April 15, 2008 Matls. IM 315
Supersedes April 20, 2004

METHOD OF MAKING, PROTECTING, CURING & TESTING CONCRETE CYLINDERS

SCOPE

This method covers procedures for making, protecting, and curing, according to AASHTO) T23. This method also covers testing concrete cylinder specimens for compressive strength. This test procedure is a supplement and not a replacement for the beam test to determine when a structure may be put in service.

I. MAKING, PROTECTING & CURING SPECIMENS

A. Apparatus for Making Specimens

1. 6 in. x 12 in. (152.4 mm x 304.8 mm) or 4 in. x 8 in. (101.6 mm x 203.2 mm) steel, brass, or single-use plastic vertical molds meeting the requirements of AASHTO M205.

2. Molds shall be the vertical type.

3. Tamping rods shall comply with AASHTO T23 and the following:

Mold Size	Tamping Rod Diameter
4 in. x 8 in (101.6 mm x 203.2 mm)	3/8 in. (9.5mm)
6 in. x 12 in. (152.4 mm x 304.8 mm)	5/8 in. (16mm)

4. Internal or external vibrators may be used. They shall comply with AASHTO T23 with the exception that the diameter of the vibrating element of the internal vibrator shall vary for each specimen size, as stated below. External vibrators shall be either a table type or a plank type.

5. Rubber hammer

6. Wood float or equivalent

B. Making Test Specimens

1. The concrete shall be sampled in accordance with IM 327, Sampling Freshly Mixed Concrete.

2. Before casting specimens, the inside surfaces of the steel or brass molds should be clean and treated with a thin coating of light grease or form oil.

3. Consolidation may be rodding with a tamping rod, or by vibration, either internal or external. Concrete with slump greater than 3 inches (75 mm) shall be consolidated by rodding. Concrete with slump of 1 inch to 3 inches (25 mm to 75 mm) shall be consolidated by rodding or vibration. Concrete with slump of less than1 inch (25 mm) shall be consolidated by vibration.

   a. Rodding. Specimens shall receive the proper number of roddings evenly distributed per layer as indicated in the table. The bottom layer shall be rodded throughout its depth. For each upper layer, the rod shall penetrate 1/2 inch (13 mm) into the underlying layer. After rodding each layer, the sides and ends of the mold shall be tapped with a rubber hammer until the surface of the concrete is relatively smooth. Use an open hand to tap the single-use molds. After consolidation, strike off the horizontal surface and finish with a float or trowel.

Mold Size	No. of Equal Depth Layers	No. of Roddings per Layer
4 in. x 8 in (101.6 mm x 203.2 mm)	2	25
6 in. x 12 in. (152.4 mm x 304.8 mm)	3	25

   b. Internal Vibration. Specimens shall receive the required number of insertions of a vibrator layer as indicated in the table. If more than one insertion is required, distribute the insertion uniformly in each layer. Each layer shall be vibrated only long enough to make the surface relatively smooth. The time required will vary with the consistency of the concrete. Over vibration may cause segregation. In compacting the concrete, the vibrator shall not rest on or touch the sides of the mold. When vibrating the top layer, the element shall penetrate about 1/2 inch (13 mm) into the bottom layer. After vibrating, tap the sides of the mold with a rubber hammer to ensure removal of entrapped air bubbles at the surface of the mold. Use an open hand to tap the single-use molds. When consolidation is complete, strike off and finish with a wood float or trowel.

Mold Size	Vibrator Diameter	No. of Equal Depth Layers	No. of Insertions per Layer
4 in. x 8 in (101.6 mm x 203.2 mm)	¾ to I inch 19 to 25 mm	2	1
6 in. x 12 in. (152.4 mm x 304.8 mm)	¾ to I 1/2 inch 19 to 38 mm	2	2

   c. External Vibration. Each layer shall be vibrated only until the surface is relatively smooth. Take care to ensure that the mold is rigidly attached or securely held against the vibrating table or vibrating surface. After consolidation, strike off and finish with a trowel or float.

C. Protecting & Curing

1. Initial Curing. During the first 24 hours after molding, specimens shall be stored under conditions that maintain the temperature immediately adjacent to the specimens in the range of 50°F to 80°F (10°C to 27°C) and prevent loss of moisture from the specimens. This may be done by covering specimens with wet burlap and placing a plastic sheet over the burlap, or use other suitable methods to ensure that the foregoing requirements are met.

