MORSE BROTHERS, INC.
CONCRETE CYLINDER MOLD INVESTIGATION
PHASE ONE REPORT

JULY, 1986

STUDY MADE BY
OREGON STATE HIGHWAY DIVISION
MATERIALS SECTION

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DOCUMENT NUMBER 00005

Technical Report Documentation Page

Specification No. 504	**ODOT No.**
Report Date July, 1986	**Report No.**

Title
Morse Brothers, Inc.
Concrete Cylinder Mold Investigation
Phase One Report

Subtitle

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Sponsoring Agency

Notes

Key Words Concrete Cylinder Molds Compressive Strength Portland Cement Concrete	**Type** Research Report
	Location

INTRODUCTION

On June 13, 1986 OSHD and Morse Brothers, Inc. decided to engage in a joint effort to isolate the differences in compressive strength, which result when cylinders ore cast in plastic molds and steel molds. This the first of two scheduled experiments will show what effect mold flexibility has on compressive strength.

THEORY

It is theorized that when cylinders are cast in accordance with AASTHO T23-85I a problem with mold flexibility arises. In section 7.3.2 of AASTHO T23-85I it states, "If voids are left by the tamping rod, tap the sides of the mold lightly with the mallet or open hand when using light-gage single-use molds to close the voids." It is believed that this tapping of the mold side could cause segregation of the aggregate in the concrete. This could ultimately reduce the compressive strength, and this reduction of strength is greatest in the most flexible molds.

SCOPE

For laboratory analysis three sets of ten cylinders were cast from the same batch of concrete at Morse Brothers' prestress yard in Harrisburg. The subsequent compressive strength testing was performed at OSHD materials laboratory in Salem.

The results were analyzed statistically at a 95% significance level. This was performed by calculating the mean difference and the standard error of the difference between the mean of the sample of two independent populations. Values from the area under the normal probability curve are compared to the accepted convention.* A significant result is a calculated probability less than 0.05, and a highly significant result is a calculated probability less than 0.01. For consistency with ACI 318-83 and ACI 301-84 the standard deviation was calculated with (n-1), the number of samples in the set, as the denominator.

* Probability and Statistics by Alder/Rossler, 1975, 6th Edition.

PROCEDURE

This procedure was developed with the premise that the concrete used to mold the cylinders was consistent throughout the batch. One cubic yard batch was used for the entire procedure.

On June 24, 1986 a class 6000 3/4 inch, 8 sack mix was batched from OSHD mix design # 86-7140 at the Morse Brothers Harrisburg prestress yard. From this batch three sets of ten cylinders were molded. The three sets where as follows:

A. Plastic molds.
B. Plastic molds with protective sheet metal jackets.
C. Steel molds.

Immediately after the cylinders were cast they were moved into the air conditioned office where the ambient temperature around the cylinders was maintained between 60 degrees F and 80 degrees F for 48 hours. The jackets from set B were removed when all of the cylinders were first brought into the office. After 48 hours all cylinders were stripped from the molds and imbedded in sand for transporting to OSHD materials laboratory.

On June 26, 1986 the cylinders arrived at the OSHD materials laboratory, and were promptly capped with sulfur mortar caps, and placed in a 73.4 degree F + or - 3 degree F moist cure room until July 22, 1986. On July 22, 1986 the cylinders were tested for a 28 day compressive strength.

TEST RESULTS

The compressive strength of each cylinder is listed in Table #1 by catagories as follows:

A. Plastic molds
B. Plastic molds with protective sheet metal jackets
C. Steel molds

The statistical comparison between catagories is listed in Table #2 and explained below:

1. For statistical analysis between Plastic molds and Plastic molds with protective sheet metal jackets, category A vs. B, exhibited a highly significant difference. The value was 0.001.

2. For statistical analysis between Plastic molds and Steel molds, category A vs C, exhibited a highly significant difference. The value was 0.000.

3. For statistical analysis between Plastic molds with protective sheet metal jackets and Steel molds, category B vs. C, exhibited a highly significant difference. The value was 0.000.

CONCLUSIONS

Although there appears to be a highly significant difference between all three category comparisons, the relationship of mold flexibility to compressive strength is proven false. As the theory states, strength should decrease with the use of more flexible molds, but the means of our catagories did not follow that relationship.

The highest mean strength was found in Steel molds, but some of the strength gain could be attributed to the water loss through the seams of the Steel molds, since the steel molds did not comply with **AASHTO TEST DESIGNATION: M 205-83I (ASTM DESIGNATION: C470-81)** for watertightness.

The next highest mean strength was in Plastic molds with no protective jackets, instead of the Plastic molds with protective sheet metal jackets. The lowest mean strength was found in Plastic molds with protective sheet metal jackets.

Since this experiment was performed on an 8-sack mix with a low water cement ratio, which results in a relatively stiff mix, it stands to reason that for other mixes with less cement less tapping will be required to fill the voids left by rodding. This should result in less of a difference in compressive strength due to the mold flexibility.

