CONCRETE CYLINDER MOLD INVESTIGATION
SUMMARY REPORT

March 12, 1987

STUDY MADE BY
OREGON STATE HIGHWAY DIVISION
MATERIALS SECTION

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INTRODUCTION

In 1985, Oregon State Highway Division (OSHD) began using single use plastic cylinder molds in the field and in prestress yards for acceptance testing. Before this time, field inspectors had been using steel, paper, and tin molds, while the prestress yards had been using re-usable steel cylinder molds. A major reason for changing to plastic molds was that the tin and steel molds were producing cylinders that were out of round and not in compliance with specifications.

By the end of the 1985 construction season, one of the prestress yards challenged the compressive strength test results of the cylinders cast in plastic molds. The prestress yard felt that the plastic molds produced lower compressive strengths than the steel molds. In December of 1985, the OSHD Materials Section began a research study to determine the cause for the observed differences in strengths of cylinders cast by the prestress yard vs. cylinders cast by OSHD inspectors. Several factors affecting strength were considered, including types of molds, method of curing, method of transporting, flexibility of molds, and thermal conductivity of molds. The major emphasis of the research was to be on the difference in the compressive strengths between cylinders cast in plastic molds and steel molds.

This report is a summary of six reports written at different stages of the research study. The six reports in this summary are:

1. Eugene Sand and Gravel High-Strength Concrete Research Study January 1986.

2. Eugene Sand and Gravel High-Strength Concrete Research Study Phase Two. February 1986.

3. Morse Brothers, Inc. Harrisburg Concrete Cylinder Mold Investigation, Phase One. July 1986.

4. Morse Brothers, Inc. Harrisburg Concrete Cylinder Mold Investigation, Phase Two. August 1986.

5. Morse Brothers, Inc. Clackamas Concrete Cylinder Mold Investigation. September 1986.

6. River Bend, Salem Concrete Cylinder Mold Investigation. February 1987.

The statistical significance of all results in the research study were tested at a 95% confidence level. For the purpose of this study statistical values greater than .05 were considered non-significant, while values of .05 or less were considered significant. Statistical values of .01 or less were considered highly significant. For a more complete review of the statistical analysis performed, the individual report should be obtained.

Test 4 Difference Due to Intermediate Cure

The first group of concrete cylinders for this test was immediately transported to the Materials Lab for processing. The second group of cylinders was temporarily stored at the Eugene Inspectors office, then transported to the Materials Lab for processing. The mean compressive strength of the cylinders that were immediately transported was 6292 psi and 6034 psi for the cylinders that were temporarily stored in the Eugene office. The percent mean difference shows that the temporarily stored cylinders produced 4.1% lower strength than the cylinders that were immediately transported. This is a highly significant difference with a Z statistic of 0.002.

Test 5 Difference Due to Method of Transporting

Three different methods of transporting concrete cylinders to the Materials Lab were used in this test. The first was ASTM Sand Method, the second was OSHD vertical racks, and the last one was loose in the back of a pick-up.

a. ASTM Sand VS OSHD Racks
The mean compressive strength of the cylinders transported using the ASTM Sand Method was 6034 psi and 5965 psi for the cylinders transported by OSHD racks. The percent mean difference shows that the cylinders transported by the OSHD rack produced 1.14% lower strengths then those transported by the ASTM sand method. The result is not statistically significant with a Z statistic of 0.303.

b. ASTM Sand VS Back of Pick-up
The mean compressive strength of the cylinders transported using the ASTM Sand Method was 6034 psi and 5928 psi for the cylinders transported loose in the back of a pick-up. The percent mean difference shows that the cylinders transported in the back of a pick-up produced 1.76% lower strengths then the cylinders transported by the ASTM sand method. The result is not statistically significant, with a Z statistic of 0.08.

Conclusion for Report 1

This portion of the study indicated a highly significant difference in the compressive strengths.

The test results indicate that plastic molds produced lower strengths than unsealed steel molds. The difference between the two types of molds is approximately 13%. This is the largest significant difference of the test variables.

