PRELIMINARY CONCRETE DESIGN STUDIES

FOR THE

INITIAL ACCELERATOR HOUSING

ABA REPORT # 90

REPORT FOR RECORD COVERING THE PRELIMINARY INVESTIGATIONS AND TESTING OF CONCRETE AND CONCRETE MATERIALS.

CONTRACT #ABA-301-3

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-SYNOPSIS-

Preliminary investigations of the concrete materials and the fresh concrete were made at the Abbot A. Hanks Laboratory in San Francisco, California, using materials proposed by the contractor for use in the Accelerator Housing construction.

Representative samples of cement, fine and coarse aggregate, air entraining agent, and water-reducing admixture were delivered to the laboratory by the suppliers.

The aggregates were tested for gradation and physical properties, cement for chemical and physical properties, A.E. agent and W.R. admixture for dosage requirements, and all for performance in the concrete mix.

Both the cement and aggregates meet the respective specification requirements or limits for each. Exceptionally good compressive strengths were obtained. However, the increase in strength with the admixture was below the specification limits at 28 days of age. Increased drying shrinkage was also noted in the concrete with the admixture. The total shrinkage and the shrinkage increase with the admixture was above the maximum limits established by the specifications. Both of these items are covered thoroughly in the "Discussion of the Test Results".

-SUMMARY-

Materials:

<u>Cement</u>--Type II, Ideal Cement Company, from the "San Juan Bautista" Plant.

<u>Aggregates</u>--<u>Fine</u> - Supplied by the Henry J. Kaiser Company, from the "Felton" Plant. The fine aggregate is a fair to poorly graded "Feldspathic" sand composed predominately of quartz and feldspar. The particle shape ranges from sub-angular to angular.
<u>Coarse</u> - Supplied by the Granite Rock Company from the quarry near Watsonville, California. The aggregate is from the "Santa Lucia" granite formation and is composed chiefly of quartz and feldspar with minor amounts of hornblend and biotite mica. The rock is sound, strong and only slightly weathered. The particle shape ranges from sub-angular to angular after crushing.

<u>Air Entraining Agent</u>--"Darex" manufactured by the Dewey and Almy Chemical Division, W. R. Grace Company, 2140 Davis Street, San Leandro, California. This is an aqueous solution of purified and modified salts of a sulfonated hydrocarbon.

<u>Water Reducing Admixture</u>--"WRDA", manufactured by Dewey and Almy Chemical Division, W. R. Grace Company. This is a Type "A" (ASTM-C-494-62T) admixture in the "Modified Lignosulfonic Acid" classification.

Both the A.E. agent and the WR admixture and name brands commonly used. General acceptance was made on suppliers certification. Note copy of certification, last page of this report.

Handling of Materials:

Cement--Six (6) sacks of cement were combined in a plastic-lined box for use in the concrete trial batches. Grab samples of cement were obtained from each bag and combined for testing for chemical and physical properties.

Aggregates--Fine - nine (9) sacks (approximately 1000 lb.) were combined in a box in a moist condition. After combining, samples were obtained for gradation and testing for physical properties. As the sand was used in the individual trial batches, samples of the sand in that batch were checked for free moisture. Proportionated adjustments were made in the sand weight and added water of the batch.

Coarse - Approximately 800 pounds of each of the two sizes - #4-3/4" and 3/4" - 1-1/2 - were combined on the laboratory floor and dried. Two (2) sacks - approximately 200 pounds - of the 1-1/2" - 2-1/2" were treated similarly. Representatime samples were taken from the combined piles for gradation and physical properties. As these aggregates were used in the trial batches, adjustments were made in the added water to compensate for the absorption.

Air entraining agent and WR admixture, both were used in the same solution concentrate as delivered by the supplier.

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Mix Design:

Proportions for the trial batches were selected in accordance with recommended practices outlined in A.C.I. Standard, "Recommended Practice for Selecting Proportions for Concrete". ACI-614.

