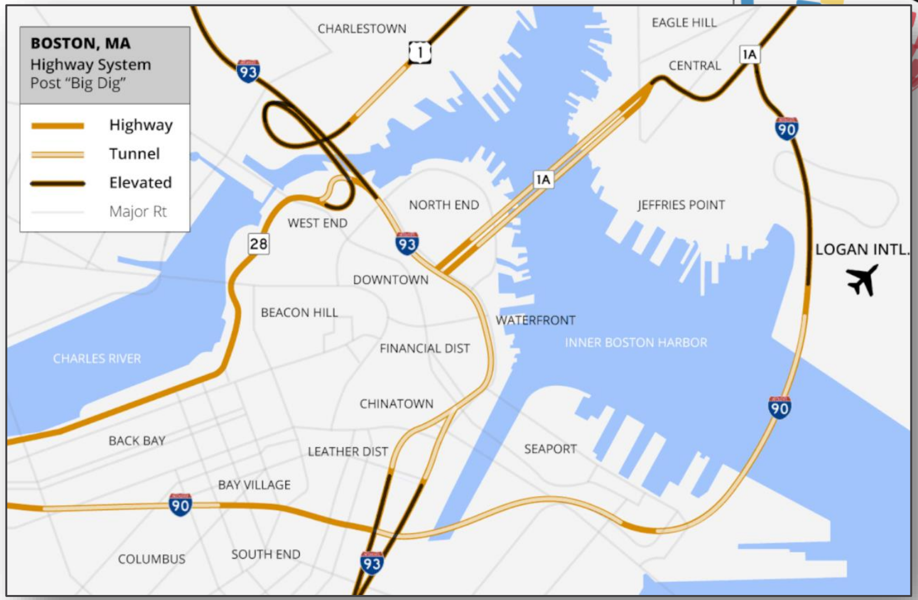
AGENDA

- **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

SOURCE: http://www.nbcnews.com/id/22809747/ns/us_news-life/t/million-settlement-covers-big-dig-tragedy/#.XNQs1hRKi70

SOURCES: SEE PAPER

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**

PROGRESS

- ❖ **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.

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP:

- DIVISION 00 — PROCUREMENT AND CONTRACTING REQUIREMENTS

SPECIFICATIONS GROUP

GENERAL REQUIREMENTS SUBGRO

- DIVISION 01 — GENERAL REQU

FACILITY CONSTRUCTION SUBGRO

- DIVISION 02 — EXISTING COND
- DIVISION 03 — CONCRETE
- DIVISION 04 — MASONRY
- DIVISION 05 — METALS
- DIVISION 06 — WOOD, PLASTI
- DIVISION 07 — THERMAL AND
- DIVISION 08 — OPENINGS
- DIVISION 09 — FINISHES
- DIVISION 10 — SPECIALTIES
- DIVISION 11 — EQUIPMENT
- DIVISION 12 — FURNISHINGS
- DIVISION 13 — SPECIAL CONSTRUCT
- DIVISION 14 — CONVEYING EQUIPM
- DIVISION 15 — RESERVED FOR FUTU

FACILITY SERVICES SUBGROUP:

- DIVISION 20 — MECHANICAL SUPPORT
- DIVISION 21 — FIRE SUPPRESSION
- DIVISION 22 — PLUMBING
- DIVISION 23 — HEATING VENTILATING AND AIR CONDITI
- 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 CONSTRU

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 EQUIP
- 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

CSI MasterFormat: **50 Divisions**

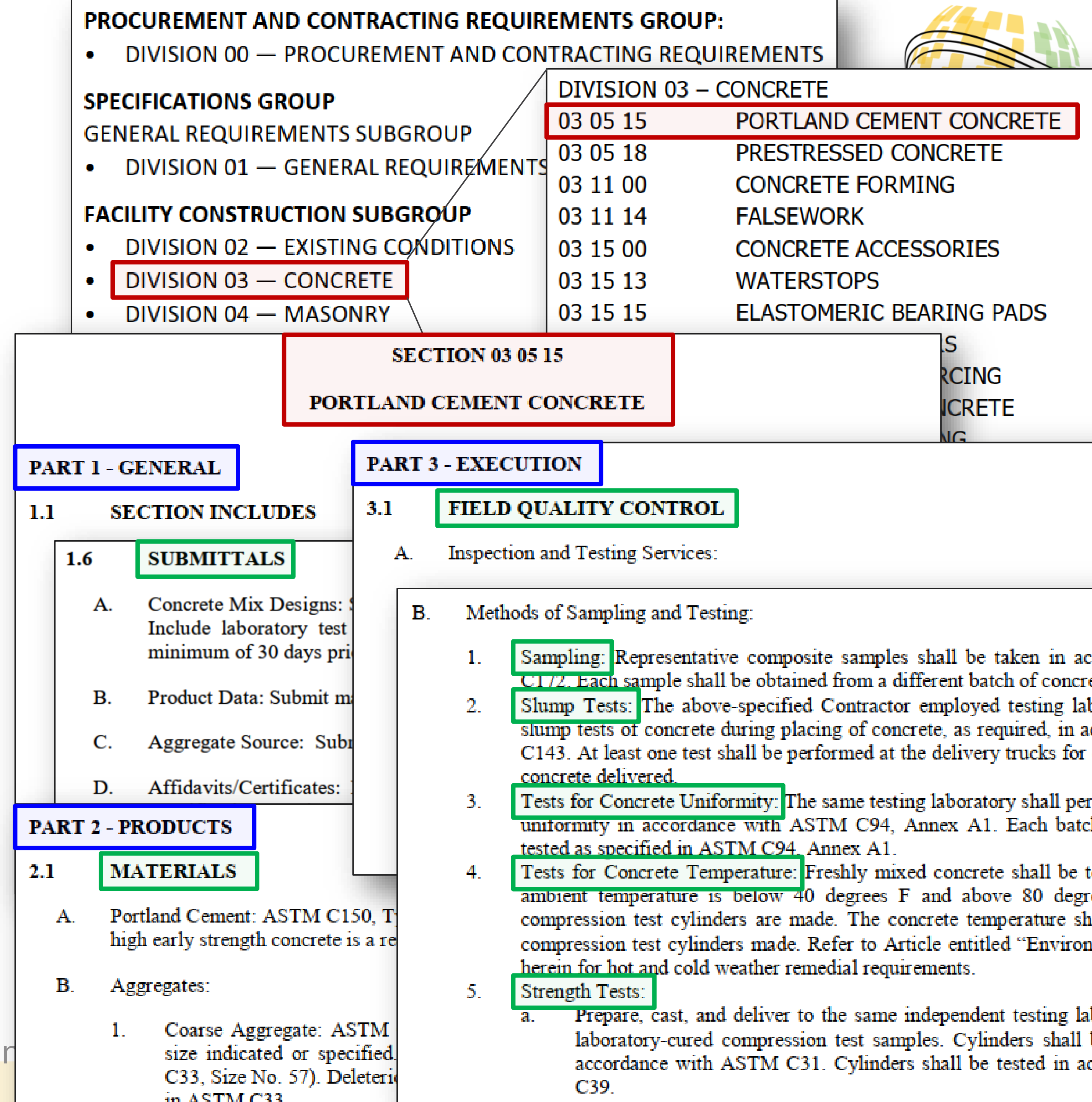
INTRODUCTION

CONSTRUCTION SPECIFICATIONS

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

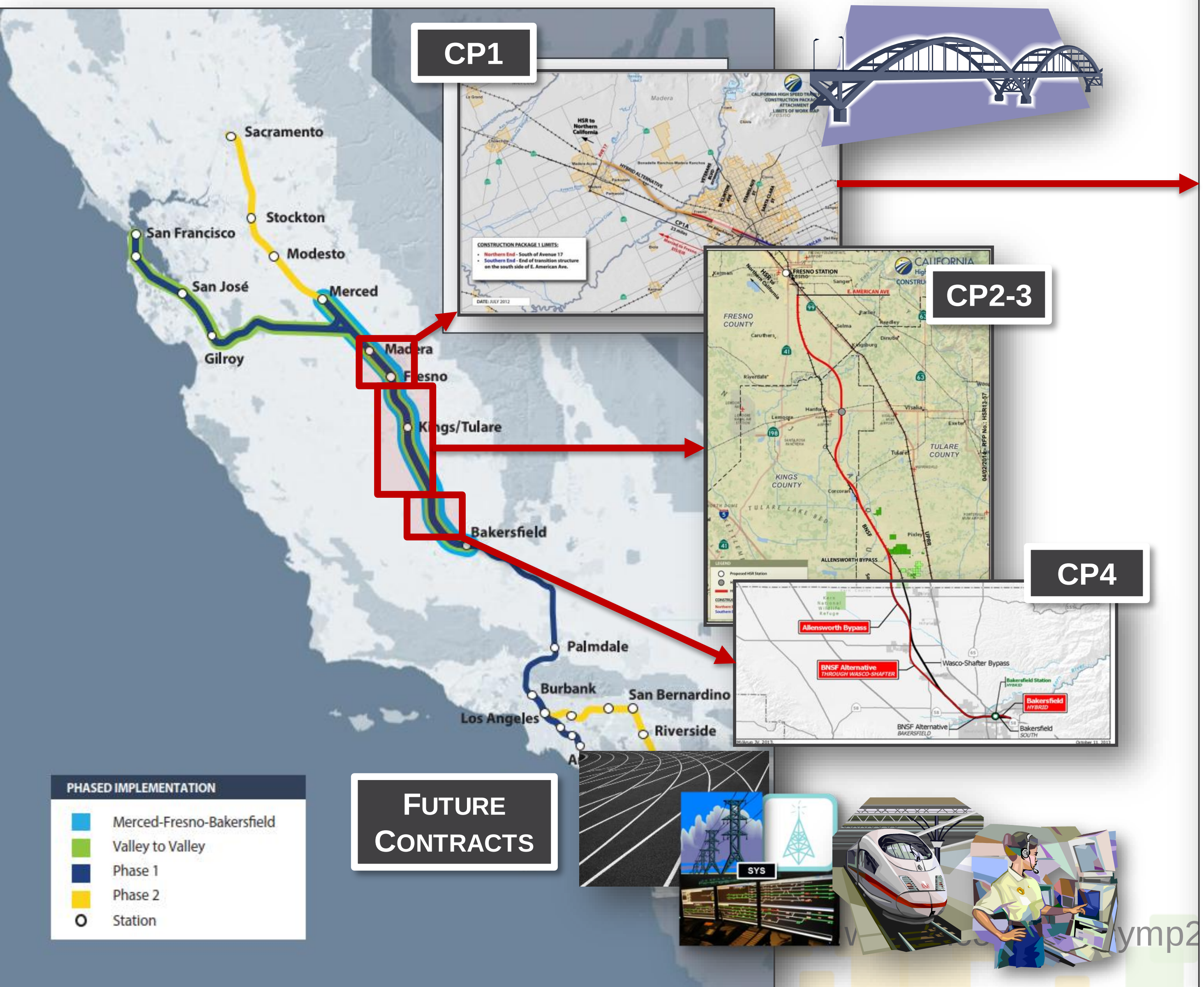
Part 2 – Products: Describes the (performance) requirements, the acceptable (prescriptive or proprietary) products, **materials**, and sometimes even specific suppliers. **Big-Dig**: Would have contained the acceptable materials and material standards.

