Method of Test for

OBTAINING AND TESTING DRILLED CORES FOR STRUCTURAL CONCRETE

DOTD Designation: TR 228

I. Scope

A. This method outlines the procedures for obtaining, preparing and testing cores drilled from in-place hardened structural concrete for compressive strength determinations.
B. With Department approval, cores may be obtained when acceptance cylinders for compressive strength are damaged, low in-place concrete quality is suspected, and/or signs of distress appear in the structure during and after construction, and if there is an investigation of the structural element in question.

II. Reference Documents

A. DOTD TR 225 – Obtaining and Testing Drilled Cores and Sawed Beams of Concrete for Pavement
B. DOTD TR 226 – Making, Field Curing, and Transporting Concrete Test Specimens
C. DOTD TR 230 – Curing, Capping, and Determining the Compressive Strength of Cylindrical Concrete Specimens
D. AASHTO T 24/ASTM C42 – Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
E. AASHTO T 148 – Measuring Length of Drilled Concrete Cores
F. AASHTO T 231 – Capping Cylindrical Concrete Specimens
G. ASTM C823 – Practice for Examination and Sampling of Hardened Concrete in Constructions
H. ACI PRC-214.4 – Obtaining Cores and Interpreting Core Compressive Strength Results

III. Apparatus

A. Personal Protective Equipment
B. Concrete Pachometer (Cover Meter)
C. Ground Penetrating Radar (GPR)
D. Permanent Marker & Temporary Chalk Marker
E. An approved drilling apparatus with a diamond-impregnated drill bit attached to the core barrel to obtain an appropriate diameter core with water for cooling.
F. Core Extraction Tool
G. Camera
H. Hammer, Chisel or Flathead Screwdriver
I. Pencil, Sketchpad, and Clipboard
J. Suitable Measuring Tape & Caliper
K. Plastic Bags, Wrapping Material or Nonabsorbent Container
L. Concrete Patching Material from the AML

IV. Coring Plan

A. The contractor shall submit a coring plan to the Engineer for review prior to coring. The plan shall contain a drawing of the element showing the As-built locations of rebar, proposed coring locations, orientation of the core, and photographs of the element prior to coring.
B. Selection of the element/segment coring location shall be in an area representative of the failing samples, as determined by the Engineer. In elements where concrete is placed in lifts, obtain cores from the approximate center of the lift, when possible.
C. No core shall be taken within 6 inches from any identifiable joint, edge or corner.
D. Consult plans for reinforcing steel locations to avoid damaging reinforcement.
E. Use non-destructive techniques to confirm and record the depth and the location of longitudinal and transverse reinforcement to avoid damaging reinforcement. Use visual inspection and the results of the nondestructive evaluation to identify possible locations of cores with sound concrete.
F. Use the temporary chalk marker to mark the location of the reinforcing steel and the desired location of the core(s) on the element.

V. Coring

A. Coring shall be done in accordance with the approved plan and in the presence of the Engineer.
B. Unless otherwise directed by the Engineer, take at least two (2), but no more than three (3) cores (including damaged cores that are unusable for testing) from the segment of the structure represented by the concrete in question.
C. Take cores in a manner to avoid damaging reinforcement.
D. Core specimens should have diameters of 4.00 to 6.00 inches and an L/D between 1.0 and 2.0 to minimize errors introduced by the strength correction factors.
E. Core specimens shall have a minimum diameter of 3.70 inches or no less than two times the nominal maximum size of the coarse aggregate used in the concrete mix, whichever is larger.
F. Using the permanent marker, mark the core with unique labeling. Identify this unique label on the sketch of coring locations.
G. Determine and record the core's diameter and length.
H. Repair each coring location with an approved patching product from the AML. Product shall be appropriate for the intended use of the patch.

VI. Protection, Identification & Transportation of Specimens

A. The coring operator should be informed beforehand that the cores are for strength testing and require proper handling and storage.
B. Samples shall be numbered and their orientation in the structure indicated by permanent marking on the core itself.
C. To preserve the "as-is" condition of the concrete and prevent net moisture gain or loss, wipe off surface water from the drilling process and allow remaining surface moisture to evaporate.

D. Within 1 hour of extracting the core, individually wrap, bag or place each specimen in a nonabsorbent container to seal the specimens and prevent moisture loss.
E. Before bagging the specimen, record important characteristics, such as extraction location of each core, maximum aggregate size, presence and location of reinforcing steel in the specimen, and any features that may affect strength such as cracks, honeycombs and voids.
F. Clearly label the external wrapping with the unique identifier.
G. In order to prevent specimens from being damaged, maintain at ambient temperature, and protect cores from exposure to direct sunlight. Specimens shall be transported to the testing laboratory in accordance with TR 226.

