OFFICE MEMORANDUM

DATE: November 8, 1976

TO: L. T. Oehler
Engineer of Research

FROM: M. G. Brown

SUBJECT: Study of Deck Concrete in S03 of 64014, US 31 under Winston Rd West of Rothbury.
Research Project 76 TI-355. Research Report No. R-1028.

The following is a summary of tests run on cores from the subject four-span structure and a review of related construction data. The cores were drilled as requested by D. D. Dolph in a letter of June 21, 1976 to D. F. Malott. This was subsequent to obtaining low beam breaks and modified cube tests from the first span poured on April 27, 1976 (span 2). A total of 16 4-in. cores were drilled full depth in the four spans on June 23, 1976 and were stored 48 hours in the moist room before capping and running the compression test. The results of these tests are given in Table 1 and indicate values lower than should be expected for the other three deck pours as well as span 2. In viewing these data, it should be kept in mind that core strengths are generally about 90 percent of comparable molded cylinders (see ACI Journal, March 1968, p 186).

Since it was reported from the field that considerable amounts of additional mix water were needed at the job site to bring the slump up to 3-1/2 in. for placement, the cores were closely examined and tested for permeable voids (ASTM C 642) and water loss by air drying. The permeable voids test would be affected by the water-cement ratio as placed, but also by the voids in the slag coarse aggregate and, to some extent, the air content of the individual cores. The loss of water in 72 hours of air drying from the saturated condition is thought to also reflect the final water-cement ratio of the individual cores. These data are given in Table 2 and there appears to be a general trend between percent permeable voids, 72-hour water loss, and compressive strength. Core 76 CC-560 and to a lesser extent CC-564, and CC-572 departed from the general trend and this appeared to be explained by the fact that these three cores contained more mortar, or less slag coarse aggregate. The cement content was not run on these cores because there was a considerable variation in the sand to slag ratio which would affect the accuracy of the chemical method.

Data from project records given in Table 3 indicate that, at times, the air content ran slightly high, in the 8 to 9 percent range. The problem of slump

control and job site addition of water was indicated on the inspectors report. The maximum amount of water added per cubic yard at the job site was stated as 4, 8, 6.5, and 4.6 gallons for the pours of April 27 and 28, and May 3 and 4, respectively. It was reported that this additional water was needed at the job site because of variations in the initial slag moisture content and the haul time as indicated by the 90-minute discharge time. The data in Table 2 would indicate that there was some non-uniformity of mixing and high water-cement ratios in the areas cored. There would appear to have been an error in calculating the net water-cement ratio on the back of the plant report for the four pour dates. The calculated values for the four day's pours ran from 0.33 to 0.35 which is unrealistically low. The actual mix design computes to 0.43 and the pour of April 12, 1976 on S06 of 64014 calculated 0.45. This pour used exactly the same materials as used on Winston Rd and also came from the same supplier, Hart Redi-Mix. The average core strength for each span is shown in Table 3 and the comparable molded cylinder value in parentheses. This latter value is based on a 0.9 core to cylinder ratio previously referenced.

In summary, we would offer the following conclusions and recommendations based on the core test data.

1. The strength level of all four pours is about 70 to 80 percent of what should be expected, with span 2 being somewhat lower than the other three.

2. It would appear that the primary reason for the lower strengths is due to high water-cement ratios in a majority of the cores and in combination with somewhat high air levels, in some cases. This reasoning is based on the range in permeable voids and 72 hour moisture loss in Table 2.

3. The lower strength level probably is not enough to impair the structural performance of the deck, but resistance to penetration of chlorides and the surface wear resistance would not be as good as it should be. There should be no problem in durability with the higher air levels of Table 3 but some treatment to reduce permeability to chlorides should be considered.

4. We would recommend a pachometer survey be made and if there are areas deficient in cover, a thin overlay of latex modified mortar would be warranted for the entire deck.

5. If the concrete cover proves to be adequate, an additional treatment with linseed oil-mineral spirits might be warranted next year, after a good cleaning of residual dirt. It is assumed the initial two coats have been applied.

TESTING AND RESEARCH DIVISION

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TABLE 1

SUMMARY OF COMPRESSIVE STRENGTH OF DECK CORES

(S03 of 64014)