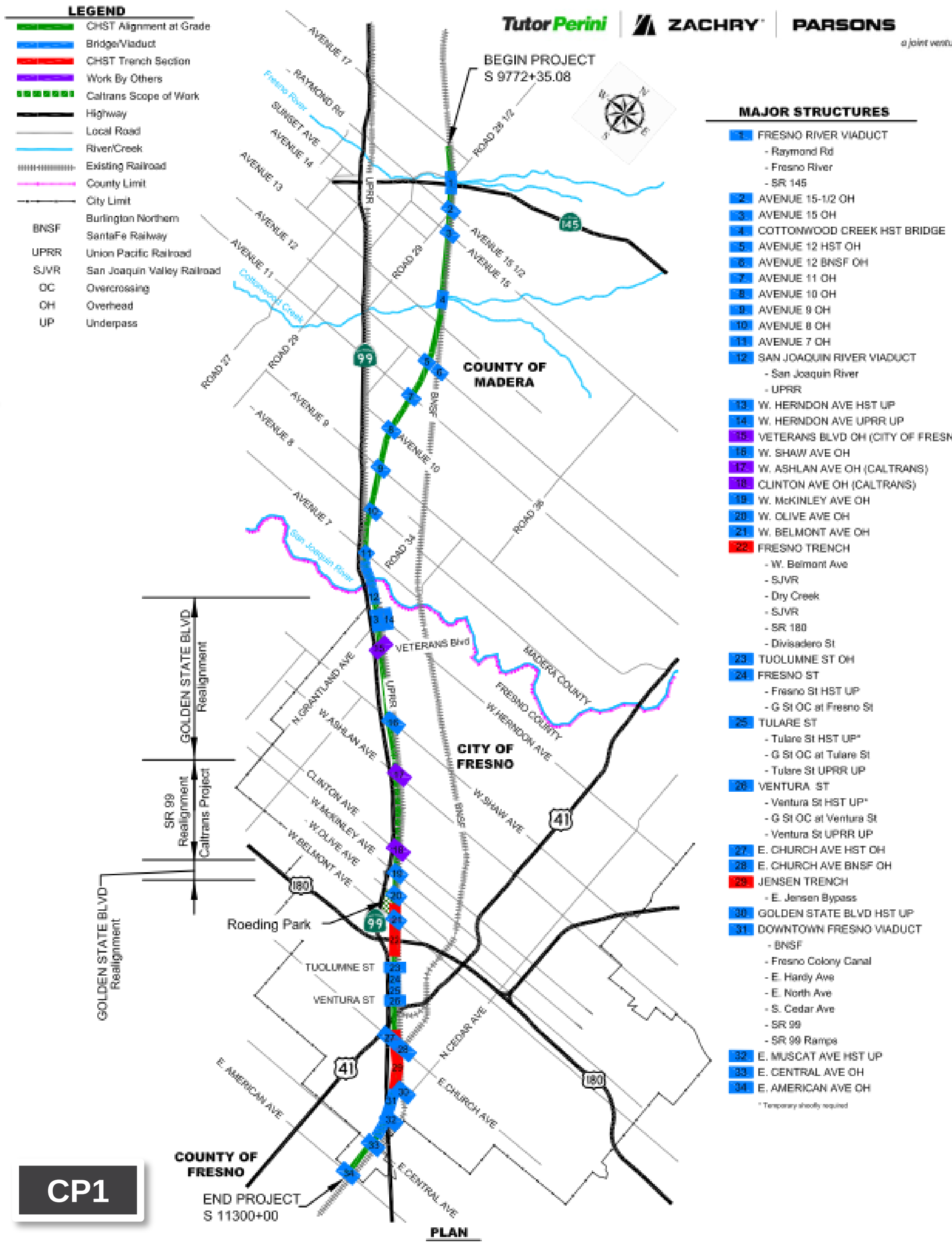
Part 3 – Execution: Describes the methods of installation and how to measure quality or effectiveness. **Big-Dig**: Would have identified the **inspections and tests** to be performed, including the bold load tests.



Case Study Project

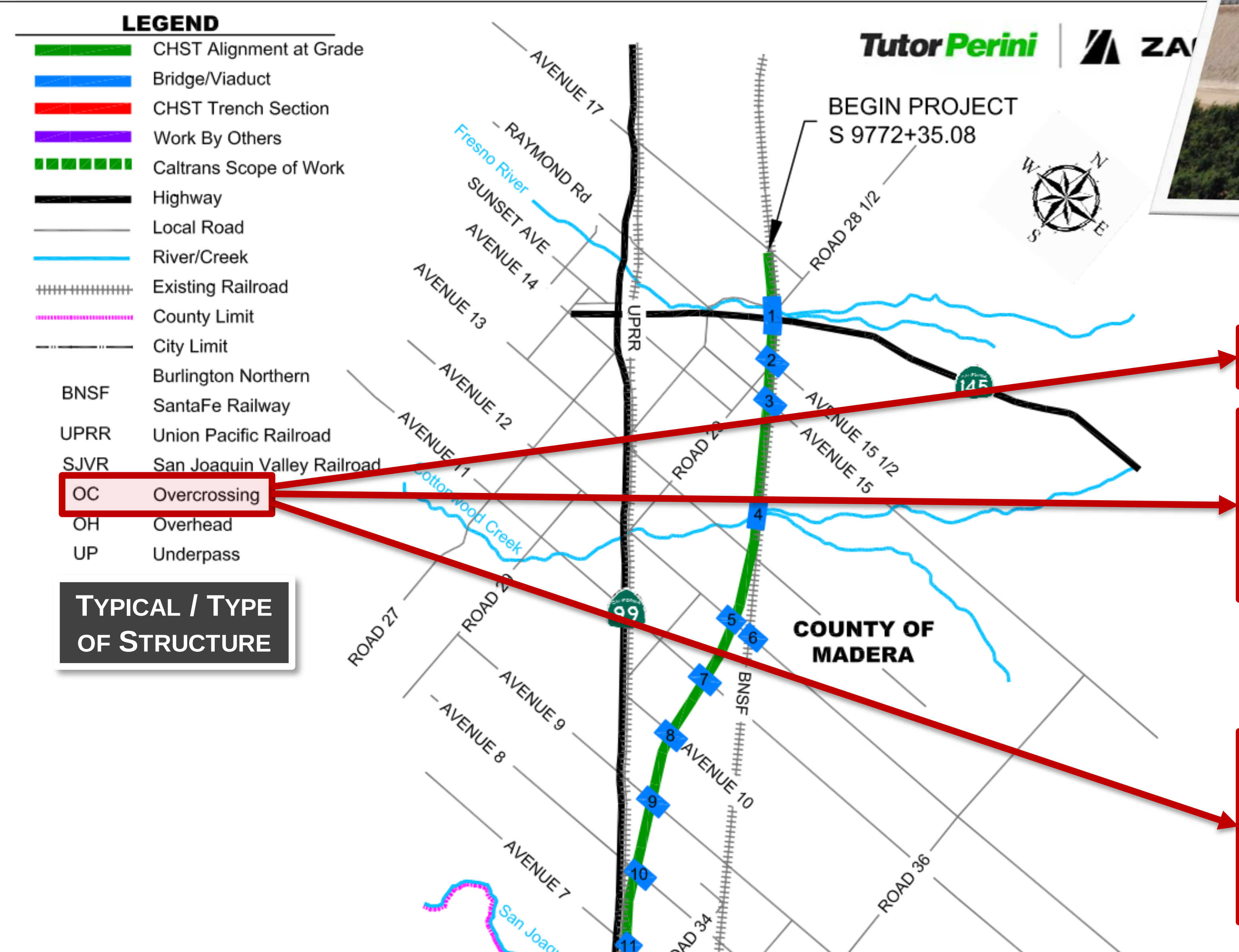
California High-Speed Rail System





Case Study Project

California High-Speed Rail System (Cont'd)



Typical / Type of Structure

Ave 10 Overhead

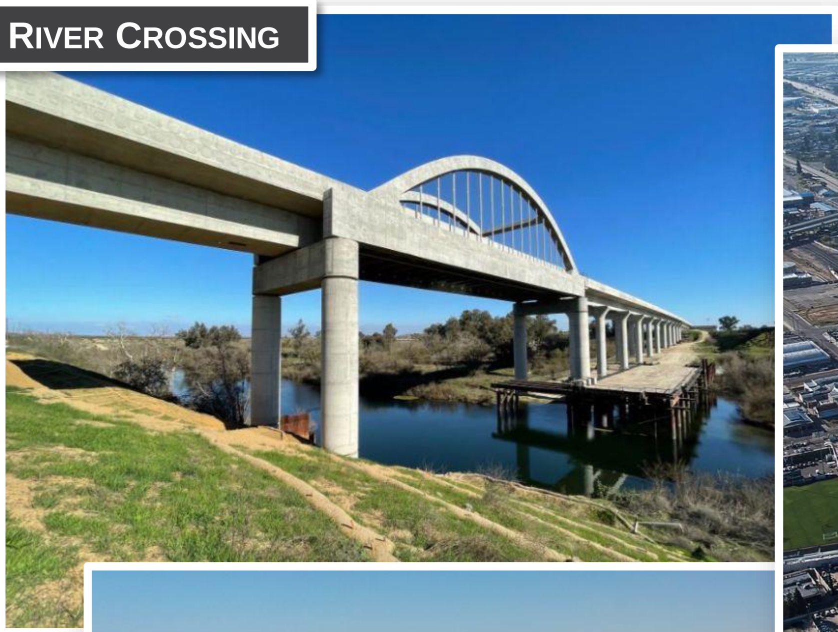
1. FRESNO RIVER VIADUCT
   - Raymond Rd
   - Fresno River
   - SR 145
2. AVENUE 15-1/2 OH
3. AVENUE 15 OH
4. COTTONWOOD CREEK HST BRIDGE
5. AVENUE 12 HST OH
6. AVENUE 12 BNSF OH
7. AVENUE 11 OH
8. AVENUE 10 OH
9. AVENUE 9 OH
10. AVENUE 8 OH
11. AVENUE 7 OH
12. SAN JOAQUIN RIVER VIADUCT
    - San Joaquin 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