2. Curing to Determine Form Removal Time or When a Structure May be Put in Service. Cure test specimens as nearly as practicable in the same manner as the concrete in the structure. After 48 ± 4 hours, remove specimens from the molds. They shall be stored as near as possible to the point in the structure they represent and shall be afforded the same temperature protection and moisture environment as the structure until the time of testing. Specimens shall be tested while in the moisture condition resulting from the curing they receive.

3. Curing To Check the Adequacy of Laboratory Mix Proportions for Strength or As a Basis For Acceptance or For Quality Control. For this purpose, specimens are to be removed from the molds at the end of 16 to 24 hours and stored in a moist condition at 68°F to 81.5°F (20°C to 27.5°C) until the time of test. This condition can be met by immersion in saturated limewater. **NOTE:** Lime-saturated water is prepared by mixing 1 oz. (28 g) of hydrated lime, meeting the requirements of ASTM C977, with 1 gallon (3.8 liters) of water.

4. Steam Curing. When artificial heat is used to accelerate curing, concrete specimens shall be placed with the unit being cured and shall receive the same curing as the concrete they represent. Prior to testing the specimens, the temperature of the concrete shall be lowered to the temperature of the surrounding air at a rate not to exceed 40°F (22°C) per hour.

5. Special care must be given to ensure that specimens are not damaged during handling. For 16 to 24 hours after molding, specimens shall not be moved.

II. TESTING CONCRETE SPECIMENS FOR COMPRESSION

A. Apparatus

1. The testing machine shall conform to AASHTO T22. Manually operated testing machines will be accepted.

B. Time of Testing

1. Make compression tests of moist cured specimens as soon as practicable after removal from curing. Keep specimens moist by use of wet burlap or other suitable covering, which will ensure similar protection until actual time of testing.

2. The time to test specimens otherwise cured will be as directed by the engineer.

C. Test Specimens

1. Neither end of compressive test specimens when tested shall depart from the perpendicularity to the axis by more than 0.5 degrees [approximately 1/8 in. in 12 in. (3 mm in 300 mm)]

2. The ends of the specimens that are not plane within 0.002 in. (0.05 mm) shall be capped. The planeness of the ends of every tenth specimen should be checked by means of a straightedge and feeler gauge, making a minimum of three measurements on different diameters, to insure that the end surfaces do not depart from a plane by more than 0.002 in. (0.05 mm).

3. The top surface of vertically cast specimens shall be capped.

D. Capping

1. Capping equipment and procedures shall comply with that described in AASHTO T231.

2. Hardened specimens, which have been moist-cured, may be capped with a neat Portland Cement paste or sulfur mortar meeting the requirements set forth below:

   a. The Portland Cement in neat Portland Cement caps shall conform to AASHTO M85, Type I or Type III.

   b. Sulfur mortar shall conform to the compositional and compressive strength requirements of ASTM C287 for sulfur mortar, and shall be capable of developing a strength of at least 4000 psi (27.6 MPa) in two hours when tested as 2-inch (50-mm) cubes.

3. Specimens, which are to be tested in an air-dry condition, should, be capped with sulfur mortar.

4. If it is found necessary to cap specimens, and equipment and facilities for capping are not available, arrangements should be made to test such specimens at the Central Laboratory or other qualified laboratory.

E. Test Procedure

1. Placing Specimen

   a. Place the plain (lower) bearing block with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block.

   b. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen.

c. Carefully align the axis of the specimen with the center thrust of the spherically seated block.

d. As the spherically seated block is brought to bear on the specimen, rotate its moveable portion gently by hand so that uniform seating is obtained.

2. Rate of Loading

a. Apply the load continuously and without shock. Apply the load at a constant rate within the range of 20 to 50 psi (138 kPa to 345 kPa) per second. During the application of the first half of the estimated maximum load, a higher rate of loading may be permitted.

b. Do not make any adjustment in the controls of the testing machine while the specimen is yielding, especially in the period just before failure.

c. Increase the load until the specimen yields or fails, and record the maximum load carried by the specimen during test.

d. Note the type of failure (Figure 1) and the appearance of the concrete if the break appears to be abnormal.