Currently OSHD is using Plastic single-use cylinder molds for all acceptance testing, and after evaluating the results herein, no change in our policy is recommended at this time. A further evaluation will be made when phase two of this study is completed.

COMPRESSIVE STRENGTH OF CYLINDERS

TABLE I

CATEGORY	A	B	C
	7430	7320	7920
	7935	7390	8285
	7740	7390	7875
	7750	7540	7940
	7695	7390	7790
	7595	7340	8250
	7370	7320	7835
	7675	7490	7725
	7525	7285	8135
	7630	7670	8395
MEAN	7634.5	7413.5	8015.0
STD. DEV.	165.13	119.58	232.98
STD. ERROR	52.22	37.81	73.66

STATISTICAL COMPARISON OF CATEGORIES

TABLE II

CATEGORY	A vs B	A vs C	B vs C
MEAN DIFF.	221.0	380.5	601.5
% MEAN DIFF.	3.0	5.0	8.1
STD. ERROR (of mean diff.)	64.47	90.29	82.80
RATIO	3.428	4.214	7.264
AREA VIA TABLES	0.4997	0.5000	0.5000
(0.5-AREA)2	0.001	0.000	0.000
SIGNIFICANCE	HIGHLY	HIGHLY	HIGHLY
CONFIDENCE LVL	99	99	99

A = Plastic molds

B = Plastic molds with sheet metal jackets

C = Steel molds

ILLUSTRATION #1

Table I
Areas Under the Normal Probability Curve

The entries under *A* denote the area between the line of symmetry (that is, $z = 0$) and the given *z*-value.

z	*A*	*z*	*A*	*z*	*A*	*z*	*A*
0.00	0.0000	0.30	0.1179	0.60	0.2268	0.90	0.3169
.01	.0040	.31	.1217	.61	.2291	.91	.3186
.02	.0060	.32	.1266	.62	.2324	.92	.3212
.03	.0120	.33	.1283	.63	.2357	.93	.3238
.04	.0160	.34	.1331	.64	.2389	.94	.3264
.06	.0199	.36	.1368	.66	.2422	.96	.3289
.06	.0239	.36	.1406	.66	.2454	.96	.3316
.07	.0279	.37	.1443	.67	.2486	.97	.3340
.08	.0319	.38	.1480	.68	.2518	.98	.3366
.09	.0369	.39	.1617	.69	.2549	.99	.3389
.10	.0398	.40	.1664	.70	.2580	1.00	.3413
.11	.0438	.41	.1691	.71	.2612	1.01	.3438
.12	.0478	.42	.1628	.72	.2642	1.02	.3461
.13	.0517	.43	.1664	.73	.2673	1.03	.3485
.14	.0557	.44	.1700	.74	.2704	1.04	.3508
.16	.0596	.46	.1736	.76	.2734	1.06	.3531
.16	.0636	.46	.1772	.76	.2764	1.06	.3554
.17	.0676	.47	.1808	.77	.2794	1.07	.3577
.18	.0714	.48	.1844	.78	.2823	1.08	.3599
.19	.0754	.49	.1879	.79	.2852	1.09	.3621
.20	.0793	.50	.1916	.80	.2881	1.10	.3643
.21	.0832	.51	.1950	.81	.2910	1.11	.3665
.22	.0871	.52	.1986	.82	.2939	1.12	.3686
.23	.0910	.53	.2019	.83	.2967	1.13	.3708
.24	.0948	.54	.2054	.84	.2996	1.14	.3729
.26	.0987	.56	.2088	.86	.3023	1.16	.3749
.26	.1026	.56	.2123	.86	.3051	1.16	.3770
.27	.1064	.57	.2157	.87	.3079	1.17	.3790
.28	.1103	.58	.2190	.88	.3106	1.18	.3810
.29	.1141	.59	.2224	.89	.3133	1.19	.3830

ILLUSTRATION #2

Table I. Areas Under the Normal Probability Curve
(continued)