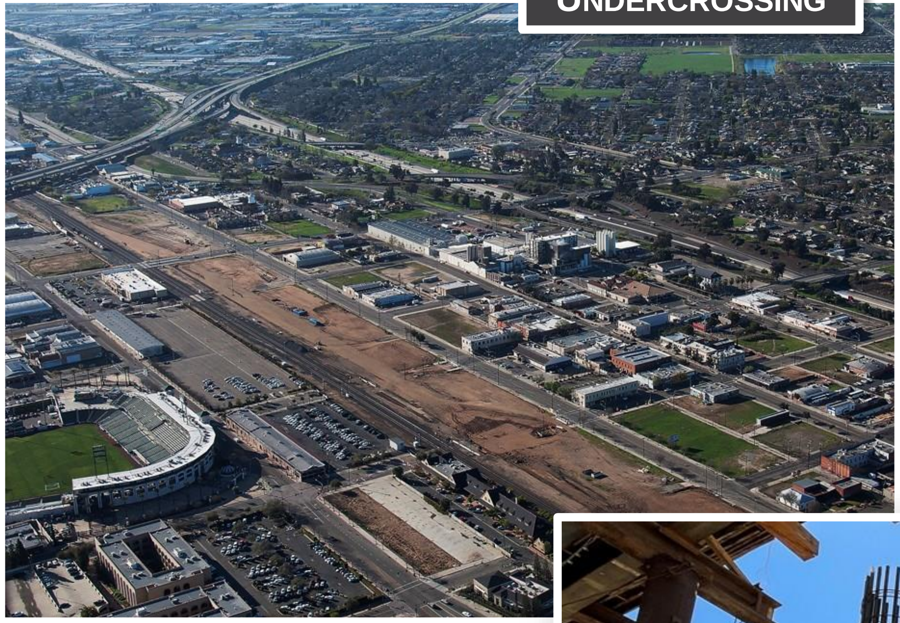
Case Study Project

California High-Speed Rail System (Cont'd)

River Crossing



Undercrossing



Trench

Viaducts

225+ Major Structures
(Quality Milestones)

PROGRESS

- **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

Design – Build Delivery Method	Planning	Preliminary Engineering	Acquirer / Owner	Final Design	Construction	Operations & Maintenance	Supplier / Design–Build Firm

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 ...

1.3 DEFINITIONS

A. The word "concrete" ... indicates normal w... strength of 3,000 psi ... 145 pounds per cubi...

B. The term "lightweig... unit weight of 115 p...

CALIFORNIA HIGH-SPEED TRAIN PROJECT - CONSTRUCTION SPECIFICATIONS

Agreement No: HSR13-06

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.

B. Methods of Sampling and Testing:

Concrete Sampling

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 all compression test cylinders. Refer to Article titled Environmental Requirements herein for hot and cold weather remedial requirements.

Concrete Strength Test

5. 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 ...

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.

Project Name: STR07 ITR3803 MTA Project No.: G17201.01 Page 1 of 1 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

MOORE TWINING ASSOCIATES, INC.

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

Report Of: 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

Report Date: 03/23/2018

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

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

Cylinder Marked Set	Cylinder Marked Nbr	Age Tested (date : days)	Diameter (in)	Area (in²)	Maximum Load (lbs)	Break Type	Cure Loc	Compressive Strength (PSI)	Average Strength (PSI)
1	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 f'c. The strength may not achieve the 28day f'c.									
1	2	03/23/18 : 28	6.00	28.274	131,820	Type 2	Lab	4,660	

Typical Industry Approach to Construction Specs

Construction Quality Management and Procedures

Spec: 03 05 15 – Portland Cement Concrete – QA/QC Requirements

1.7 QUALITY ASSURANCE/CONTROL

...

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.

Construction Quality Procedures (CQP)

CQP No.	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

CQP B1.9 Excerpt: Inspection & Testing

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 Contrac... ...M template is provided (see Form CQP B1.9FB).
- Works subject to the requirements o... ...nated 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.

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

Construction Quality Forms (CQF)

Typical Industry Approach to Construction Specs

Construction Quality Forms

SECTION 03 05 15

PORTLAND CEMENT CONCRETE

PART 1 - GENERAL

1.6 SUBMITTALS

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

B. Product Data: Submit manufacturer's product data for propose

C. Aggregate Source: Submit aggregate source.

PART 2 - PRODUCTS

2.3 MIX DESIGNS

A. Selection of mix proportions shall conform to the applicab
ACI 211.2. Concrete shall comply with ACI 301 and ACI 3
designs will produce concrete suited for proper placement
mixes shall include recommended amounts of admixture and

B. Mix design for subway structures and below-grade retaining
shall include 15 percent replacement of the cement with
admixture conforming to ASTM C1017, to provide a den
shrinkage and permeability characteristics.

C. Mix design for architectural concrete and formed concrete th
the finished work 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

CQP B1.9 Form D: Concrete Placement Checklist (Pour Card)

CONCRETE PLACEMENT CHECKLIST (POUR CARD)

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

Contractor:		Date:	
Milestone:		Structure Type:	
Proejct 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 verifed.						
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

Typical Industry Approach to Construction Specs

Inspection & Testing Plans (ITP)

SECTION 03 05 15

PORTLAND CEMENT CONCRETE

PART 3 - EXECUTION

Inspection & Testing

3.1 FIELD QUALITY CONTROL

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 truc
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.

Inspection & Test Plan (ITP) for Production Dilled Concrete Shaft

4.2.1 Concrete Sampling and Testing

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

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:

Location: Ave 11 OH MADERA COUNTY Weather:

Description of Work and Location: STR 07 ITR 2229 COMPACT
STR 07 ITR 2344 CONC. S

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

CATEGORY	#	HOURS	CATEGORY	#	Hours	CATEGO
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 SIZE, mm	AGG 1: GRADING	AGG 2: GRADING	AGG 3: GRADING	COARSE GRADING	COMBINED 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

RECT 1-8, 1-10, 1-12 TLM

CONCRETE TICKET

CUSTOMER ID	P.O. NUMBER / JOB NUMBER	TICKET NUMBER	DATE
RECNO INC.		28194	2016-03-07

DELIVER TO: TUOLUMNE ST. & "G" ST FRESNO

DIRECTIONS: 99 SOUTH TO FRESNO ST. LEFT TO "F" ST. LEFT TO MERCERD ST. RIGHT TO "H" ST. LEFT TO JOB

TIME DUE	TIME BATCHED	TIME ARRIVE	TIME START	FINISH POUR	REV. COUNT
11:44	10:49 AM	11:40	11:52	12:26	127

PLANT NO.	TRUCK	DRIVER	SLUMP	AIR	WEIGHING LOCATION
	67		9.00 "	2.0	Friant

QUANTITY THIS LOAD	QUANTITY ORDERED	QUANTITY DELIVERED	PRODUCT CODE	PRODUCT DESCRIPTION	UNITS OF MEASURE	UNIT PRICE	EXTENDED PRICE
9.50	57.00	19.00	40HSRWHFA	DRILLED SHAFTS WET HO	YARD		
9.50			40HSRWH	HSR WET HOLE MIX		0.00	0.00
9.50			ZONE	ZONE DELIVERY CHARGE		0.00	0.00

Concrete Truck Log

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

CONCRETE TRUCK LOG

Milestone: TLM
ACTIVITY NO.
SPEC SECTION: 030315
LOCATION: TOULUMNE
BATCH PLANT: [redacted]
INSPECTOR: [redacted]

ACTIVITY DESCRIPTION: ABUTMENT #1-8, 1-10, 1-12

MIX NO: 40HSRWHFA
TECHNICIAN: [redacted]

THEORETICAL CONCRETE VOLUME: 55 Tim Logan=Batch operator
DATE: 3-7-16
CONCRETE CO: [redacted]
SLUMP: >7"
AIR: <4%

Top of GMP 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	0	50	20	Y	59	9	133	CYLINDERS TAKEN
2	28194	67	9.5	19	1049	1226	1140	87	0						127	LARGE CLUMPS (A FEW)
3	28195	88	9.5	28.5	1117	1250	1205	92	0		5				126	
4	28196	73	9.5	38	1142	130	1230	108	0						120	
5	28197	70	9.5	47.5	109	224	209	73	0						120	SMALL CLUMPS (A FEW)
6	28198	66	6.5	54.0	130	249	219	79	0						122	SMALL CLUMPS (A FEW) 3.0 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)
...DRILLED CONCRETE SHAFT

Tuolumne Abutment Shaft 1-7
Tues 3-8-16

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 Verified	Initials	Date	N/A	TPZP QC Verified /Accepted	Initials	Date	N/A	RVTM #	Comments
Pre-Placement Concrete											
1	Concrete mix design approved?	✓	CZ	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.	✓	CZ	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://[redacted]egnyte.com/Sim 20QA_QC_NCRs/7.01%20-%20Mil 20OH/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://[redacted]egnyte.com/Sim 20QA_QC_NCRs/7.01%20-%20Mil 20OH/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://[redacted]egnyte.com/Sim 20QA_QC_NCRs/7.01%20-%20Mil 20OH/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://[redacted]egnyte.com/Sim 20QA_QC_NCRs/7.01%20-%20Mil 20OH/8.0%20Quality/8.1%20Cons

References & Traces to Objective Evidence (Quality Records)

Requirements Verification Traceability Matrix (RVTM)

PROGRESS

- 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

General Provisions
234 Pages, 1,334 *Shall* Statements

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

CONSTRUCTION PACKAGE 1 (HSR 13-06)

...D 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
- ...3 - Pt A - Subpart 1 – Basis of Design
- ...3 - Pt A - Subpart 2 – Organizational Conflict of Interest Policy
- ...3 - Pt A - Subpart 3 – Revised Small and Disadvantaged Business Enterprise Program
- ...3 - 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
- ... t B - Subpart 6 – Safety and Security Management Plan
- ... t B - Subpart 7 – Aesthetic Guidelines for Non-Station Structures
- ... t 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 Re... American Avenue
- B3 - Pt E - Subpart 5 – Geotechnical Baseline Re...

Environmental Documents

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02 22 00	EXISTING CONDITIONS ASSESSMENT
02 41 00	DEMOLITION

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31 38 13	REINFORCED SLOPES AND EARTH STRUCTURES
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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 su... 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 con...