	Laboratory No.	Field No.	Pour Date	Location	Compressive Strength, * psi
Span 4	76 CC-560	1	May 4, 1976	5.8 ft south of north curb 7.0 ft west of Reference Line B	2,870
	76 CC-561	2	May 4, 1976	16.1 ft south of north curb 18.7 ft west of Reference Line B	3,550
	76 CC-562	3	May 4, 1976	5.3 ft north of south curb 2.3 ft west of Reference Line 3	---
Span 3	76 CC-563	4	April 28, 1976	6.7 ft south of north curb 18.9 ft west of Reference Line 3	3,060
	76 CC-564	5	April 28, 1976	16.1 ft south of north curb 28.3 ft west of Reference Line 3	3,140
	76 CC-565	6	April 28, 1976	11.8 ft north of south curb 62.9 ft west of Reference Line 3	---
	76 CC-566	7	April 28, 1976	6.1 ft south of north curb 28.4 ft east of Reference Line 2	3,250
	76 CC-567	8	April 28, 1976	6.2 ft north of south curb 6.0 ft east of Reference Line 2	4,030
Span 2	76 CC-568	9	April 27, 1976	16.7 ft south of north curb 7.5 ft west of Reference Line 2	3,000
	76 CC-569	10	April 27, 1976	12.4 ft north of south curb 31.2 ft west of Reference Line 2	3,100
	76 CC-570	11	April 27, 1976	3.8 ft south of north curb 63.6 ft east of Reference Line 1	---
	76 CC-571	12	April 27, 1976	6.1 ft north of south curb 74.6 ft west of Reference Line 2	---
	76 CC-572	13	April 27, 1976	16.9 ft south of north curb 10.2 ft east of Reference Line 1	2,940
Span 1	76 CC-573	14	May 3, 1976	5.4 ft north of south curb 4.7 ft west of Reference Line 1	3,490
	76 CC-574	15	May 3, 1976	15.3 ft north of south curb 17.6 ft west of Reference Line 1	2,960
	76 CC-575	16	May 3, 1976	4.9 ft south of north curb 7.1 ft east of Reference Line A	3,720

* Cores tested in moist condition and results corrected to L/D ratio of 2.0 as per ASTM C 42-68. A control mix using field materials showed a compressive strength of 3,200 psi at 7 days and 5,130 psi at 28 days age. Core No. 6 damaged in field, broken at bottom and cracked vertically. Core Nos. 3, 11, and 12 broke at middle during coring.

TABLE 2
TOTAL PERMEABLE VOIDS AND VISUAL INSPECTION
(Deck Cores From S03 of 64014)

Laboratory No.	Boiled Wet Bulk Specific Gravity [1]	Percent Voids [1]	Moisture Loss, [2] percent	Visual Description [3]
76 CC-560	2.157	13.3	2.24	High sand content; good w/c ratio; normal air content. Sawed core top inspected through stereo microscope.
76 CC-561	2.104	15.1	3.19	High slag content; high w/c ratio; high air content.
76 CC-562	2.065	14.1	3.01	No compression test. High w/c ratio; high sand content.
76 CC-563	2.177	15.6	3.18	High sand content; poor consolidation; normal air content. Sawed core top inspected through stereo microscope.
76 CC-564	2.189	14.0	3.40	High sand content; low to normal air content; very high w/c ratio.
76 CC-565	(Not run due to fractures)			No compresstion test. Normal air content.
76 CC-566	2.179	15.3	2.98	High sand content; high air content; high w/c ratio.
76 CC-567	2.182	13.1	1.77	Normal sand content; normal to high air content; low w/c ratio. Sawed core top inspected through stereo microscope.
76 CC-568	2.182	14.8	2.35	High sand content; high air content; normal w/c ratio.
76 CC-569	2.123	16.0	2.91	Poor consolidation; very high air content; normal to high w/c ratio.
76 CC-570	2.113	16.4	4.10	No compression test. High air content; high w/c ratio; high sand content.
76 CC-571	2.102	14.9	3.77	No compression test. High air content; high w/c ratio; high sand content.
76 CC-572	2.132	14.0	3.03	High sand content; high air content; probably high w/c ratio. Mix appears to be very non-uniform with lines of high air with cracking.
76 CC-573	2.144	15.7	3.44	Poor consolidation; normal sand content; high w/c ratio; normal to high air content.
76 CC-574	2.120	16.0	3.40	High sand content; very high air content; probably high w/c ratio. Sawed core top inspected through stereo microscope.
76 CC-575	2.157	14.1	3.25	Very low sand content; poor bond between sand and cement paste, bond appears dirty; high air content. Sawed core top inspected through stereo microscope.

[1] In accordance with ASTM C 642
[2] Moisture loss in 3 days air drying from saturated, boiled condition.
[3] Water to cement ratio assumed related to the 3 day air dry moisture loss.

TABLE 3
FIELD CONCRETE DATA VERSUS CORE STRENGTHS

Pour Date	Span	Air Tests, percent	Slump, in.	Flexure Strength, psi		Core Strength, psi	
				7 Day	14 Day	Range	Average
May 3, 1976	1	8.9 8.0	3-1/2 2-1/4	577	650	2,960- 3,720	3,390 (3,770)*
April 27, 1976	2	7.0 7.9 8.0 9.0	4 3-1/2 4 3	550	576	2,940- 3,100	3,010 (3,350)
April 28, 1976	3	6.0 8.0 5.5 6.0 6.5 8.5	2-3/4 3 2-3/4 3-1/4 --- ---	617	640	3,060- 4,030	3,370 (3,740)
May 4, 1976	4	6.0 8.2	3-1/2 ---	475	669	2,870- 3,550	3,210 (3,570)

* Note: Average core strength in parentheses is predicted molded cylinder strength using ratio of 0.90 for core to cylinder ratio.