z	*A*	*z*	*A*	*z*	*A*	*z*	*A*
1.20	0.3849	1.55	0.4394	1.90	0.4713	2.25	0.4878
1.21	.3869	1.56	.4406	1.91	.4719	2.26	.4881
1.22	.3888	1.57	.4418	1.92	.4726	2.27	.4884
1.23	.3907	1.58	.4430	1.93	.4732	2.28	.4887
1.24	.3925	1.59	.4441	1.94	.4738	2.29	.4890
1.25	.3944	1.60	.4452	1.95	.4744	2.30	.4893
1.26	.3962	1.61	.4463	1.96	.4750	2.31	.4896
1.27	.3980	1.62	.4474	1.97	.4756	2.32	.4898
1.28	.3997	1.63	.4485	1.98	.4762	2.33	.4901
1.29	.4015	1.64	.4495	1.99	.4767	2.34	.4904
1.30	.4032	1.65	.4505	2.00	.4773	2.35	.4906
1.31	.4049	1.66	.4515	2.01	.4778	2.36	.4909
1.32	.4066	1.67	.4525	2.02	.4783	2.37	.4911
1.33	.4082	1.68	.4535	2.03	.4788	2.38	.4913
1.34	.4099	1.69	.4545	2.04	.4793	2.39	.4916
1.35	.4155	1.70	.4554	2.05	.4798	2.40	.4918
1.36	.4131	1.71	.4564	2.06	.4803	2.41	.4920
1.37	.4147	1.72	.4573	2.07	.4808	2.42	.4922
1.38	.4162	1.73	.4582	2.08	.4812	2.43	.4925
1.39	.4177	1.74	.4591	2.09	.4817	2.44	.4927
1.40	.4192	1.75	.4599	2.10	.4821	2.45	.4929
1.41	.4207	1.76	.4608	2.11	.4826	2.46	.4931
1.42	.4222	1.77	.4616	2.12	.4830	2.47	.4932
1.43	.4236	1.78	.4625	2.13	.4834	2.48	.4934
1.44	.4251	1.79	.4633	2.14	.4838	2.49	.4936
1.45	.4265	1.80	.4641	2.15	.4842	2.50	.4938
1.46	.4279	1.81	.4649	2.16	.4846	2.51	.4940
1.47	.4292	1.82	.4656	2.17	.4850	2.52	.4941
1.48	.4306	1.83	.4664	2.18	.4854	2.53	.4943
1.49	.4319	1.84	.4671	2.19	.4857	2.54	.4945
1.50	.4332	1.85	.4678	2.20	.4861	2.55	.4946
1.51	.4345	1.86	.4686	2.21	.4865	2.56	.4948
1.52	.4357	1.87	.4693	2.22	.4868	2.57	.4949
1.53	.4370	1.88	.4700	2.23	.4871	2.58	.4951
1.54	.4382	1.89	.4706	2.24	.4875	2.59	.4952

ILLUSTRATION #3

Table I. Areas Under the Normal Probability Curve
(concluded)

z	A	z	A	z	A	z	A
2.60	0.4953	2.95	0.4984	3.30	0.4995	3.65	0.4999
2.61	.4955	2.96	.4985	3.31	.4995	3.66	.4999
2.62	.4956	2.97	.4985	3.32	.4996	3.67	.4999
2.63	.4957	2.98	.4986	3.33	.4996	3.68	.4999
2.64	.4959	2.99	.4986	3.34	.4996	3.69	.4999
2.65	.4960	3.00	.4987	3.35	.4996	3.70	.4999
2.66	.4961	3.01	.4987	3.36	.4996	3.71	.4999
2.67	.4962	3.02	.4987	3.37	.4996	3.72	.4999
2.68	.4963	3.03	.4988	3.38	.4996	3.73	.4999
2.69	.4964	3.04	.4988	3.39	.4997	3.74	.4999
2.70	.4965	3.05	.4989	3.40	.4997	3.75	.4999
2.71	.4966	3.06	.4989	3.41	.4997	3.76	.4999
2.72	.4967	3.07	.4989	3.42	.4997	3.77	.4999
2.73	.4968	3.08	.4990	3.43	.4997	3.78	.4999
2.74	.4969	3.09	.4990	3.44	.4997	3.79	.4999
2.75	.4970	3.10	.4990	3.45	.4997	3.80	.4999
2.76	.4971	3.11	.4991	3.46	.4997	3.81	.4999
2.77	.4972	3.12	.4991	3.47	.4997	3.82	.4999
2.78	.4973	3.13	.4991	3.48	.4998	3.83	.4999
2.79	.4974	3.14	.4992	3.49	.4998	3.84	.4999
2.80	.4974	3.15	.4992	3.50	.4998	3.85	.4999
2.81	.4975	3.16	.4992	3.51	.4998	3.86	.4999
2.82	.4976	3.17	.4992	3.52	.4998	3.87	.5000
2.83	.4977	3.18	.4993	3.53	.4998	3.88	.5000
2.84	.4977	3.19	.4993	3.54	.4998	3.89	.5000
2.85	.4978	3.20	.4993	3.55	.4998		
2.86	.4979	3.21	.4993	3.56	.4998		
2.87	.4980	3.22	.4994	3.57	.4998		
2.88	.4980	3.23	.4994	3.58	.4998		
2.89	.4981	3.24	.4994	3.59	.4998		
2.90	.4981	3.25	.4994	3.60	.4998		
2.91	.4982	3.26	.4994	3.61	.4999		
2.92	.4983	3.27	.4995	3.62	.4999		
2.93	.4983	3.28	.4995	3.63	.4999		
2.94	.4984	3.29	.4995	3.64	.4999		