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
	...	4000psi Concrete Mix Dsgn 63T1G01C	INFO	000
	...	4000psi Concrete Mix Design 60T1G01	INFO	000
	...	Project Wide 5000 psi Concrete Mix	INFO	000
	...	Road 27 OH- 8500psi Concrete Mix	INFO	000
15362	...	OM 5000 psi 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 5000psi Concrete Mix Design	INFO	000
13729	...	UPRR 4000psi 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 psi Concrete Mix	INFO	000
11363	...	5000psi Concrete Mix Dsgn 60B1G03	INFO	000
10919	...	6000psi Concrete Mix Design 60F1G12	INFO	000
10918	...	6000 psi Concrete Mix Design	INFO	000
10917	...	4000 PSI Concrete Mix 40F1G03	INFO	000
10916	...	5000psi 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/Sim 20QA_QC_NCRs/7.01%20-%20Mil 20OH/8.0%20Quality/8.1%20Cons

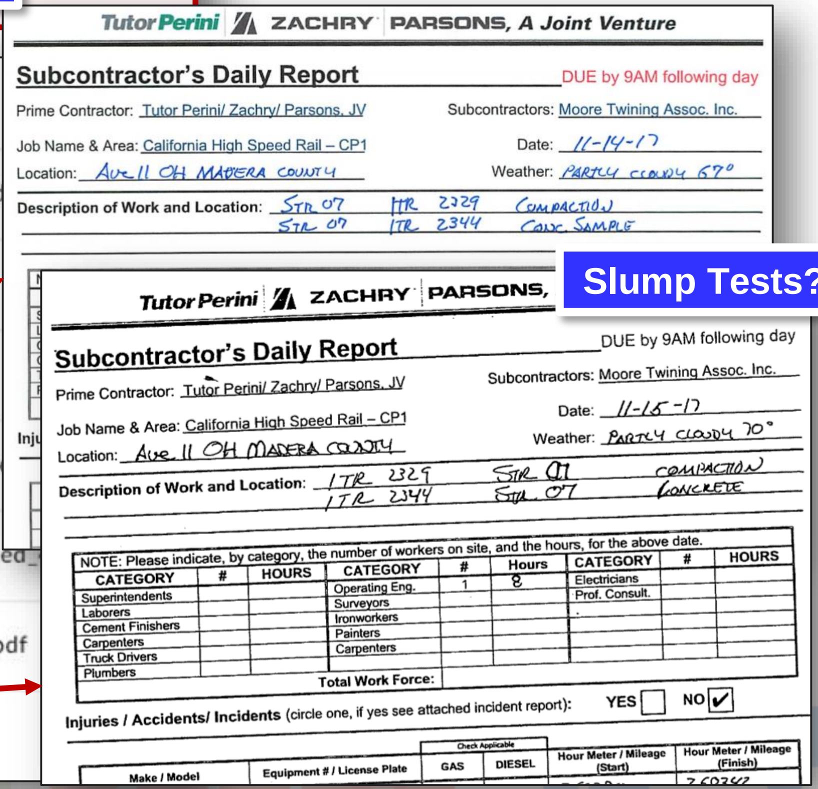
Objective Evidence

Quality Milestone Data Pack (QMDP)

- 1.0 Executive Summary
- 2.0 Environmental Compliance
- 3.0 Verification, Validation, and Self Certificatio
- 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

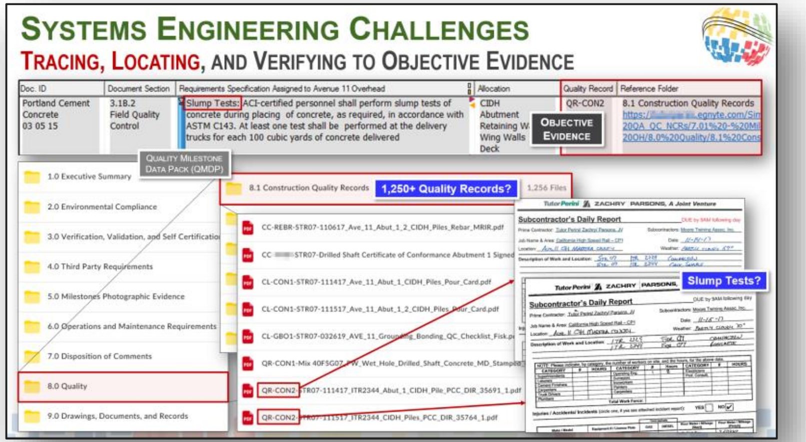
- CC-REBR-STR07-110617_Ave_11_Abut_1_2_CIDH_Piles_Rebar_MRIR.pdf
- CC STR07-Drilled Shaft Certificate of Conformance Abutment 1 Signed
- CL-CON1-STR07-111417_Ave_11_Abut_1_CIDH_Piles_Pour_Card.pdf
- CL-CON1-STR07-111517_Ave_11_Abut_1_2_CIDH_Piles_Pour_Card.pdf
- CL-GBO1-STR07-032619_AVE_11_Grounding_Bonding_QC_Checklist_Fisk.p
- 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

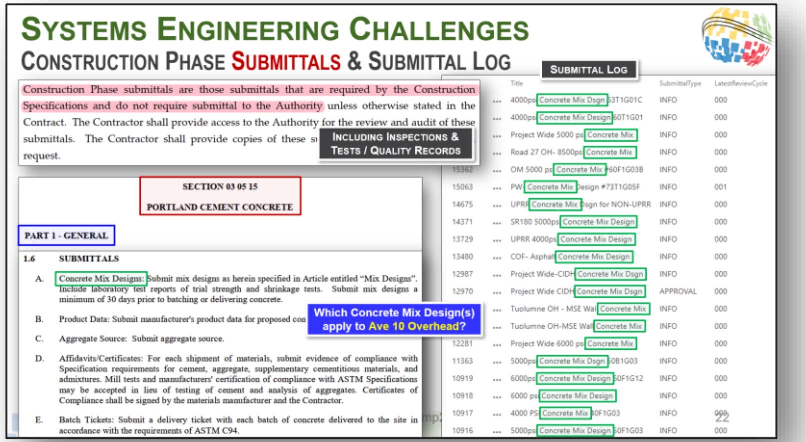


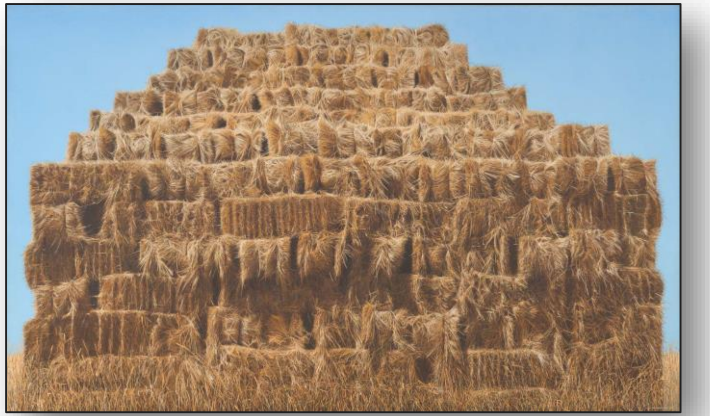
Slump Tests?