This information also shows that OSHD Materials Lab test equipment and procedures produced significantly lower compressive strengths on the test samples than Eugene Sand and Gravel's test equipment and procedures. The difference in strengths between the two testing facilities is approximately 5%. It should be noted that OSHD Materials Lab is certified by CCRL (Cement and Concrete Research Laboratory) while Eugene Sand and Gravel is not.

Finally, the testing indicates that the cylinders which were temporarily stored at the Eugene Inspector's office produced lower strengths than the cylinders that were immediately transported. The difference in strength between the two was approximately 4%.

After reviewing the test data, it was evident that the largest factor in the strength difference was the type of mold used to cast the cylinders. Eugene Sand and Gravel's steel cylinder molds did not conform to OSHD and AASHTO requirements since they were not water tight. It was decided that further testing was necessary on three variables of cylinder molds, those conforming to AASHTO M205-83, unsealed molds (as used in the first set of tests), and plastic molds. All cylinders were to be immediately transported after initial cure and tested at the OSHD Materials Lab to eliminate the other variables with a significant difference in compressive strengths concluded in report 1.

REPORT 2. <u>EUGENE SAND AND GRAVEL HIGH-STRENGTH CONCRETE RESEARCH STUDY, PHASE TWO, FEBRUARY, 1986</u>

In the Eugene Sand and Gravel Phase Two of this study, the testing variables were set as type of mold, method of sealing, and method of consolidation. The purpose of this report was to identify which of the variables had a significant effect on the compressive strengths of the concrete cylinders.

Table 2 shows the test comparisons, mean compressive strengths, standard deviations, standard errors, coefficients of variation, and the statistical significance.

<u>Test 1 Difference Between Eugene S & G and OSHD Steel Molds</u>

All cylinder molds in this test conformed to AASHTO M205-83, and the method of consolidation was by rodding. The mean compressive strength of the cylinders cast in the Eugene Sand and Gravel molds was 6359.5 psi and 6544 psi for the cylinders cast in OSHD molds. The percent the mean difference shows that the cylinders cast in the Eugene Sand and Gravel molds produced 2.82% lower strengths than the cylinders cast in the OSHD molds. The result is not statistically significant, with a Z statistic of 0.119.

<u>Test 2 Difference Due to Sealed and Unsealed Steel Molds</u>

In this test cylinders were cast in Eugene Sand and Gravel steel molds, one group being unsealed and another group being sealed as specified by AASHTO M205-83. The method of consolidation for both groups was by rodding. The mean compressive strength of the cylinders cast in the sealed molds was 6359.5 psi and 6276.5 psi for the cylinders cast in unsealed molds. The percent mean difference shows that the unsealed molds produced 1.31% lower strengths than the cylinders cast in the sealed molds. The result is not statistically significant, with a Z statistic of 0.39.

Test 3 Difference Due to Consolidation

In this test cylinders were cast in Eugene Sand and Gravel unsealed steel molds. One group of the cylinders was consolidated by vibrating and another group was consolidated by rodding. The mean compressive strength for the cylinders consolidated by vibrating was 7000.5 psi and 6276.5 psi for the cylinders consolidated by rodding. The percent mean difference shows that the cylinders that were consolidated by rodding produced 10.34% lower strengths than the cylinders consolidated by vibrating. This is a highly significant difference with a Z statistic of 0.000.

Test 4 Difference Due to Type of Mold

All cylinders used in this test were sealed to conform with AASHTO M205-83, and the method of consolidation was by rodding.

a. Eugene Sand and Gravel Steel Molds VS OSHD Plastic Molds
The mean compressive strength of the cylinders cast in the steel molds was 6359.5 psi and 5788.5 psi for the cylinders cast in plastic molds. The percent mean difference shows that the plastic molds produced 8.98% lower strengths than the steel. This is a highly significant difference with a Z statistic of 0.000.