Batching and Mixing:

All the solids were weighed to the nearest 0.10 pounds, the water to 0.01 pound and the agent and admixture to the nearest 1cc

A 3.3 cubic foot capacity tilting drum mixer was used to mix all the trial batches. The batch size for the mixes with 1-1/2" maximum size aggregate was three cubic feet. For the batches with 2-1/2" maximum size aggregate it was 2.70 cubic feet. Charging time ranged from 3 to 4 minutes; and a mixing time of 6 minutes was established for all batches.

Testing:

Fresh Concrete--All tests for slump, air content, unit weight and temperature were made in accordance with procedures outlined in the various ASTM recommended practices.

Hardened Concrete--Standard 6" x 12" specimens were cast for compressive strengths. A standard laboratory vibrator was employed in the lasting of the specimens instead of normal rodding. The mix with 2-1/2" maximum size aggregate was "Wet Screened" through a 1-1/2" screen to remove the plus

1-1/2" material.

The specimens for shrinkage were cast from the mixes with 1-1/2 maximum size aggregate. The molds for the casting of the shrinkage specimens were 5" x 6" x 16". Except for mold size of the shrinkage specimens, the casting, curing, capping and testing of both the compression and shrinkage specimens conformed to the ASTM procedures.

-DISCUSSION OF RESULTS-

Materials:

Cement--Test results of the representative samples of the "Ideal" Type II cement show this cement meets the provisions required by the contract specifications. Note Table I for the tabulation of the test results.

Analysis of this data, plus the results of the tests for compressive strength of the concrete containing this cement indicate that the rate of strength development may be very slow. This is due principally to the low tricalcium silicate content (42%), a fairly low tricalcium aluminate content (4.5%) and a moderately coarse grind (specific surface 3250 CM^2/gram).

The combination of a low C3S and a moderately low C3A is most desirable in the cement for the housing construction, the low heat generation resulting from this combination will be a significant aid in lowering volume change and lessening the tendency towards cracking. However, this combination, along with a coarser grind may require more cement to develop strengths at earlier ages. Note the compressive strength results, Table 3 and Figure 1.

Aggregates--Both the fine and coarse aggregate meets the specification limitations for gradation and physical properties. The fine aggregate is somewhat poorly graded with 60 to 65 percent of the particle sizes passing the number 16 sieve size and retained on the number 50 sieve size. The sand has an average fineness modulus of 2.46. No organic impurities were present. The sand has a specifid gravity of 2.55 and an absorption factor of 0.8 percent. The coarse aggregate is reasonably uniformly graded. It appears that approximately .5 percent sifnificant undersize exists in both the 3/4" and 1-1/2" size fraction. As construction progresses and an average figure for this undersize is established, field adjustments will be made for "Clean Separation". This will provide more uniform grading of the total coarse aggregate. Tests for the abrasive resistance of the coarse aggregates, (Los Angeles Abrasion Test) show these aggregates to be highly resistant to abrasion with an average weighted loss of 25 percent.

This is particularly significant in that no finish screening is provided or required in this contract and minimum breakage during handling can be expected with these aggregates. They are exceptionally dense with a specific gravity of 2.88 and a low absorption factor ranging from 0.7 percent to 1.0 percent. Note Table 2 for a summary of these tests.

WR admixture and A.E. agent - No tests were performed on the agent or admixture solutions as such. The influence these had on the concrete properties are discussed further along in this report.

<u>Tests of the Fresh Concrete</u>:

Tests for slump, air content, unit weight and temperature were run on all mixes. Variation in these properties were held within normal limitations for laboratory testing to insure comparable results. Note Table 3 for summary of these tests and batch data.

Tests for rate of hardening were made on concrete from the first trial batches (#1 & 2) that were run to establish water and agetn requirements for the test series. These mixes varied slightly in air content and water content from the mixes shown in Table 3 but these factors have very little, if any, influence on the rate of hardening. Results of these tests show very little difference in the rate of hardening of the mortars in plain concrete or those with the WRDA. Note Figure 3.

Good workable mixes were obtained at the proportions shown in Table 3. The water content of the mix with the WRDA was reduced approximately 8 percent. This is within the general range of water reduction resulting from the use of this type of WR admixture. These tests indicate that the maximum water contents required by the specifications may be difficult to stay within, as the lab mixes required nearly the maximum water to obtain the required slump.

