You Didn't Get a Perfect Wall Finish—Whose Fault Was It?

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Introduction

- We don’t often think about specifications being failures.
- But when they do not perform the way they were intended, failures can and do occur.
- This case involves a large university classroom building on the west coast that utilized a significant amount of self-consolidating concrete (SCC) for the extensive architectural, structural concrete in the building.

- Reportedly, the architectural firm was known for great designs, but not very experienced with construction.
- The structural engineering firm was experienced and sound.
- The concrete subcontractor was experienced with a good reputation.

What is self-consolidating concrete?

- According to Portland Cement Association, SCC is a "high-performance concrete that can flow easily into tight and constricted spaces without segregating and without requiring vibration. The key to creating self-consolidating concrete (SCC), also referred to as self-compacting, self-leveling, or self-placing concrete, is a mixture that is fluid, but also, stable, to prevent segregation."

VIDEO

- Normal concrete cannot achieve this; in order to make it flow without vibration considerable additional water would have to be added that would lower strength, result in segregation of aggregates, and result in very poor quality.
- SCC was made possible by a new generation of superplasticizers developed in the late 1980s. They permit the amount of water to be the same or less and still have the same, and even better, workability.
- SCC must be carefully proportioned, and workability must be evaluated by several special tests.

Test methods for SCC (not used for normal concrete)

- Slump flow test (ASTM C1611)
- J-ring test (ASTM C1621)
- Segregation test (ASTM C1610)

Slump flow test

Diameter of flow is measured (20 to 28 in.)

J-ring test

Difference in elevation between inside and outside the ring (0.5 in.)

Segregation test

Measured by the difference in amount of coarse aggregate in top and bottom cylinders after a specified time (15% max after 15 min.)

So what was the problem?

- University and their design team did not like the quality of the surface finish of the SCC that was furnished by the concrete subcontractor for cast-in-place architectural concrete—including color, staining, uniformity but mostly bugholes.
- There were other issues such as irregular surfaces due to formwork not being stiff enough but that was not in my scope.
- I represented the concrete subcontractor; my scope was to evaluate the SCC based on the specifications.

Issues with specifications

- Specs were prepared by architect and engineers and approved by university.
- The university and design team had not accepted many of the SCC cast-in-place wall placements, citing incorrect color, staining, out-of-plane wall surfaces, and especially, bugholes.
- The university and design team maintained that it was a performance specification, but was it?

Performance Specifications

- National Ready Mix Concrete Association defines a performance specification as[5]: "**A performance specification for concrete materials establishes performance indicators measured by standard test methods with defined acceptance criteria stated in contract documents and with no accompanying restrictions on concrete mixture proportions"**
- Good example is buying a cake—you can specify:
  - Size and number of layers
  - Flavor of cake and icing
  - But if you give them the recipe for how to make it, it is no longer a performance spec—you just bought whatever they produce.

Aggregates

- Specification had required that all aggregates must come from a specific source since they wanted a particular color.
- However, after the contract was let, it was found by the contractor that the aggregate was not readily available in the size required and a 5 or 6 week delay would occur.
- The contractor submitted a substitute source, and it was immediately rejected, but due to the potential delay in securing the specified aggregate it was finally accepted four months after originally being proposed.

Problems with aggregate specs

- Aggregate was specified that was not available.
- Reportedly, the project manager was advised by the contractor prior to bid date that the specified aggregate was not available.
- The specification of a specific aggregate should not be part of a performance specification. Color can be specified, but contractor should be left to select the aggregate.
- The substitute aggregate should not have initially been rejected; the result was significant delays without reimbursement to the contractor.