b. OSHD Steel Molds VS OSHD Plastic Molds
The mean compressive strength of the cylinders cast in the steel molds was 6544 psi and 5788.5 psi for the cylinders cast in plastic molds. The percent mean difference shows that the cylinders cast in the plastic molds produced 11.54% lower strengths than the cylinders cast in steel molds. This is a highly significant difference with a Z statistic of 0.000.

c. Eugene Sand and Gravel and OSHD Steel Molds (combined) VS OSHD Plastic Molds
The mean compressive strength of the combined Eugene Sand and Gravel and OSHD steel molds was 6451.8 psi and 5788.5 psi for the cylinders cast in OSHD plastic molds. The percent mean difference shows that the cylinders cast in the plastic molds produced 10.28% lower strengths than the

cylinders cast in the steel molds. This is a highly significant difference with a Z statistic of 0.000.

Conclusion for Report 2

This portion of the study indicated a highly significant difference in compressive strengths in four (4) areas. The test results indicate that the cylinders consolidated by vibrating produced higher strengths than those consolidated by rodding. The difference in compressive strength between the two is approximately 10%. Consolidating the cylinders by vibrating did not comply with AASHTO T23.

The testing also indicated a highly significant difference due to the type of mold used in casting cylinders. As indicated in the first report, the plastic molds produced strengths lower than the steel molds.

After reviewing the test data from reports 1 and 2, the greatest factor in the strength difference was due to the type mold used to cast the cylinders. To eliminate the difference in the strengths due to consolidation, in future tests, cylinders will be consolidated by the rodding method. The decision was made to do additional testing using a different concrete producer. Another variable that was examined in the next set of tests was mold flexibility.

REPORT 3. MORSE BROTHERS, INC. HARRISBURG CONCRETE CYLINDER INVESTIGATION, PHASE 1. JULY, 1986

In this report, the testing variables were type of molds and mold flexibility. It was theorized that tapping on the side of the light gauged plastic molds could segregate the aggregate and cause lower compressive strengths. In this test, three groups of cylinders were cast. The first group of cylinders was cast in OSHD plastic molds, the second group was cast in Morse Brothers unsealed steel molds, and the last group was cast in OSHD plastic molds fitted with a sheet metal jacket. After the cylinders had been consolidated, finished by striking off the top surface, and moved to the curing room, the sheet metal jackets were removed. The method of consolidation for all the cylinders was by rodding.

Table 3 shows the test comparisons, mean compressive strengths, standard deviations, standard errors, coefficients of variation, and the statistical significance.

Test 1 Difference Due to Mold Flexibility

a. Plastic Molds VS Plastic Molds With Sheet Metal Jacket
The mean compressive strength of the cylinders cast in the plastic molds was 7634.5 psi and 7413.5 psi for the cylinders cast in plastic molds with the sheet metal

jackets. The percent mean difference shows that the plastic molds with sheet metal jackets produced 2.89% lower than the cylinders cast in the plastic molds. This is a highly significant difference with a Z statistic 0.001.

b. Morse Brothers Harrisburg Steel VS Plastic With Sheet Metal Jacket
The mean compressive strength of the cylinders cast in the steel molds was 8015 psi and 7413.5 psi for the cylinders cast in plastic mold with sheet metal jackets. The percent mean difference shows that the cylinders produced 7.50% lower strengths than the steel molds. This is a highly significant difference with a Z statistic of 0.000.

Test 2 Difference Due to Type of Mold

The mean compressive strength of the Morse Brothers steel molds was 8015 psi and 7634.5 psi for the cylinders cast in OSHD plastic molds. The percent mean difference shows that the cylinders cast in the plastic molds produced 4.75% lower strengths than the cylinders cast in the steel molds. This is a highly significant difference with a Z statistic of 0.000.

Conclusion for Report 3

This portion of the study indicated a highly significant difference in the two areas tested. A highly significant difference in strengths for the mold flexibility test was shown except the molds with sheet metal jackets to restrict flexibility produced the lowest strengths of the three groups tested. The theory that the flexibility of the plastic mold produced lower strengths because of segregation during consolidation was shown to be false.