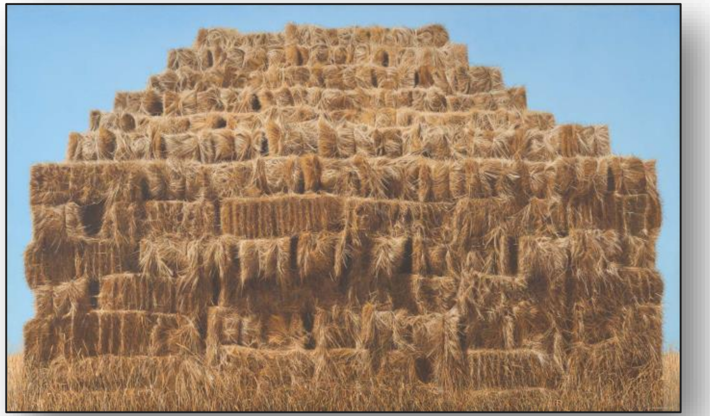
Systems Engineering Challenges

Summary









Requirements **Traceability** **Objective Evidence**

PROGRESS

- ❖ **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

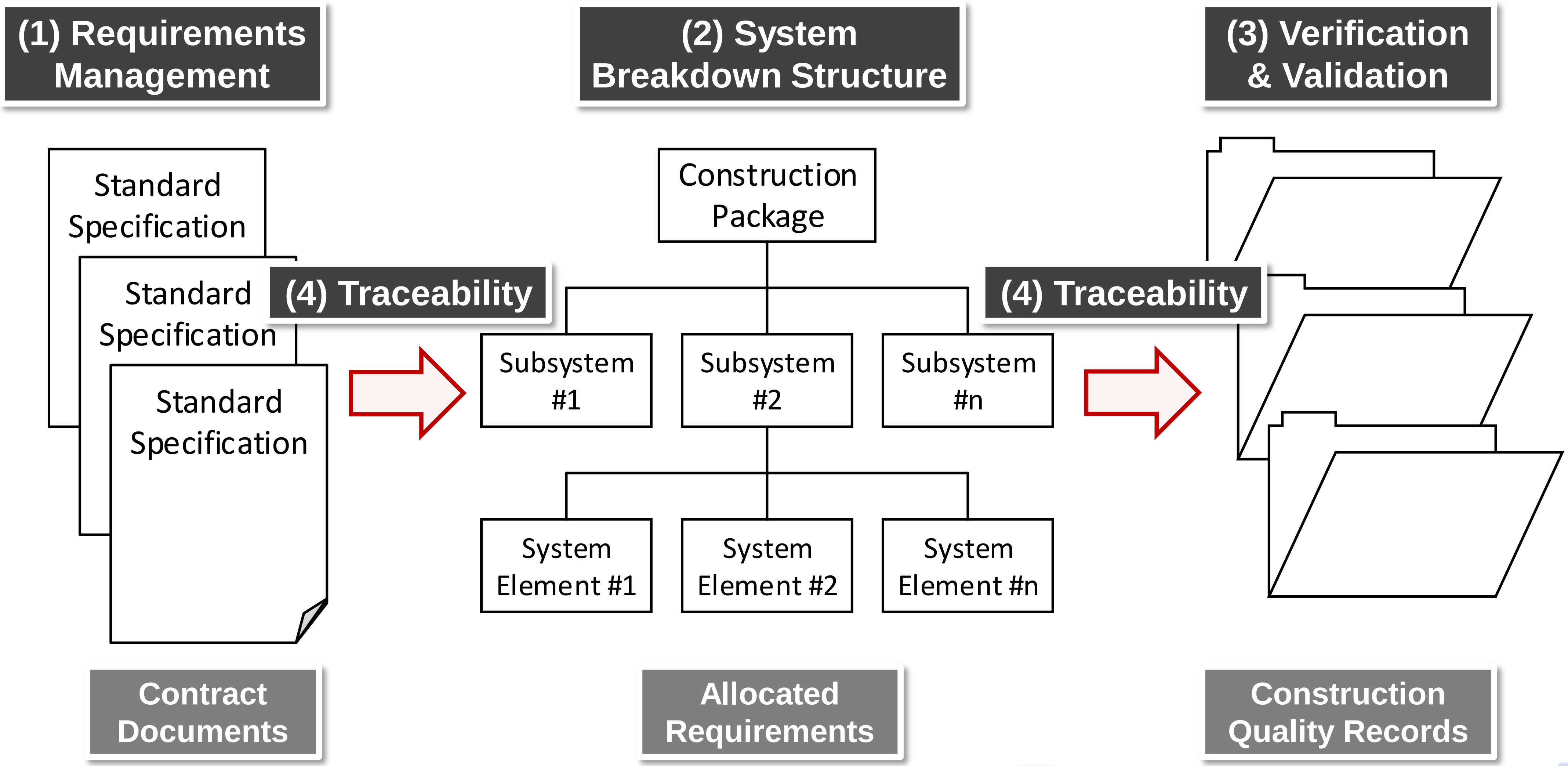
Systems Engineering Objectives

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

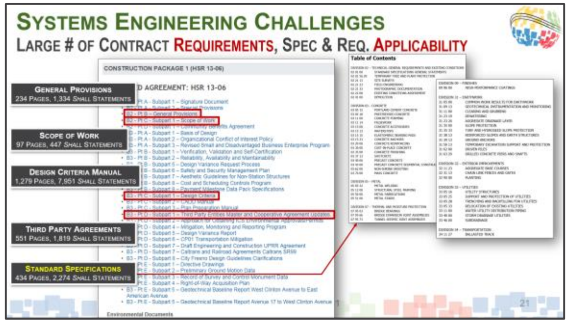


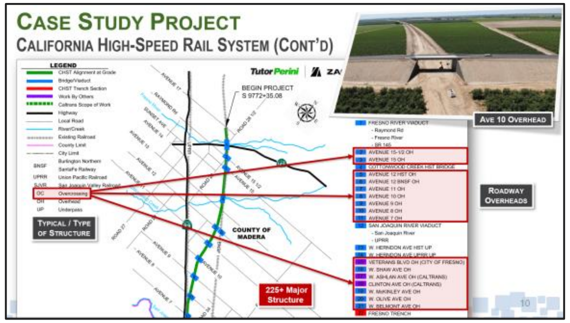
PROGRESS

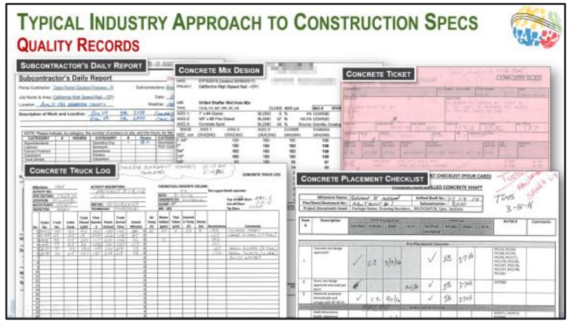
- Problem Statement & Offered Solution
- Background & Introduction
- Systems Engineering Challenges Faced
- Systems Engineering Objectives
- **Systems Engineering Activities Performed**
  1. Requirements Management
  2. System Breakdown Structure
  3. Verification and Validation
  4. Traceability
- Summary,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

Systems Engineering Activities Performed

Step 1: Requirements Management – Req. Mgmt. Database Model



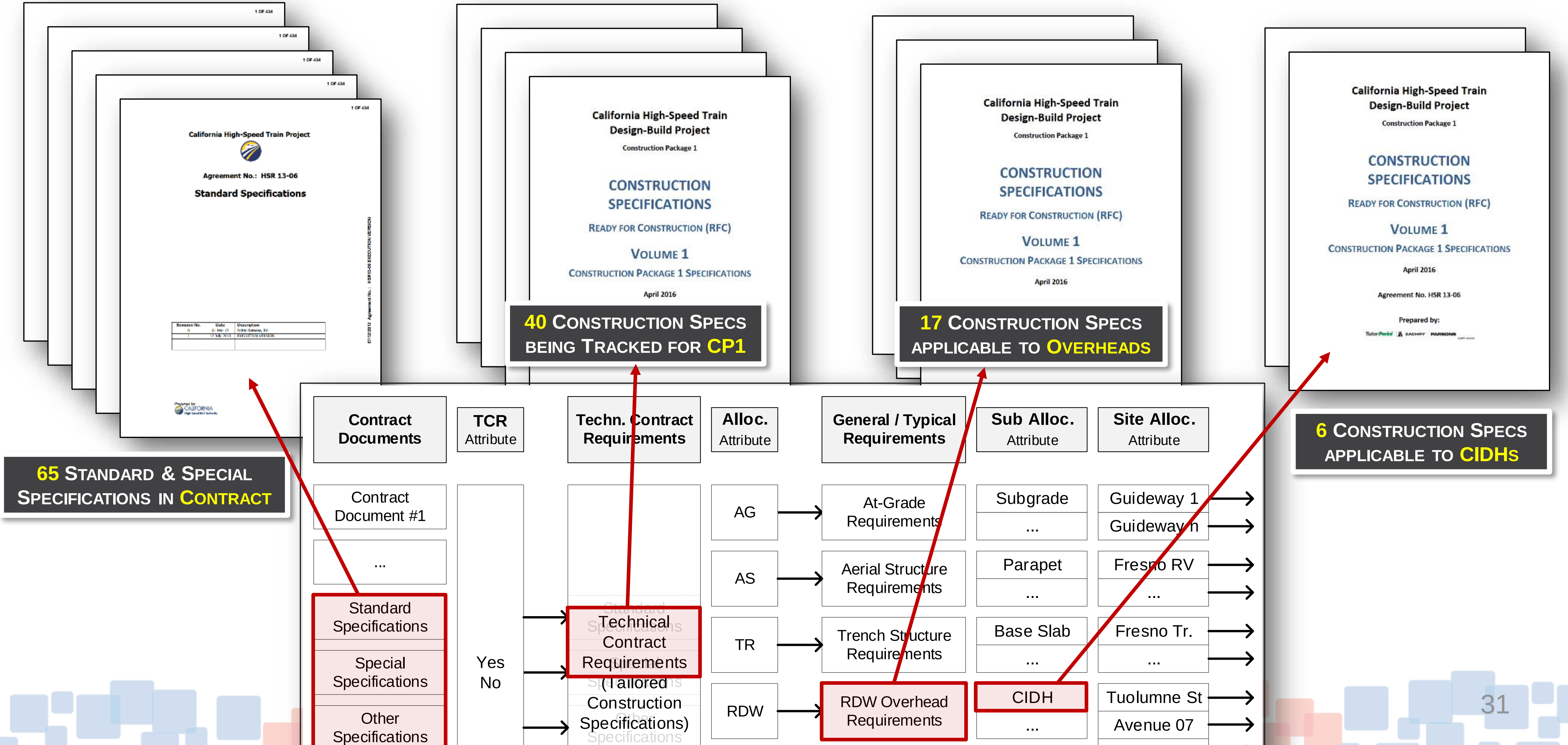




Contract Documents	**TCR** Attribute	**Techn. Contract Requirements**	**Alloc.** Attribute	**General / Typical Requirements**	**Sub Alloc.** Attribute	**Site Alloc.** Attribute	**Site/Submittal Specific Req.** (RVTM)	**Objective Evidence**
Contract Document #1	Yes No	Technical Contract Requirements (Tailored Construction Specifications)	AG	At-Grade Requirements	Subgrade	Guideway 1	Guideway 1	Quality Records contained in QMDP Folders
					...	Guideway n	Guideway n	
...			AS	Aerial Structure Requirements	Parapet	Fresno RV	Fresno R. Viaduct	
					...	...	...	
Standard Specifications			TR	Trench Structure Requirements	Base Slab	Fresno Tr.	Fresno Trench	
Special Specifications					...	...	...	
Other Specifications			RDW	RDW Overhead Requirements	CIDH	Tuolumne St	Tuolumne St OH	
...					...	Avenue 07	Avenue 07 OH	
						Avenue 10	Avenue 10 OH	
						...	...	
Contract Document #n			...	...	...	...	...	
					...	...	...	

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

Prepared by:

CP1 Inspection & Test Plan

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 m
Construction Specifications.

- CHSTP Standard Specifications, Executed Version, Rev
- General Provisions, Executed Version, Rev 7 – July 30,
- Scope of Work, Executed Version, Rev 9 – July 31, 2013
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- 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 herei
Include laboratory test reports of trial strength and sh
minimum of 30 days prior to batching or delivering co

2 PRODUCTS

2.1 MATERIALS

A. Portland Cement: ASTM C150, Type II, low alkali. T
where high early strength concrete is a requirement a

3 EXECUTION

3.1 FIELD QUALITY CONTROL

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

5. Strength Tests:
a. Prepare, cast, and deliver to the same indepe
laboratory-cured compression test samples. Cyl
accordance with ASTM C31. Cylinders shall be t
C39.
b. The minimum number of test cylinders to be
each placement shall be four cylinders for each
additional sets of test cylinders are required bey
tests, each set shall consist of a minimum of tw
c. All cylinders in a set shall be marked with a u
number on the record of concrete placed. All cy
independent testing laboratory.
d. From each set of cylinders cast, one cylinder
at 28 days in accordance with ASTM C39. If the
cylinder shall be discarded.
tests are below the s
the fourth cylinder at
enefit: Tests required
's benefit, shall be pe
ntrol program.

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-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_an
- 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

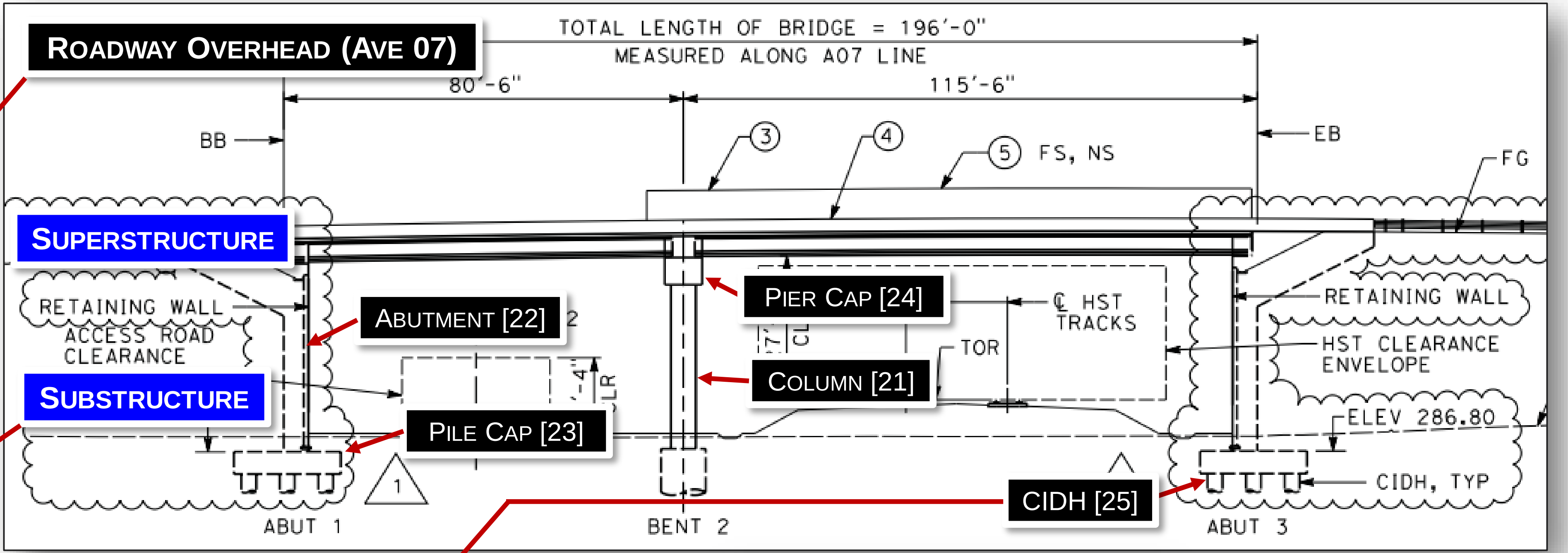
Corresponding "Test Cases" (Expected Objective Evidence)