Concrete Mixture Design

- Referenced ACI 211 for proportioning, intended for normal concrete. Doesn't work for SCC.
- Specified maximum water-to-cement ratio, 0.45
- Specified use of a supplementary cementitious material
- Required slump flow test with correct flow values
- Specified aggregate grading and maximum aggregate size

- Required a permeability reducing additive to be used in some cases
- Required a high range water reducer to be used.
- Required a viscosity modifying admixture to be used to prevent segregation
- Specified shrinkage limit

Problems with mixture proportions spec

- Should have left proportioning to contractor; instead specified the wrong proportioning guide (ACI 211) and never referenced the appropriate documents for SCC, ACI 237.
- Specified water-to-cement ratio
- Failed to provide test methods for all tests, e.g. segregation and shrinkage; failed to mention J-ring test; didn't give limits for segregation test.

- Specified many of the constituents in the mix
- OK to specify strength, workability requirements, shrinkage, permeability but must let contractor decide the constituents
- Giving the recipe in the spec makes the specifier responsible for the resulting concrete if specs are followed.

Surface Finish Specifications

- **First issue** was bugholes on the surface.
- The specification stated: "Finished concrete surface shall be free of bugholes to the extent published by Cresset Chemical Company for "CCS 1" in connection with "Crete-Lease" Form Release or equal."
- The only specification for surface finish regarding bugholes was a 2-in. photo for a proprietary form release agent with no indication of how photo was made or the scale.