The tests results also indicated a highly significant difference in compressive strength between the steel molds and the plastic molds. The difference between the two group being approximately 5.0%. The Morse Brothers Inc. Harrisburg steel cylinder molds were not water tight as required by AASHTO M205-83. This could cause a change in the compressive strengths of the cylinders cast in the steel molds, although as indicated in the Eugene Sand and Gravel Phase two report the result is not statistically significant for the purpose of the report.

This report concurs with the previous test data that indicated the greatest factor is the type of mold used when fabricating cylinders.

The decision was made to do additional testing at Morse Brothers Harrisburg plant. The scope of the testing in the next phase would be mold flexibility, and thermal conductivity.

REPORT 4. MORSE BROTHERS, INC. HARRISBURG CONCRETE CYLINDER MOLD INVESTIGATION, PHASE TWO. AUGUST, 1986

In this set of tests, three groups of cylinders were cast, the first group in OSHD plastic molds, the second in Morse Brothers Harrisburg unsealed steel molds, and the last group was OSHD plastic molds with sheet metal jackets. After the cylinders had been consolidated, finished by striking off the top surface, and moved to the curing room, the sheet metal jackets were removed. All cylinders were consolidated by the rodding method and tested for compressive strengths at 3 days.

The theory for the mold flexibility is the same as in Morse Brothers, Inc. Harrisburg Phase One. The theory of the thermal conductivity is that steel molds have a higher K value than the plastic molds. The higher K value would result in a higher heat loss in the steel molds, causing a lower temperature in the initial cure of the cylinder. This lower initial cure temperature would result in a lower compressive strength in an early cylinder break and a higher strength at a later break date.

Table 4 shows the test comparisons, mean compressive strengths, standard deviations, standard errors, coefficients of variation, and statistical significance.

Test 1 Difference Due to Mold Flexibility

a. OSHD Plastic Molds VS OSHD Plastic With Sheet Metal Jackets
The mean compressive strength of the cylinders cast in the plastic molds was 6088.5 psi and 6059.5 psi for the cylinders cast in plastic molds with the sheet metal jackets. The percent mean difference shows that the plastic molds with the sheet metal jackets produced 0.48% lower strengths than the cylinders cast in the plastic molds. The result is not statistically significant, with a Z statistic of 0.5028.

b. Morse Brothers Harrisburg Steel Molds VS OSHD Plastic with Sheet Metal Jackets
The mean compressive strength of the cylinders cast in the steel molds was 6205.5 psi and 6059.5 psi for the cylinders cast in plastic molds with the sheet metal jackets. The percent mean difference shows that the cylinders cast in the plastic molds with the sheet metal jackets produced 2.35% lower strengths than the cylinders cast in the steel molds. This is a statistically significant result, with a Z statistic of 0.0132.

Test 2 Difference Due to Thermal Conductivity

The mean compressive strength of the cylinders cast in steel molds was 6205.5 psi and 6088.5 psi for the cylinders cast in plastic molds. The percent mean difference shows that the cylinders cast in the plastic molds produced 1.89% lower strengths than the cylinders cast in the steel molds. The result is not statistically significant, with a Z statistic of 0.0524.

Conclusion for Report 4

This portion of the study indicated there was no significant difference between the cylinders cast in the plastic molds and the cylinders cast in the plastic molds with sheet metal jackets. The tests do indicate a significant difference between the cylinders cast in the steel molds and the cylinders cast in the plastic molds with sheet metal jackets. As in the Morse Brothers Harrisburg Phase one report, the cylinders with the sheet metal jackets obtained the lowest strengths of the groups tested. With this information, the theory of the mold flexibility can be considered false.

The statistical analysis of the 3 day compressive strength tests indicate that the theory of the thermal conductivity was not proven. Statistically it was not significant at the 95% confidence level but it would be significant at the 94.5% level. The Morse Brothers Harrisburg steel molds were not water tight as required by AASHTO M205-83. This could cause a change in the compressive strengths of the cylinders cast in steel molds, although as indicated in the Eugene Sand and Gravel Phase two report, the result is not statistically significant for the purpose of this report.