<u>Tests of the Hardened Concrete</u>:

<u>Comprehensive Strength</u>--Good, if not exceptionally good, strength results were obtained with this combination of materials at the unusually low cement contents used. As previously noted in the discussion of the cement, the <u>rate</u> of strength development is <u>slow</u> at the early ages. However, the concrete can be expected to continue to gain appreciable strength at later ages and with the extended curing plus appreciation of the water proof membrane required for the housing structure, this is a most favorable condition. This test series indicates that the minimum cement content for the concretes with 2-1/2" MSA (4.7 SKS/C.Y.) may be reached with good control. To reach the minimum cement for the mixes with 1-1/2" MSA (5.1 SKS/C.Y.) can hardly be expected. A cement content in the neighborhood of 5.5 SKS/Cubic Yard is more realistic. Note Table 3 and Figure 1 for a summary and illustration of the strength data.

The specifications require a minimum strength gain of 10 percent with the use of the WR admixture. This gain was obtained at the early ages (up to 14 days). At 28 days of age, this gain dropped to 5%. This may or may not be a normal condition with this combination of materials. This reduction in gain at later ages appears odd and would not, in this writer's opinion, generally be expected. Due to the start of the contractors operations prior to the completion of the 28th day, test results the decision was made to accept the admixture based on the 7 and 14 day results. At this time the strength gain met the required minimum and was accepted.

The results of this one test comparison can not be considered conclusive and additional tests have been made of the job concrete to establish this value. It might be well to note at this time that experience on the job with the job concrete show water-reduction with the admixture up to 12 percent. It is certainly reasonable to expect that strength gain commensurate with any where near this water reduction would exceed the minimum strength increase required.

Drying Shrinkage:

The total shrinkage of the concrete with the admixture at 21 days of age is .005 percent above the specification maximum and the difference in shrinkage between thisconcrete and the plain concrete is 15 percent higher than expected.

Once again, it was necessary to base acceptance of the admixture on results at early agest. In comparing the early results with the tests conducted by the University of California in their preliminary concrete studies (Refer to R.E. Davis Report June 15, 1963) ABA results were 11 percent less at 3 days and 6 percent higher in 7 days. In that different cements were used in the two tests and realizing the wide variation in shrinkage at early ages that often is experienced with different cements and the admixtures it appeared that within reasonable limits, similar results had been observed in this concrete. At this time, there was no reason to expect that the difference in shrinkage would increase with age for the early age results of the tests (3 and 7 days) definitely indicated a diminishing difference. This compared favorably with the results of the University of California testing. Based on this analysis of early results, the admixture was conditionally accepted for use. Later, on completion of the 21 days tests, the expected trend had reversed and increased to a level above the established limits. It is very possible that this difference may diminish at later ages.

A close scrutiny of these results was made at this time including a thorough check of the procedures employed by the University of California in their testing. Several differences other than the cement were found that very possibly makes comparison more difficult and less reliable. The differences are: The shrink age difference with admixture in the tests conducted by the University of California were ~~XX~~at different cement contents; the ABA specimens were cast with concrete with 1-1/2" MSA--the University of California specimens with 2-1/2" MSA. Less water is required in the mixes with the larger aggregate which could effect the shrinkage of both the plain and the admix concrete. It should be noted that the plain mix, without admixture showed nearly 20 percent increase in shrinkage above the results of the plain concretes tested by the University of California.

Due to these variables and considering the fact that good, uniform, and high quality concrete was being produced on the job with these materials, it became a quality control determination, but with design engineering concurrence. To, 1) continue using these materials, 2) continue recordings of shrinkage of the ABA specimens at later ages, and 3) duplicate the test with job concrete with 2-1/2" MSA. The latter has been done as of this writing and results will be available in late August.

-SUGGESTIONS AND RECOMMENDATIONS-

In future specifications, a close appraisal should be made of the specification limit for drying shrinkage. Since the door is left open for a selection of, or a combination of several local cements and numerous WR admixtures, it is suggested that the limit for shrinkage, at the early age of 21 days be increased to a maximum not lower than 0.030 percent.