VII. Laboratory Specimen Preparation & Compressive Strength Testing

A. Core Specimens shall be conditioned in accordance with DOTD TR 225 – Obtaining and Testing Drilled Cores and Sawed Beams of Concrete for Pavement and tested in accordance with DOTD TR 230 – Curing, Capping, and Determining the Compressive Strength of Cylindrical Concrete Specimens with the exceptions listed below.
B. Cores that contain rebar or other embedded metal objects oriented close to parallel to the axis of the core, have been damaged in the process of removal, or show other abnormal defects shall not be used.
C. If possible, trim cores containing embedded reinforcement or other metal object to obtain a core with no reinforcement. The size, shape, and location of the rebar within the core shall be documented in the test report.
D. Length Measurement – Prior to testing, determine the average length of the core to the nearest 0.05 inch. If the core will be tested with bonded caps, determine the average length before and after capping, and use the length after capping to compute the L/D ratio. If the core will be tested with unbonded caps or with ground ends, determine the average length of the prepared core before testing and use that length to compute the L/D ratio. In no case shall the L/D be less than 1.0.
E. Diameter Measurement – Determine the average diameter by averaging two measurements taken at right angles to each other at the mid-height of the core. Record the average core diameter to the nearest 0.01 inch if the difference in core diameters does not exceed 2% of the average, otherwise record to the nearest 0.05 inch. Do not test a core if the difference between the largest and smallest diameter exceeds 5% of the average.
F. Calculations
    1. The compressive strength of each specimen shall be calculated using the computed cross-sectional area based on the average diameter of the specimen. If the ratio of capped length to diameter is less than 1.94, allowance for the L/D is made by multiplying the compressive strength by the applicable strength correction factor given in the following table:

L/D	Correction Factor	L/D	Correction Factor	L/D	Correction Factor	L/D	Correction Factor
1.00	0.870	1.28	0.933	1.56	0.965	1.84	0.987
1.01	0.872	1.29	0.934	1.57	0.966	1.85	0.988
1.02	0.875	1.30	0.936	1.58	0.966	1.86	0.989
1.03	0.877	1.31	0.937	1.59	0.967	1.87	0.990
1.04	0.880	1.32	0.938	1.60	0.968	1.88	0.990
1.05	0.882	1.33	0.939	1.61	0.969	1.89	0.991
1.06	0.884	1.34	0.940	1.62	0.970	1.90	0.992
1.07	0.887	1.35	0.942	1.63	0.970	1.91	0.993
1.08	0.889	1.36	0.943	1.64	0.971	1.92	0.994
1.09	0.892	1.37	0.944	1.65	0.972	1.93	0.994
1.10	0.894	1.38	0.945	1.66	0.973	1.94	0.995
1.11	0.896	1.39	0.946	1.67	0.974	1.95	1.000
1.12	0.899	1.40	0.948	1.68	0.974	1.96	1.000
1.13	0.901	1.41	0.949	1.69	0.975	1.97	1.000
1.14	0.904	1.42	0.950	1.70	0.976	1.98	1.000
1.15	0.906	1.43	0.951	1.71	0.977	1.99	1.000
1.16	0.908	1.44	0.952	1.72	0.978	2.00	1.000
1.17	0.911	1.45	0.954	1.73	0.978	2.01	1.000
1.18	0.913	1.46	0.955	1.74	0.979	2.02	1.000
1.19	0.916	1.47	0.956	1.75	0.980	2.03	1.000
1.20	0.918	1.48	0.957	1.76	0.981	2.04	1.000
1.21	0.920	1.49	0.958	1.77	0.982	2.05	1.000
1.22	0.923	1.50	0.960	1.78	0.982	2.06	1.000
1.23	0.925	1.51	0.961	1.79	0.983	2.07	1.000
1.24	0.928	1.52	0.962	1.80	0.984	2.08	1.000
1.25	0.930	1.53	0.962	1.81	0.985	2.09	1.000
1.26	0.931	1.54	0.963	1.82	0.986	2.10	1.000
1.27	0.932	1.55	0.964	1.83	0.986	2.10+	*

*Core shall be trimmed to an L/D between 1.94 – 2.10

2. Compute the arithmetic average of the values in a lot using the following formula:

$$\overline{X} = \frac{X_{1+}\, X_{2+} \cdots + X_n}{n}$$

Where:

X_1, X_2 and X_n are the individual strengths of the cores

$\overline{X}$ = the arithmetic average

n = number of cores

VIII. Report

A. The report should include the following information:
   1. Project number
   2. Lot & sample number
   3. Date poured
   4. Temperature at pour
   5. Temperature of fresh/plastic concrete at pour
   6. Date cored
   7. Age of the element/segment in question
   8. Core location and orientation
   9. Core condition (honeycombing, segregation, defects, drilling damage, etc.)
   10. Moisture condition
   11. Photos of site location and cores
   12. Average diameter of the specimen
   13. Cross-sectional area of the specimen to the nearest 0.01 in^2
   14. Maximum load indicated by the testing machine for each specimen
   15. Compressive strength of each core to the nearest psi
   16. Length of each test specimen before and after capping or end preparation to the nearest 0.05 inch
   17. L/D ratio and any strength correction factor used
   18. Patching material used

B. Report the average compressive strength to the nearest psi.