The decision was made to do additional testing in a different geographical area of the state. The next set of tests were to be completed using material from Morse Brothers, Inc. Clackamas. (Portland area)

REPORT 5. MORSE BROTHERS, INC. CLACKAMAS CONCRETE CYLINDER MOLD INVESTIGATION, SEPTEMBER, 1986

The testing variable for this test was set at type of mold used to cast cylinders. The compressive strength test results in this report were obtained over a period of approximately two months and were cast from 32 different batches of concrete. For the purpose of this report, a pairwise and student t statistical analysis was performed on the data and the compressive strengths were corrected using an average diameter obtained for both the plastic and steel molds used at Morse Brothers Clackamas.

Table 5 shows the test comparisons, mean compressive strengths, standard deviations, standard errors, coefficients of variation, and statistical significance.

Test 1 Difference Due to Type of Test Mold

In this test, cylinders were cast using Morse Brothers Clackamas unsealed steel cylinder molds and OSHD plastic molds, and consolidated by rodding. The corrected mean compressive strength for the cylinders cast in the steel molds was 7462.5 psi and the mean compressive strength of the cylinders cast in the plastic molds was 6998.1 psi. The percent mean difference shows that the cylinders cast in the plastic molds produced 6.22% lower strengths than the cylinders in the steel molds. This is a highly significant difference with a student t statistic of 10.84.

Conclusion for Report 5

This report indicated a significant difference in compressive strengths between the Morse Brothers Clackamas steel molds and OSHD plastic molds of approximately 6%. This correlates with all the other reports showing that plastic cylinder molds produce lower strengths than steel cylinder molds. The Morse Brothers Clackamas steel cylinder molds were not water tight as required by AASHTO M205-83. This could cause a change in the compressive strengths of the cylinders cast in the steel molds, although as indicated in the Eugene Sand and Gravel Phase Two report the result is not statistically significant for the purpose of this report.

The decision was made to do additional testing between the steel and plastic cylinder molds using a moderate strength concrete. The next set of tests were to be completed using materials from River Bend in Salem.

REPORT 6. RIVER BEND, SALEM, CONCRETE CYLINDER MOLD INVESTIGATION. FEBRUARY, 1987

The variable in River Bend Salem study was the class of concrete to see if the previous conclusions carried through from high strength to moderate strength concrete. All cylinder molds used complied with AASHTO M205-83 and were consolidated by rodding.

Table 6 shows the test comparisons, mean compressive strengths, standard deviations, standard errors, coefficients of variation, and statistical significance.

Test 1 Difference Due to Type of Mold

In this test, cylinders were cast in OSHD sealed steel molds and OSHD plastic molds. The mean compressive strength of the cylinders cast in steel molds was 4511 psi and 4216 psi for the cylinders cast in plastic molds. The percent mean difference shows that cylinders cast in plastic molds produced 6.54% lower strengths then cylinders cast in steel molds. This is a highly significant difference with a Z statistic of 0.0012.

Conclusion for Report 6

This report indicates a highly significant difference in compressive strengths between the OSHD plastic molds and OSHD steel molds of approximately 6%. This correlates with all the other reports showing that plastic cylinder molds produce lower strengths than steel cylinder molds.

CONCLUSION FOR RESEARCH STUDY

A review of the six reports concludes there is a statistically significant difference between the compressive strength of steel molds and plastic molds, however, no specific reason for the difference could be found.

To establish an approximate overall percent mean difference, further analysis was performed on the tests labeled "Difference Due To Type of Mold" from the following reports:

1. Eugene Sand and Gravel Phase Two
2. Morse Brothers, Inc. Harrisburg Phase One
3. Morse Brothers, Inc. Clackamas
4. River Bend, Salem

The test results from Eugene Sand and Gravel Phase One will not be used in the analysis because the compressive strength tests were not corrected for cylinder diameter.

Table 7 shows the percent mean difference for each group of test results, and the overall results for mean compressive strengths, standard deviations, mean difference and percent mean difference.

The unweighted percent mean difference overall of the cylinders used in these reports show that the plastic cylinder molds produced approximately 7.0% lower strengths then the steel molds.