F. Calculations

1. Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the cross sectional area, and express the result to the nearest 10 psi (0.1 MPa). The attached tables may be used to facilitate these computations.

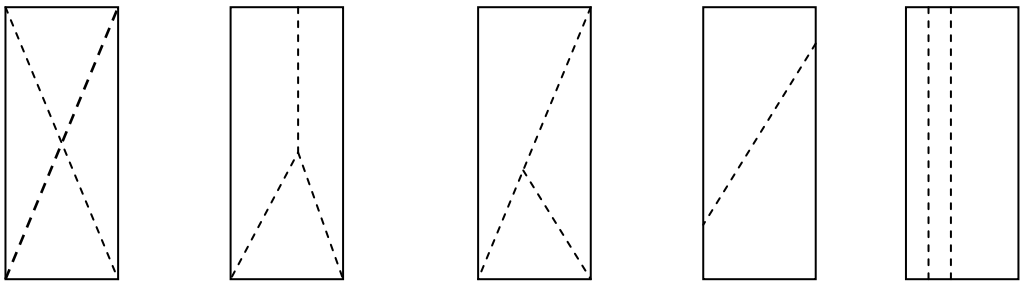

Figure 1. Compressive Fracture Types

Figure 2. Compression Testing Machine

Table for Computing MPa/1000 kPa on 6 in. to 12 in. (154.mm x 304.8 mm) Cylinders
Area = 0.01824m²

Load (kN)	MPa	Load (kN)	MPa	Load (kN)	MPa	Load (kN)	MPa	Load (kN)	MPa
175	9.59	425	23.30	675	37.01	925	50.71	1175	64.42
180	9.87	430	23.57	680	37.28	930	50.99	1180	64.69
185	10.14	435	23.85	685	37.55	935	51.26	1185	64.97
190	10.42	440	24.12	690	37.83	940	51.54	1190	65.24
195	10.69	445	24.40	695	38.10	945	51.81	1195	65.52
200	10.96	450	24.67	700	38.38	950	52.08	1200	65.79
205	11.24	455	24.95	705	38.65	955	52.36		
210	11.51	460	25.22	710	38.93	960	52.63		
215	11.79	465	25.49	715	39.20	965	52.91		
220	12.06	470	25.77	720	39.47	970	53.18		
225	12.34	475	26.04	725	39.75	975	53.45		
230	12.61	480	26.32	730	40.02	980	53.73		
235	12.88	485	26.59	735	40.30	985	54.00		
240	13.16	490	26.86	740	40.57	990	54.28		
245	13.43	495	27.14	745	40.84	995	54.55		
250	13.71	500	27.41	750	41.12	1000	54.82		
255	13.98	505	27.69	755	41.39	1005	55.10		
260	14.25	510	27.96	760	41.67	1010	55.37		
265	14.53	515	28.23	765	41.94	1015	55.65		
270	14.80	520	28.51	770	42.21	1020	55.92		
275	15.06	525	28.78	775	42.49	1025	56.20		
280	15.35	530	29.06	780	42.76	1030	56.47		
285	15.63	535	29.33	785	43.04	1035	56.74		
290	15.90	540	29.61	790	43.31	1040	57.02		
295	16.17	545	29.88	795	43.59	1045	57.29		
300	16.45	550	30.15	800	43.86	1050	57.57		
305	16.72	555	30.43	805	44.13	1055	57.84		
310	17.00	560	30.70	810	44.41	1060	58.11		
315	17.27	565	30.98	815	44.68	1065	58.39		
320	17.54	570	31.25	820	44.96	1070	58.66		
325	17.82	575	31.52	825	45.23	1075	58.94		
330	18.09	580	31.80	830	45.50	1080	59.21		
335	18.37	585	32.07	835	45.78	1085	59.48		
340	18.64	590	32.35	840	46.05	1090	59.76		
345	18.91	595	32.62	845	46.33	1095	60.03		
350	19.19	600	32.89	850	46.60	1100	60.31		
355	19.46	605	33.17	855	46.88	1105	60.58		
360	19.74	610	33.44	860	47.15	1110	60.86		
365	20.01	615	33.72	865	47.42	1115	61.13		
370	20.29	620	33.99	870	47.70	1120	61.40		
375	20.56	625	34.27	875	47.97	1125	61.68		
380	20.83	630	34.54	880	48.25	1130	61.95		
385	21.11	635	34.81	885	48.52	1135	62.23		
390	21.38	640	35.09	890	48.79	1140	62.50		
395	21.66	645	35.36	895	49.07	1145	62.77		
400	21.93	650	35.64	900	49.34	1150	63.05		
405	22.20	655	35.91	905	49.62	1155	63.32		
410	22.48	660	36.18	910	49.89	1160	63.60		
415	22.75	665	36.46	915	50.16	1165	63.87		
420	23.03	670	36.73	920	50.44	1170	64.14		