Systems Engineering Activities Performed

Step 2: System Breakdown Structure (SBS)

Types

- 10_At-Grade
- 20_Aerial_Structure
- 30_Trench
- 40_Roadway_Overhead



Elements

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

Lowest Level Replacement Units (LLRU)

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

Construction Specifications

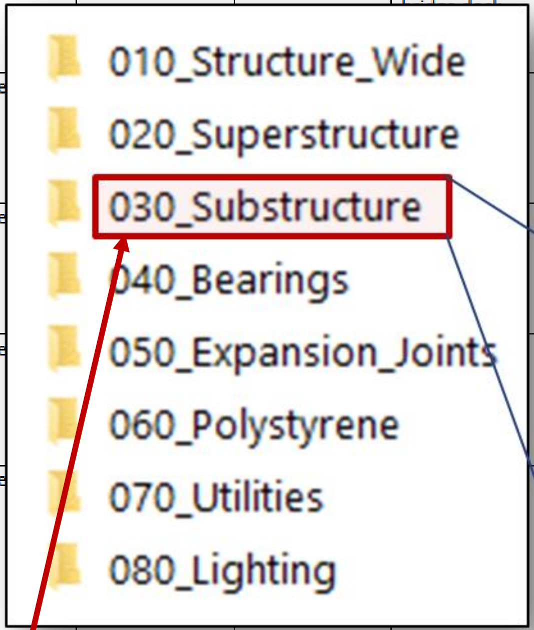
- 03_05_15-PCC
- 03_20_00-CR
- 03_30_00-CIP
- 03_35_00-CF
- 26_05_26-G&B
- 31_63_29-DCP&S

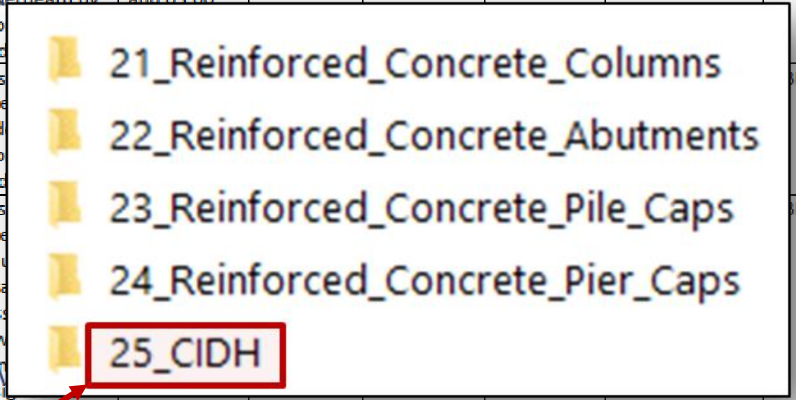
6 Construction Specs applicable to CIDHs

CP1 RAM Allocation Report (RAR)

Table 1 - RAM Allocation Matrix

		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	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 boo lado	Between 12:01 am and 05:00	Less than 5 hours	Structures	TBD	TBD	TBD
22	RAM 22	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure				This acce und boo lado						
23	RAM 23	Site Work	Structures	Grade Separations (HST overpass and underpass)		Substructure				This acce is bu Exca poss how ele desi "capacity protected" to mitigate accessibility needs.						
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





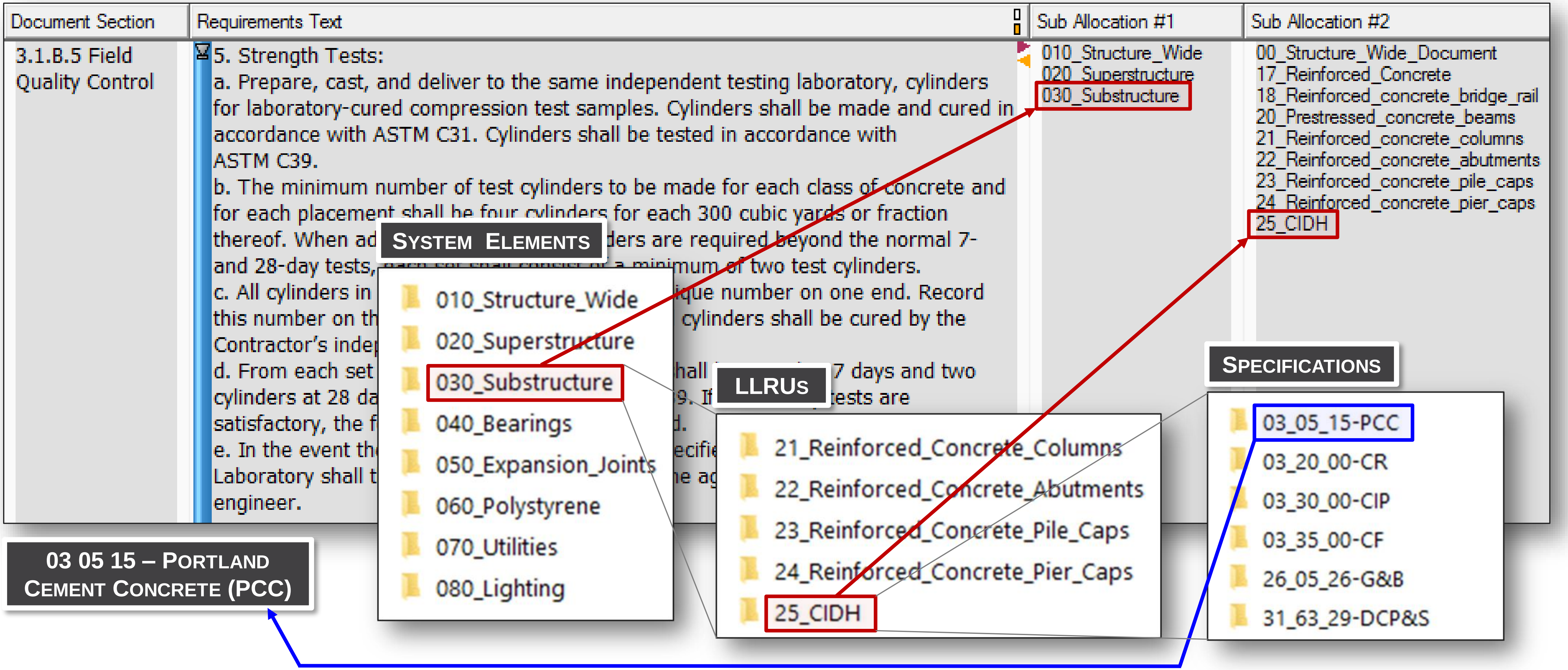
RAM ID

Element

LLRU

Systems Engineering Activities Performed

Step 2: Using SBS for Requirements Allocation



Systems Engineering Activities Performed

Step 2: Using SBS for QMDP Folder Structure

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

Element / **LLRU**

- 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_Utilities
  - 080_Lighting

Portland Cement Concrete Specification

Corresponding "Test Cases" (Expected Objective Evidence)

- 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
- 1_MAT-B-Aggregates.pdf
- 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

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
Include laboratory test reports of trial strength and shrinkage tests. Submit mix designs
minimum of 30 days prior to batching

2 PRODUCTS

2.1 MATERIALS

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

3 EXECUTION

3.1 FIELD QUALITY CONTROL

B. Methods of Sampling and Testing:
1. Sampling: Representative composit
Each sample shall be obtained from a

5. Strength Tests:
a. Prepare, cast, and deliver to t
laboratory-cured compression te
accordance with ASTM C31. Cyli
C39.
b. The minimum number of test
each placement shall be four cyl
additional sets of test cylinders a
tests, each set shall consist of a
c. All cylinders in a set shall be n
number on the record of concret
independent testing laboratory.
d. From each set of cylinders cas
at 28 days in accordance with AS
cylinder shall be discarded.
e. In the event the 28-day tests a
Laboratory shall then test the fo

Contractor's Benefi
he Contractor's be
r's quality control

- 8.0 Quality
  - 8.1 Construction Quality Records
    - 010_Structure_Wide
    - 020_Superstructure
    - 030_Substructure
      - 21_Reinforced_Concrete_Columns
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        - 03_30_00-CIP
        - 03_35_00-CF
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    - 040_Bearings
    - 050_Expansion_Joints
    - 060_Polystyrene
    - 070_Utilities