Based on the results of this study, the Materials Section has adopted a value of 6% as the overall difference between plastic cylinders and steel cylinders. This value was selected because of the consistent results obtained in the Morse Bros. Harrisburg, Morse Bros. Clackamas, and River Bend reports, and because of the small percentage of prestress concrete produced at the Eugene Sand and Gravel prestress yard. This value was also selected because of the River Bend report results, since they are representative of the large volume of moderate strength concrete used around the State.

SUGGESTIONS FOR FUTURE RESEARCH

At this time no further studies are proposed to determine if there is a difference in compressive strengths between plastic molds and steel molds. A difference has been well established. However, this study did not determine a reason why the difference exists. Possible areas for future research include:

1. A study to determine which molds (plastic or steel) produce compressive strength results that are more representative of actual strength in the structure as determined from concrete cores.

2. Further study of the thermal conductivity of the molds, including:
   a. Larger population of test cylinders than used in report 4.
   b. The effects of different types of cement and admixtures.

3. The effects of mix design properties could be tested, including:
   a. Cement content
   b. aggregate sources

4. Further literature research and testing of the effects of mold type on concrete reaction rate and hydration.

TABLE I

Report 1 EUGENE SAND AND GRAVEL HIGH STRENGTH CONCRETE RESEARCH STUDY

TEST 1 Difference Due To Test Lab and Equipment

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Eugene Sand and Gravel	7515	182	57.5	2.42
OSHD MATERIALS LAB	7123	331	104.67	4.65

MEAN DIFFERENCE	392
PERCENT OF MEAN DIFFERENCE	5.22%
STANDARD ERROR OF MEAN DIFFERENCE	119.45
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	3.28
(0.5 - AREA)2	0.001
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TEST 2 Difference Due To Type of Test Mold

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
STEEL	7284	180	56.92	2.47
PLASTIC	6297	172	54.39	2.73

MEAN DIFFERENCE	987
PERCENT OF MEAN DIFFERENCE	13.55%
STANDARD ERROR OF MEAN DIFFERENCE	78.73
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	12.54
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE I (CONTINUED)

TEST 3 Difference Due To Long-Term Cure

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
WATER TANK	7122	331	104.67	4.65
OSHD MOIST CURE ROOM	7284	180	56.92	2.47

MEAN DIFFERENCE	162
PERCENT OF MEAN DIFFERENCE	2.22%
STANDARD ERROR OF MEAN DIFFERENCE	119.15
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	1.36
(0.5 - AREA)2	0.17
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	83

TEST 4 Difference Due To Intermediate Cure

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
IMMEDIATE TRANSPORTED	6292	171	54.07	2.72
TEMPORARY STORAGE	6034	137	43.32	2.27

MEAN DIFFERENCE	258
PERCENT OF MEAN DIFFERENCE	4.10%
STANDARD ERROR OF MEAN DIFFERENCE	69.28
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	3.724
(0.5 - AREA)2	0.0002
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE I (CONTINUED)

TEST 5 Difference Due To Method of Transporting

a. ASTM SAND VS OSHD RACKS

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
ASTM SAND	6034	137	43.32	2.27
OSHD RACK	5965	162	51.23	2.72

MEAN DIFFERENCE	69
PERCENT OF MEAN DIFFERENCE	1.14%
STANDARD ERROR OF MEAN DIFFERENCE	67.09
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	1.03
(0.5 - AREA)2	0.303
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	70

b. ASTM SAND VS BACK OF PICKUP

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
ASTM SAND	6034	137	43.32	2.27
BACK OF PU	5928	136	43.01	2.29

MEAN DIFFERENCE	106
PERCENT OF MEAN DIFFERENCE	1.76%
STANDARD ERROR OF MEAN DIFFERENCE	61.04
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	1.74
(0.5 - AREA)2	0.08
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	92