(Load in Thousands)

Table for Computing lb./in.² on 6 in. x 12 in. Cylinders
Area = 28.2744 in.²

Load	Psi	Load	Psi	Load	Psi	Load	Psi	Load	Psi
40	1410	90	3180	140	4950	190	6720	240	8490
41	1450	91	3220	141	4990	191	6760	241	8520
42	1490	92	3250	142	5020	192	6790	242	8560
43	1520	93	3290	143	5060	193	6830	243	8590
44	1560	94	3320	144	5090	194	6860	244	8630
45	1590	95	3360	145	5130	195	6900	245	8670
46	1630	96	3400	146	5160	196	6930	246	8700
47	1660	97	3430	147	5200	197	6970	247	8740
48	1700	98	3470	148	5230	198	7000	248	8770
49	1730	99	3500	149	5270	199	7040	249	8810
50	1770	100	3540	150	5310	200	7070	250	8840
51	1800	101	3570	151	5340	201	7110	251	8880
52	1840	102	3610	152	5380	202	7140	252	8910
53	1870	103	3640	153	5410	203	7180	253	8950
54	1910	104	3680	154	5450	204	7220	254	8980
55	1950	105	3710	155	5480	205	7250	255	9020
56	1980	106	3750	156	5520	206	7290	256	9050
57	2020	107	3780	157	5550	207	7320	257	9090
58	2050	108	3820	158	5590	208	7360	258	9120
59	2090	109	3860	159	5620	209	7390	259	9160
60	2120	110	3890	160	5660	210	7430	260	9200
61	2160	111	3930	161	5690	211	7460	261	9230
62	2190	112	3960	162	5730	212	7500	262	9270
63	2230	113	4000	163	5760	213	7530	263	9300
64	2260	114	4030	164	5800	214	7570	264	9340
65	2300	115	4070	165	5840	215	7600	265	9370
66	2330	116	4100	166	5870	216	7640	266	9410
67	2370	117	4140	167	5910	217	7670	267	9440
68	2410	118	4170	168	5940	218	7710	268	9480
69	2440	119	4210	169	5980	219	7750	269	9510
70	2480	120	4240	170	6010	220	7780		
71	2510	121	4280	171	6050	221	7820		
72	2550	122	4310	172	6080	222	7850		
73	2580	123	4350	173	6120	223	7890		
74	2620	124	4390	174	6150	224	7920		
75	2650	125	4420	175	6190	225	7960		
76	2690	126	4460	176	6220	226	7990		
77	2720	127	4490	177	6260	227	8030		
78	2760	128	4530	178	6300	228	8060		
79	2790	129	4560	179	6330	229	8100		
80	2830	130	4600	180	6370	230	8130		
81	2860	131	4630	181	6400	231	8170		
82	2900	132	4670	182	6440	232	8210		
83	2940	133	4700	183	6470	233	8240		
84	2970	134	4740	184	6510	234	8280		
85	3010	135	4770	185	6540	235	8310		
86	3040	136	4810	186	6580	236	8350		
87	3080	137	4850	187	6610	237	8380		
88	3110	138	4880	188	6650	238	8420		
89	3150	139	4920	189	6680	239	8450		

(Load in Thousands)