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- 1.7_QAC-E-Cement_and_Aggregates.pdf
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- 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_Cementit
- 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
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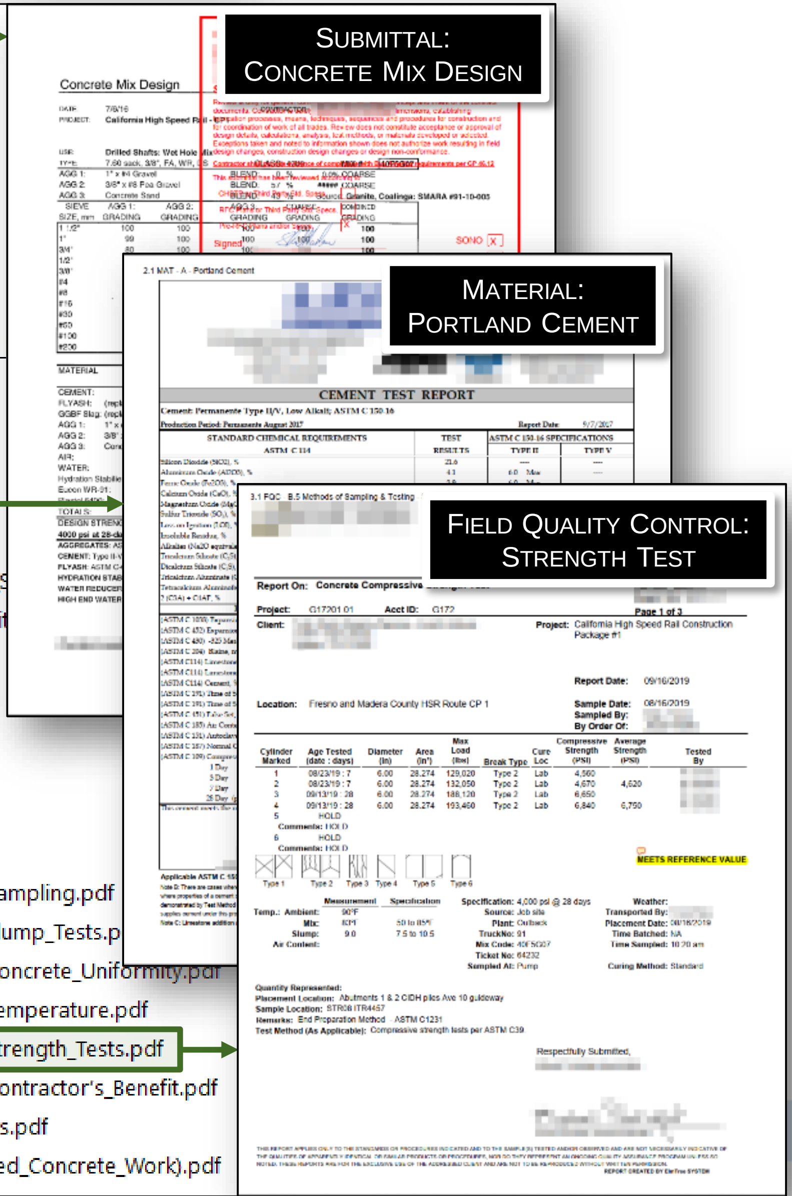
- 3.1_FQC-B.1_Methods_of_Sampling&Testing-Sampling.pdf
- 3.1_FQC-B.2_Methods_of_Sampling&Testing-Slump_Tests.p
- 3.1_FQC-B.3_Methods_of_Sampling&Testing-Concrete_Uniformity.pdf
- 3.1_FQC-B.4_Methods_of_Sampling&Testing-Temperature.pdf
- 3.1_FQC-B.5_Methods_of_Sampling&Testing-Strength_Tests.pdf
- 3.1_FQC-B.6_Methods_of_Sampling&Testing-Contractor's_Benefit.pdf
- 3.1_FQC-C-Evaluation_and_Acceptance_of_Tests.pdf
- 3.1_FQC-D-Acceptance_of_Structure_(Completed_Concrete_Work).pdf



03 05 15 – Portland Cement Concrete (PCC)

Corresponding "Test Cases" (Expected Objective Evidence)

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.

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.

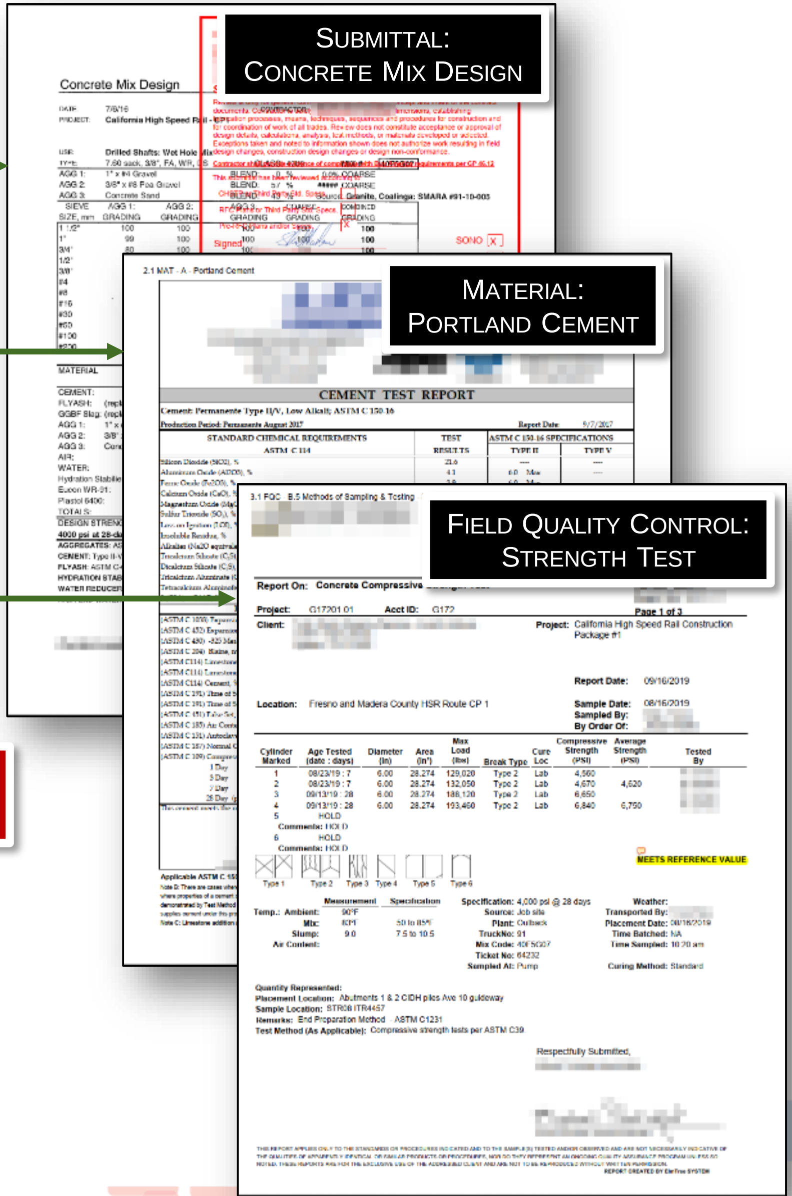
d. From each set of cylinders cast, one cylinder shall be tested at 7 days and two cylinders at 28 days in accordance with ASTM C39. If the 28-day tests are satisfactory, the fourth cylinder shall be discarded.

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

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

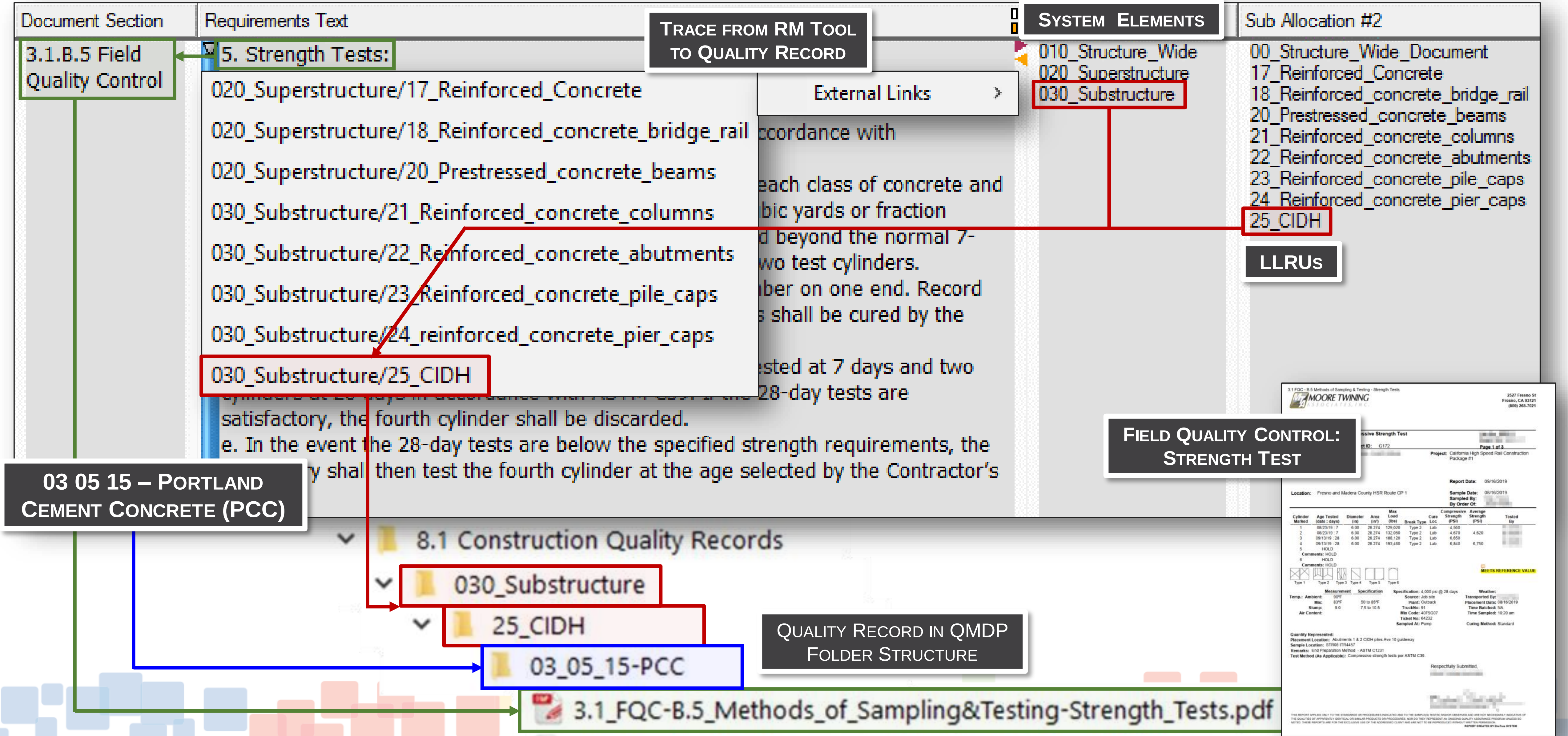
03 05 15 – Portland Cement Concrete (PCC)

Demonstration of Compliance



Systems Engineering Activities Performed

Step 4: Traceability – Using Req. Mgmt. Tool (Automated Tracing)



Systems Engineering Activities Performed

Step 4: Traceability – Inherent Traceability (w/o RM Tool)

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
Include laboratory test reports of trial strength and shrinkage tests. Submit mix designs
minimum of 30 days prior to batching

2 PRODUCTS

2.1 MATERIALS

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

3 EXECUTION

3.1 FIELD QUALITY CONTROL

B. Methods of Sampling and Testing:
1. Sampling: Representative composite
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5. Strength Tests:
a. Prepare, cast, and deliver to t
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b. The minimum number of test
each placement shall be four cyl
additional sets of test cylinders a
tests, each set shall consist of a
c. All cylinders in a set shall be n
number on the record of concret
independent testing laboratory.
d. From each set of cylinders cas
at 28 days in accordance with AS
cylinder shall be discarded.
e. In the event the 28-day tests a
Laboratory shall then test the fo

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

03 05 15 – Portland Cement Concrete (PCC)