TABLE 2

Report 2 EUGENE SAND AND GRAVEL HIGH STRENGTH CONCRETE RESEARCH STUDY

TEST 1 Difference Between Eugene Sand and Gravel and OSHD Steel Molds

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Eugene Sand and Gravel	6359.5	287.08	90.78	4.51
OSHD MATERIALS LAB	6544	239.36	75.69	3.66

MEAN DIFFERENCE	184.5
PERCENT OF MEAN DIFFERENCE	2.82%
STANDARD ERROR OF MEAN DIFFERENCE	118.19
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	1.56
(0.5 - AREA)2	0.119
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	88

TEST 2 Difference Due To Sealed and Unsealed Steel Molds

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
SEALED STEEL	6359.5	287.08	90.78	4.51
UNSEALED STEEL	6276.5	108.77	34.40	1.73

MEAN DIFFERENCE	83
PERCENT OF MEAN DIFFERENCE	1.31%
STANDARD ERROR OF MEAN DIFFERENCE	97.08
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	0.855
(0.5 - AREA)2	0.390
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	61

TABLE 2 (CONTINUED)

TEST 3 Difference Due To Method of Consolidation

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
VIBRATED	7000.5	146.16	46.22	2.09
RODDED	6276.5	108.77	34.40	1.73

MEAN DIFFERENCE	724
PERCENT OF MEAN DIFFERENCE	10.34%
STANDARD ERROR OF MEAN DIFFERENCE	57.62
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	12.57
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

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TEST 4 Difference Due To Type of Mold

a. EUGENE SAND AND GRAVEL VS OSHD PLASTIC

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Eugene S & G Steel	6359.5	287.08	90.78	4.51
OSHD Plastic	5788.5	125.7	39.75	2.17

MEAN DIFFERENCE	571
PERCENT OF MEAN DIFFERENCE	8.98%
STANDARD ERROR OF MEAN DIFFERENCE	99.10
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	5.762
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE 2 (CONTINUED)

TEST 4 (Continued)

b. OSHD STEEL VS OSHD PLASTIC

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
OSHD Steel	6544	239.36	75.69	3.66
OSHD Plastic	5788.5	125.70	39.75	2.17

MEAN DIFFERENCE	755.5
PERCENT OF MEAN DIFFERENCE	11.54%
STANDARD ERROR OF MEAN DIFFERENCE	85.49
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	8.837
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

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c. EUGENE SAND AND GRAVEL AND OSHD STEEL VS OSHD PLASTIC

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Combined Steel	6451.8	663.25		
OSHD Plastic	5788.5	125.7	39.75	2.17

MEAN DIFFERENCE	663.3
PERCENT OF MEAN DIFFERENCE	10.28%
STANDARD ERROR OF MEAN DIFFERENCE	75.53
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	8.782
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE 3

Repot 3 MORSE BROTHERS INC, HARRISBURG CONCRETE CYLINDER MOLD INVESTIGATION

TEST 1 Difference Due To Mold Flexibility

a. OSHD PLASTIC VS OSHD PLASTIC WITH SHEET METAL JACKETS

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Plastic	7634.5	165.13	52.22	2.16
Metal Jacket	7413.5	119.58	37.81	1.61

MEAN DIFFERENCE	221
PERCENT OF MEAN DIFFERENCE	2.89%
STANDARD ERROR OF MEAN DIFFERENCE	64.47
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	3.428
(0.5 - AREA)2	0.001
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

b. MORSE BROTHERS INC, HARRISBURG STEEL VS OSHD PLASTIC W/SHEET METAL JACKET

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Steel	8015	232.98	73.66	2.91
Metal Jackets	7413.5	119.58	37.81	1.61

MEAN DIFFERENCE	601.5
PERCENT OF MEAN DIFFERENCE	7.50%
STANDARD ERROR OF MEAN DIFFERENCE	82.80
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	7.264
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE 3 (CONTINUED)

TEST 2 Difference Due To Type of Mold

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Steel	8015	232.98	73.66	2.91
Plastic	7634.5	165.13	52.22	2.16

MEAN DIFFERENCE	380.5
PERCENT OF MEAN DIFFERENCE	4.75%
STANDARD ERROR OF MEAN DIFFERENCE	90.29
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	4.214
(0.5 - AREA)2	0.000
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