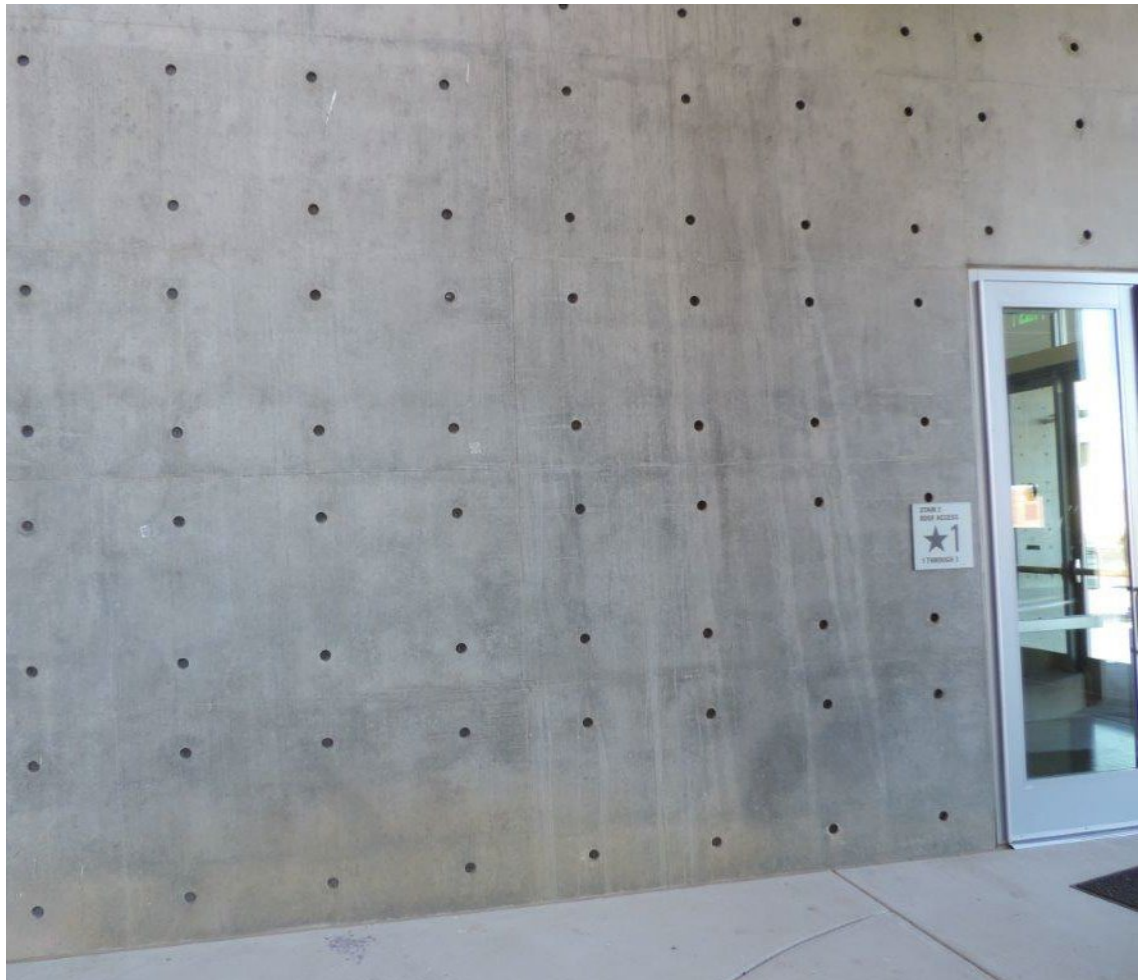

CCS 1
Applied Film Thickness
<0.0005 inches
CCS 2
Applied Film Thickness
0.001 inches
CCS 3
Applied Film Thickness
0.002 inches
CCS 4
Applied Film Thickness
0.003 inches
CCS 5
Applied Film Thickness
0.004 inches
CCS 6
Applied Film Thickness
0.005 inches

- The university and design team did not want to accept many of the SCC finishes claiming that the finishes did not meet the spec based on the photo.

- Design team brought in an outside expert who said he thought it was a very good finish. Owner didn't accept their own expert's opinion.
- I made an inspection of the building and found the surfaces to be better than for other buildings on the campus that used exposed, non-SCC concrete.
- The building had mostly good surfaces but some bugholes were in evidence.
- Question: What would have been a better performance spec for bugholes?

SCC walls

More SCC walls



Other building surfaces-non SCC

Other campus buildings—non SCC

- **Second issue** on surface finish was vibration. Spec specifically excluded vibration.
- But when design team was not happy with surface finish, they required contractor to vibrate but refused to pay for it.

- **Third issue** was staining of walls.
- Owner's reps said that staining was due to fly ash which was required by the owner's spec.
- Eventually the contractor was ordered to eliminate fly ash in mix.

Problem with surface finish specs

- The use of a small proprietary photo to determine acceptance of large architectural exposed concrete wall subject to bugholes is not acceptable. The university's own standards for specifications did not permit it.
- ACI 237, the ACI document on SCC (that the specs did not reference), stated that defects such as bugholes are largely reduced (but not eliminated.)
- Their own expert thought the surface finish was very good but owner still rejected the finishes.

- Since spec for SCC was a prescriptive spec rather than performance, the owner should have accepted finish.
- The concrete should not have been required to be vibrated. ACI 237 says vibration will do more harm than good for SCC. Method of consolidation should not have been included
- Staining was said, by the project manager, to be caused by addition of fly ash (that was required by the spec), and eventually they required it to be omitted.
- But the prescriptive spec that required fly ash to be used caused significant delays for which the owner refused to pay.

Results

- The concrete subcontractor filed suit against the university. In turn the university filed suit against the subcontractor.
- After eight weeks of testimony, the jury returned a verdict that upheld the lawsuit against the university but also upheld the lawsuit against the subcontractor. They agreed on the SCC issue for the contractor and with the owner on the formwork issues.
- But the jury awarded no money to either side.
- Win-win or lose-lose?

- Both sides were unhappy--it was a tie.
- As Darrell Royal, the former Texas football coach once said before tie breakers came into being, “A tie is like kissing your sister.”
- The subcontractor’s attorney: “We all walked away like the father of the bride after the wedding—empty pockets!”

Lessons Learned

- Performance specifications should not include prescriptive requirements, but designers don't always feel comfortable in only specifying performance criteria.
- If prescriptive specifications are used, the owner must be prepared to accept the results assuming the contractor follows the specs.

- If specialty materials such as SCC are going to be specified, the design team should employ an expert to assist in writing the specs and evaluating the results in the field.
- Spec writing is often the unappreciated part of the process, but it is as important as the design.

Conclusion

- We must learn from mistakes in order that history doesn't repeat itself.
- If there isn't already, there should be an ancient Chinese proverb that says, "Much better to learn from mistakes of others than from mistakes by you."
- Specifications are important!