- 8.0 Quality
  - 8.1 Construction Quality Records
    - 010_Structure_Wide
    - 020_Superstructure
    - 030_Substructure
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      - 22_Reinforced_Concrete_Abutmen
      - 23_Reinforced_Concrete_Pile_Caps
      - 24_Reinforced_Concrete_Pier_Caps
      - 25_CIDH
        - 03_05_15-PCC
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        - 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_Utilities
    - 080_Lighting

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- 1.7_QAC-C-Mix_Designs.pdf
- 1.7_QAC-D-Contractor's_Quality_Management_
- 1.7_QAC-E-Cement_and_Aggregates.pdf
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- 1.8_ENV-B-Cold_Weather_Concreting.pdf
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- 2.1_MAT-D-Concrete_Admixtures_and_Cementit
- 2.1_MAT-E-Water.pdf
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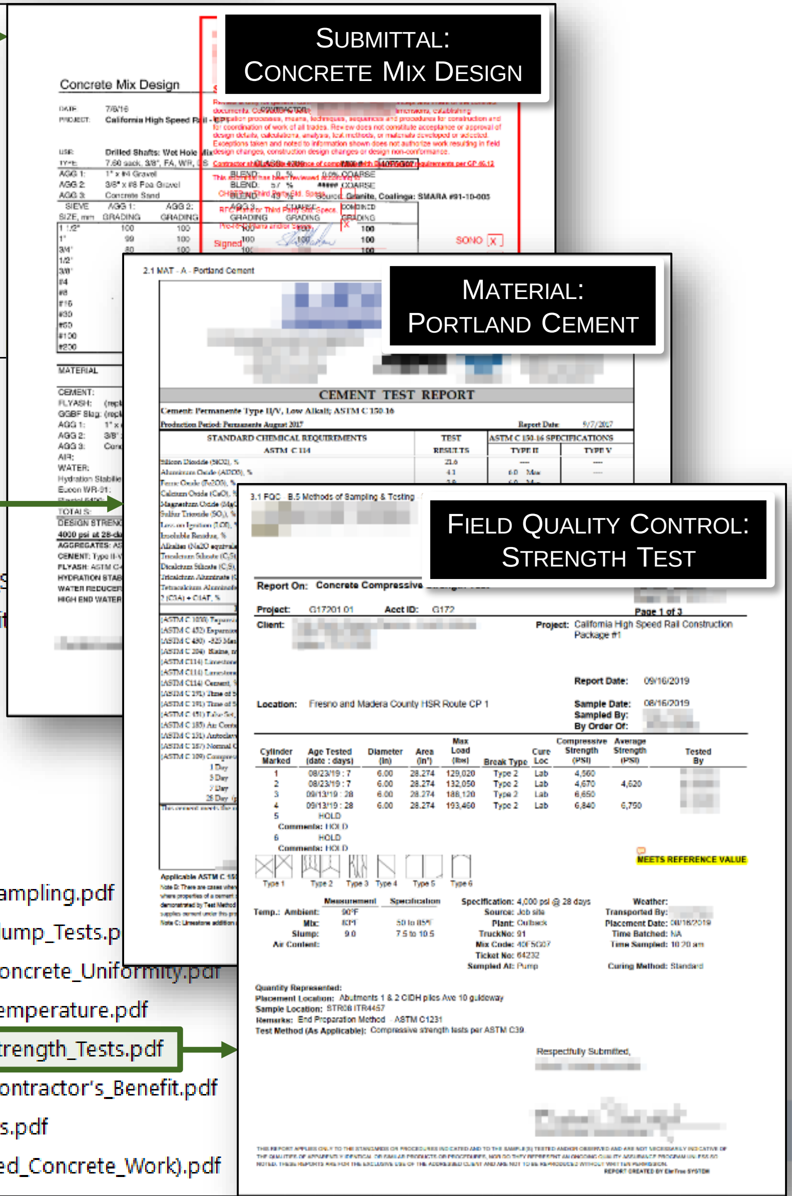
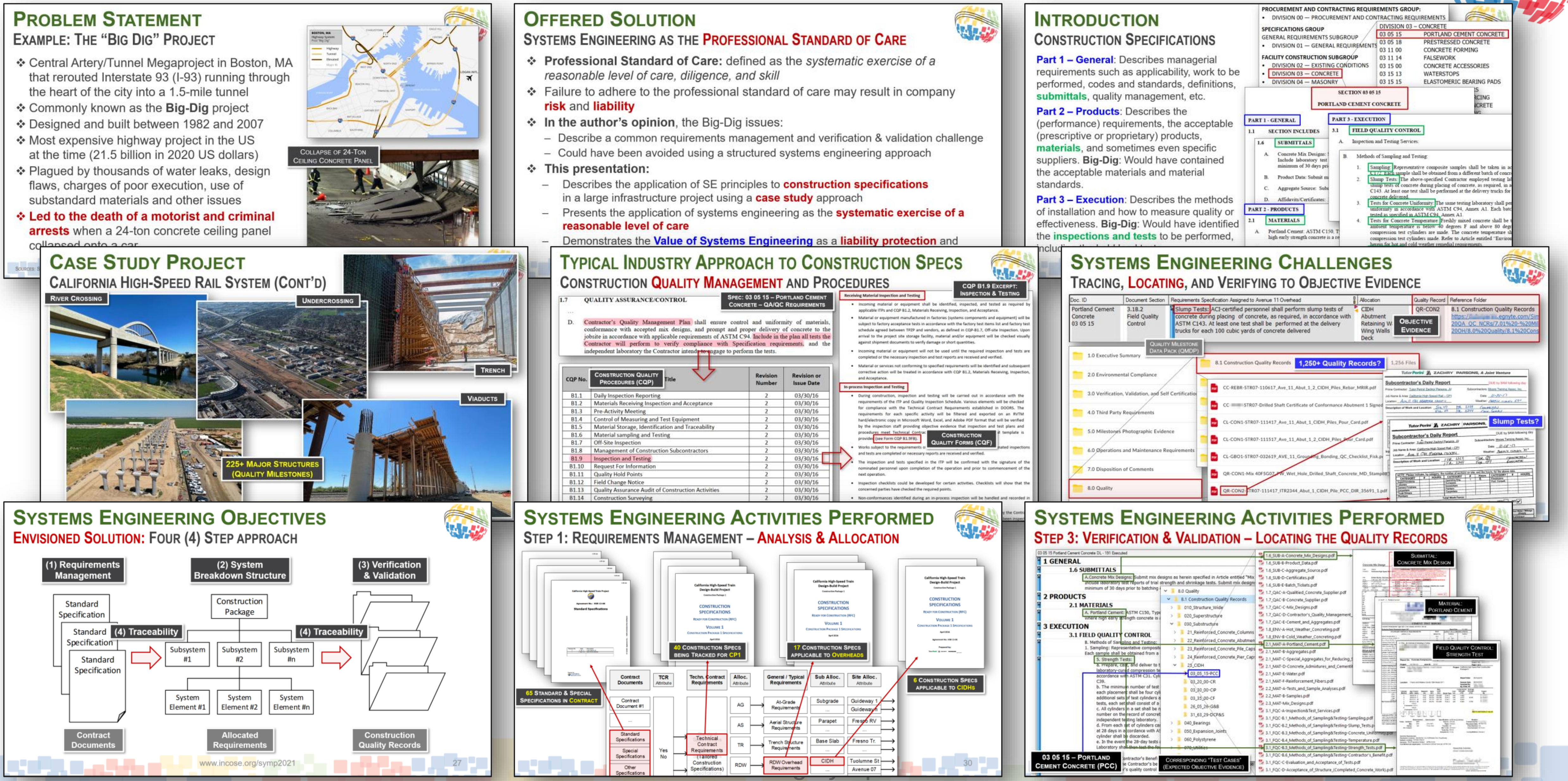
- 3.1_FQC-B.5_Methods_of_Sampling&Testing-Strength_Tests.pdf
- 3.1_FQC-B.6_Methods_of_Sampling&Testing-Contractor's_Benefit.pdf
- 3.1_FQC-C-Evaluation_and_Acceptance_of_Tests.pdf
- 3.1_FQC-D-Acceptance_of_Structure_(Completed_Concrete_Work).pdf



PROGRESS

- 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
COLLAPSE OF 24-TON CEILING CONCRETE PANEL
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
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, includ
CASE STUDY PROJECT
CALIFORNIA HIGH-SPEED RAIL SYSTEM (CONT'D)
RIVER CROSSING
UNDERCROSSING
TRENCH
VIADUCTS
225+ MAJOR STRUCTURES (QUALITY MILESTONES)
TYPICAL INDUSTRY APPROACH TO CONSTRUCTION SPECS
CONSTRUCTION QUALITY MANAGEMENT AND PROCEDURES
SPEC: 03 05 15 – PORTLAND CEMENT CONCRETE – QA/QC REQUIREMENTS
CQP B1.9 EXCERPT: INSPECTION & TESTING
CONSTRUCTION QUALITY PROCEDURES (CQP)
CONSTRUCTION QUALITY FORMS (CQF)
SYSTEMS ENGINEERING CHALLENGES
TRACING, LOCATING, AND VERIFYING TO OBJECTIVE EVIDENCE
QUALITY MILESTONE DATA PACK (QMDP)
1,250+ Quality Records?
OBJECTIVE EVIDENCE
Slump Tests?
SYSTEMS ENGINEERING OBJECTIVES
ENVISIONED SOLUTION: FOUR (4) STEP APPROACH
(1) Requirements Management
(2) System Breakdown Structure
(3) Verification & Validation
(4) Traceability
(4) Traceability
Standard Specification
Construction Package
Subsystem #1
Subsystem #2
Subsystem #n
System Element #1
System Element #2
System Element #n
Contract Documents
Allocated Requirements
Construction Quality Records
www.incose.org/symp2021
27
SYSTEMS ENGINEERING ACTIVITIES PERFORMED
STEP 1: REQUIREMENTS MANAGEMENT – ANALYSIS & ALLOCATION
65 STANDARD & SPECIAL SPECIFICATIONS IN CONTRACT
40 CONSTRUCTION SPECS BEING TRACKED FOR CP1
17 CONSTRUCTION SPECS APPLICABLE TO OVERHEADS
6 CONSTRUCTION SPECS APPLICABLE TO CIDHS
30
SYSTEMS ENGINEERING ACTIVITIES PERFORMED
STEP 3: VERIFICATION & VALIDATION – LOCATING THE QUALITY RECORDS
SUBMITTAL: CONCRETE MIX DESIGN
MATERIAL: PORTLAND CEMENT
FIELD QUALITY CONTROL: STRENGTH TEST
03 05 15 – PORTLAND CEMENT CONCRETE (PCC)
CORRESPONDING "TEST CASES" (EXPECTED OBJECTIVE EVIDENCE)

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 Delivers 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**

31st Annual INCOSE international symposium

virtual event

July 17 - 22, 2021

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