Table for Computing lb./in.² on 4 in. x 8 in. Cylinders
Area = 12.5666 in.²

Load	Psi	Load	Psi	Load	Psi	Load	Psi
10	800	50	3980	90	7160	130	10350
11	880	51	4060	91	7240	131	10420
12	950	52	4140	92	7320	132	10500
13	1030	53	4220	93	7400	133	10580
14	1110	54	4300	94	7480	134	10660
15	1190	55	4380	95	7560	135	10740
16	1270	56	4460	96	7640	136	10820
17	1350	57	4540	97	7720	137	10900
18	1430	58	4620	98	7800	138	10980
19	1510	59	4700	99	7880	139	11060
20	1590	60	4770	100	7960	140	11140
21	1670	61	4850	101	8040	141	11220
22	1750	62	4930	102	8120	142	11300
23	1830	63	5010	103	8200	143	11380
24	1910	64	5090	104	8280	144	11460
25	1990	65	5170	105	8360	145	11540
26	2070	66	5250	106	8440	146	11620
27	2150	67	5330	107	8520	147	11700
28	2230	68	5410	108	8590	148	11780
29	2310	69	5490	109	8670	149	11860
30	2390	70	5570	110	8750	150	11940
31	2470	71	5650	111	8830	151	12020
32	2550	72	5730	112	8910	152	12100
33	2630	73	5810	113	8990	153	12180
34	2710	74	5890	114	9070	154	12260
35	2790	75	5970	115	9150	155	12330
36	2860	76	6050	116	9230	156	12410
37	2940	77	6130	117	9310	157	12490
38	3020	78	6210	118	9390	158	12570
39	3100	79	6290	119	9470	159	12650
40	3180	80	6370	120	9550	160	12730
41	3260	81	6450	121	9630	161	12810
42	3340	82	6530	122	9710	162	12890
43	3420	83	6610	123	9790	163	12970
44	3500	84	6680	124	9870	164	13050
45	3580	85	6760	125	9950	165	13130
46	3660	86	6840	126	10030	166	13210
47	3740	87	6920	127	10110	167	13290
48	3820	88	7000	128	10190	168	13370
49	3900	89	7080	129	10270	169	13450

Table for Computing MPa on 4 in. x 8 in. (101.6 mm x 203.3 mm) Cylinders
Area = 0.008107 m²

Load (kN)	MPa	Load (kN)	MPa	Load (kN)	MPa	Load (kN)	MPa
45	5.55	245	30.22	445	54.89	645	79.56
50	6.17	250	30.84	450	55.51	650	80.18
55	6.78	255	31.45	455	56.12	655	80.79
60	7.40	260	32.07	460	56.74	660	81.41
65	8.02	265	32.69	465	57.36	665	82.03
70	8.63	270	33.30	470	57.97	670	82.64
75	9.25	275	33.92	475	58.59	675	83.26
80	9.87	280	34.54	480	59.21	680	83.88
85	10.48	285	35.15	485	59.82	685	84.49
90	11.10	290	35.77	490	60.44	690	85.11
95	11.72	295	36.39	495	61.06	695	85.73
100	12.34	300	37.01	500	61.68	700	86.35
105	12.95	305	37.62	505	62.29	705	86.96
110	13.57	310	38.24	510	62.91	710	87.58
115	14.19	315	38.86	515	63.53	715	88.20
120	14.80	320	39.47	520	64.14	720	88.81
125	15.42	325	40.09	525	64.76	725	89.43
130	16.04	330	40.71	530	65.38	730	90.05
135	16.65	335	41.32	535	65.99	735	90.66
140	17.27	340	41.94	540	66.61	740	91.28
145	17.89	345	42.56	545	67.23	745	91.90
150	18.50	350	43.17	550	67.84	750	92.51
155	19.12	355	43.79	555	68.46	755	93.13
160	19.74	360	44.41	560	69.08	760	93.75
165	20.35	365	45.02	565	69.69		
170	20.97	370	45.64	570	70.31		
175	21.59	375	46.26	575	70.93		
180	22.20	380	46.87	580	71.54		
185	22.82	385	47.49	585	72.16		
190	23.44	390	48.11	590	72.78		
195	24.05	395	48.72	595	73.39		
200	24.67	400	49.34	600	74.01		
205	25.29	405	49.96	605	74.63		
210	25.90	410	50.57	610	75.24		
215	26.52	415	51.19	615	75.86		
220	27.14	420	51.81	620	76.48		
225	27.75	425	52.42	625	77.09		
230	28.37	430	53.04	630	77.71		
235	28.99	435	53.66	635	78.33		
240	29.60	440	54.27	640	78.94		