3.7 Inadequate Testing

Description:

Construction projects require a quality assurance (QA) program that, among other things, involves the selection of test methods, establishing test criteria, testing the fresh concrete, testing the hardened concrete, statistical analysis of test results, and follow-up procedures.
Fresh concrete is tested for its workability (Slump test), temperature, and air content.
Hardened concrete is tested for its strength under compressive loading. The purposes of strength tests of concrete are to determine compliance with a strength specification and to measure the variability of concrete (ACI 214 provides a discussion of methods and analysis for strength tests of concrete).
It is necessary to establish the quality of the test program in order to be able to evaluate its results and conclusions.

Data to be collected and Analyzed:

1.Review project QA program
2.Review test procedures and results
3.Review analysis and reporting procedures
4.Analyze follow-up procedures (NCRs,...)
5.Analyze test program for compliance with industry standards.

Verified Refuting Evidence (see following discussion):

a.The established QA program was comprehensive and covered all critical testing areas.
b.Pour records show compliance with the parameters of the QA program.
c.Although some strength test results appear to be erroneous, the overall program meets industry standards for Good Control.
When errors are found in individual strength tests it is possible to make proper evaluation of the concrete strength by analyzing earlier or later tests from the same cylinder set. It is therefore believed that no under-strength concrete was placed as a result of inadequate testing.

Verified Supporting Evidence:

None

Conclusions:

Testing program was adequate and did not contribute to the delamination.

May identify additional perspective on this issue as RCA related efforts proceeds

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3.7 Inadequate Testing, (cont.)

Discussion:

a)Fresh concrete is subjected to a set of "acceptance" tests that determine whether it should be used or discarded. The test criteria and procedures were established in PTL's documents shown in FM 3.7 Exhibit 3 and specifications FM 3.7 Exhibit 2.

i. The Slump test is a practical test for workability that is also useful in determining if the concrete was modified or if it was mixed for extended period of time. Project specifications called for Slump of 4.5" at the pump and 4" at the discharge (FM 3.7 Exhibit 7). Analysis of pour records indicate that a strict inspection/testing process was followed and that multiple trucks were rejected when the allowed slump was exceeded. (Selected examples of reported tests and rejection handling in FM 3.7 Exhibit 4). A more complete discussion can be found in FM 2.3.

ii. Air content was measured using the pressure meter on selective trucks. The specifications called for air in the range of 3-6%. All tests fell in that range and no concrete was rejected because of air. (Selected examples of reported tests in FM 3.7 Exhibit 4)

iii. Ambient and concrete temperatures were recorded on selected loads. Trucks were rejected (or accepted after Engineer's approval) when concrete temperature exceeded 70 degrees. (specifications at FM 3.7 Exhibit 2; examples of reported tests in FM 3.7 Exhibit 4 and rejection handling in FM 3.7 Exhibit 5). A more complete discussion can be found in FM 2.5.

b)Hardened concrete was tested for compliance with design strength over time by crushing site-made cylinders after 7, 28, and 90 days.

i. Records of Statistical analysis of compressive tests as recommended by ACI 214 were not found from original construction time.

ii. Spot checks of random test results revealed problems with laboratory strength tests. An example in FM 3.7 Exhibit 6 reports test results from two adjacent samples taken on 2/16/73 from pour 712RB. Cylinder 2181 shows normal strength gain between 7 and 28 days (28%) and very small gain between 28 and 90 days (7%). Cylinder 2182 shows small strength gain between 7 and 28 days (7%) and very large gain between 28 and 90 days (37%). At 28 days cylinder 2181 was 28% stronger than cylinder 2182, whereas at 90 days the trend reversed and 2181 was 10% weaker than 2182. The most likely explanation is testing error at 28 days.
According to the pour tickets these two loads were practically identical and in full compliance with the mix design (FM 3.7 Exhibit 7).
There is no record of concern or corrective measures arising from these tests.

iii. A design analysis was performed on concrete placed in Class I structures in the year 2000 (for unrelated purpose). Part of the report is included in FM 3.7 Exhibit 8. Its significant conclusions, after analyzing strength test data from all concrete cylinders, was that the distribution followed the expected bell shape and the various mixes used on the project were statistically similar in strength properties.

3.7 Inadequate Testing, (cont.)

Discussion (cont.):

iv. Current analysis of all cylinders from 5000 psi concrete placed in the Reactor Building (RB) is included in FM 3.7 Exhibit 9. Besides providing a complete picture of the 28 days strength tests, it established that the test program met ACI 214's requirements for "Good" Standard of Concrete Control (ACI 214, Table 3.2 assigns Good control when Standard Deviation (StD) is in the range of 500-600 psi; Excellent control requires StD smaller than 400 psi). 200 tests for mix 727550-2 had a StD of 541 and 239 tests for mix DM-5 had a StD of 508.
The lower "Standard of Control" may be explained by the multiple mix-designs used, and by testing problems as demonstrated above. Although lower, it is considered acceptable for general construction testing.