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TABLE 4

Report 4 MORSE BROTHERS INC, HARRISBURG CONCRETE CYLINDER MOLD INVESTIGATION

TEST 1 Difference Due To Mold Flexability

a. OSHD PLASTIC VS OSHD PLASTIC WITH SHEET METAL JACKET

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Plastic	6088.5	101.33	32.04	1.66
Metal Jackets	6059.5	92.51	29.25	1.53

MEAN DIFFERENCE	29
PERCENT OF MEAN DIFFERENCE	0.48%
STANDARD ERROR OF MEAN DIFFERENCE	43.38
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	0.669
(0.5 - AREA)2	0.2486
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	75

TABLE 4 (CONTINUED)

TEST 1 Difference Due To Mold Flexibility (Continued)

b. MORSE BROTHERS HARRISBURG VS OSHD PLASTIC WITH SHEET METAL JACKET

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Steel	6205.5	161.44	51.05	2.60
Metal Jacket	6059.5	92.51	29.25	1.53

MEAN DIFFERENCE	146
PERCENT OF MEAN DIFFERENCE	2.35%
STANDARD ERROR OF MEAN DIFFERENCE	58.84
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	2.481
(0.5 - AREA)2	0.0132
SIGNIFICANCE @ 95% CONFIDENCE	SIGNIFICANT
CONFIDENCE LEVEL	99

TEST 2 Difference Due To Thermal Conductivity

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Steel	6205.5	161.44	51.05	2.60
Plastic	6088.5	101.33	32.04	1.66

MEAN DIFFERENCE	117
PERCENT OF MEAN DIFFERENCE	1.89%
STANDARD ERROR OF MEAN DIFFERENCE	60.27
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	1.9413
(0.5 - AREA)2	0.0524
SIGNIFICANCE @ 95% CONFIDENCE	NONE
CONFIDENCE LEVEL	95

TABLE 5

Report 5 MORSE BROTHERS INC, CLACKAMAS CONCRETE CYLINDER MOLD INVESTIGATION

TEST 1 Difference Due To Type of Mold

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Steel	7462.5	708.73	125.28	9.50
Plastic	6998.1	711.4	125.75	10.17

MEAN DIFFERENCE	464.4
PERCENT OF MEAN DIFFERENCE	6.22%
STUDENT t VALUE	10.84
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE 6

Report 6 RIVER BEND SALEM CONCRETE CYLINDER MOLD INVESTIGATION

Test 1 Difference Due To Type of Mold

SAMPLE SOURCE	MEAN (X)	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	COEFFICIENT OF VARIATION
Steel	4511	304.6	76.15	6.75
Plastic	4216	202	50.50	4.79

MEAN DIFFERENCE	295
PERCENT OF MEAN DIFFERENCE	6.54%
STANDARD ERROR OF MEAN DIFFERENCE	91.37
RATIO (MEAN DIFFERENCE/STANDARD ERROR OF MEAN DIFFERENCE)	3.23
(0.5 - AREA)2	0.0012
SIGNIFICANCE @ 95% CONFIDENCE	HIGHLY
CONFIDENCE LEVEL	99

TABLE 7

	Percent mean difference
Eugene Sand and Gravel Phase Two	
Report 2	
Test 4 (a) Eugene S & G steel vs OSHD plastic	8.98%
Test 4 (b) OSHD steel vs OSHD plastic	11.54%
Morse Brothers, Inc. Harrisburg Phase One	
Report 3	
Test 2	4.75%
Morse Brothers, Inc. Clackamas	
Report 5	
Test 1	6.22%
River Bend, Salem	
Report 6	
Test 1	6.54%

PLASTIC
MEAN = 6198.9
STANDARD DEVIATION = 1269.9

STEEL
MEAN = 6664.7
STANDARD DEVIATION = 1309.5

OVERALL
MEAN DIFFERENCE = 465.8
PERCENT MEAN DIFFERENCE = 6.99%