U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

REGION THREE

BALTIMORE, MARYLAND 21201

W.H. White
Regional Federal Highway Administrator

# Aggregate Gradation Control Study

Supplement to "Review of the States' Quality Control Procedures Used in Manufacturing Portland Cement Concrete - December 1967"

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U. S. DEPARTMENT OF TRANSPORTATION

# FEDERAL HIGHWAY ADMINISTRATION

| SUBJECT | FHWA BULLETIN |
|---|---|
| Quality Assurance Program: Aggregate Gradation Control Study (Portland Cement Concrete Coarse Aggregate) | March 29, 1976 |

The purpose of this Bulletin is to transmit informational copies of an Aggregate Gradation Control Study of Coarse Aggregate (AASHTO Designated Size No. 57) used in portland cement concrete. The study was a cooperative effort involving 20 participants; the State highway agencies of Maryland, District of Columbia, Delaware, Ohio, Pennsylvania, Virginia, and West Virginia; and the Region 3 Office of the Federal Highway Administration.

The study addresses two major questions:

1. Under existing construction practice does gradation of No. 57 aggregates change from point of production (quarry) to point of incorporation (batch plant), so as to significantly affect the quality of the concrete?

2. What areas should be further explored for future development of more realistic and practical gradation control procedures?

In answer to these two questions, study findings support the use of a single gradation indicator known as the Hudson $\bar{A}$. Such an indicator may be related closely to cement requirements and hence, concrete quality. Recommendations are also given for the use of the Hudson $\bar{A}$ as a method of controlling aggregate gradations for portland cement concrete.

The information and procedures set forth in this report should be of considerable interest to those Federal, State, and industry personnel working in the area of quality assurance especially as it relates to aggregate gradation control and portland cement concrete production.

In this regard the report should be brought to the attention of those involved in specification development, materials

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production, and construction. Sufficient copies are being furnished to provide two to each region and division and four to each State highway department.

Requests for additional copies may be directed to the U.S. Department of Transportation, Federal Highway Administration, Office of Highway Operations (HHO-32), Washington, D.C. 20590.

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Associate Administrator for
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Attachment

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# ACKNOWLEDGEMENT

We are grateful for the excellent cooperation and participation given by the following:

State Highway Department Central Laboratories:

| | |
|---|---|
| Maryland | Pennsylvania |
| District of Columbia | Virginia |
| Delaware | West Virginia |
| Ohio | |

Special assistance in developing report data:

Mr. G. W. Steele - West Virginia Department of Highways
Mr. J. W. Burdell, Jr., Chief, Fed. Aid Div., Ofc/Engineering, Wash, DC
Mr. J. P. Dunne, Jr., Specifications and Materials Engineer

Private Industry:

Kurtz Quarry - Denver, Pennsylvania
Petrillio Brothers - Wilimington, Delaware
Forrestville Concrete Company - Washington, D. C.
Contee Sand and Gravel Company - White Oak, Maryland
Marble Cliff Quarries Company - Columbus, Ohio
Arrow Universal Concrete Company - Columbus, Ohio
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Central Builders - New Columbia, Pennsylvania
Duquesne Sand Company - Pittsburgh, Pennsylvania
Faylor Lime and Stone Company - Winfield, Pennsylvania
Rockville Stone Company - Hylas, Virginia
Southern Materials Ready Mix - Couchland, Virginia
Fairmont Wall Plaster Company - Fairmont, West Virginia
Greer Limestone Company - Greer, West Virginia
Ohio Valley Sand Company - New Martinsville, West Virginia
Concrete Supply Company - St. Albans, West Virginia
Richards & Sons - Apple Grove, West Virginia

Synopsis.

The purpose of this review was to measure the effects of No. 57 coarse aggregate gradation and segregation on the cement efficiency as measured by workability and quality in Portland Cement Concrete.

Under then prevalent highway department control procedures, the aggregates could be sampled, tested, and accepted for gradation at various points prior to the batching, such as the quarry stockpile, or concrete plant stockpile. Additional handling of aggregates prior to incorporation into the concrete could cause segregation that would affect cement efficiency.

Eleven separate field studies (3 cycles each = total 33 cycles) of procedures then currently being used to control gradation in concrete aggregates were conducted; each involved sample increments from the stockpile and batcher sample increments taken at the last practical point before entering the mix. In some instances, sample increments were also lifted at an intermediate point between the stockpile and batcher points. Fine aggregate sample increments were also taken at the batcher point to determine compliance with specification requirements.

The effect of the gradation changes in the No. 57 aggregate upon the cement efficiency was evaluated, utilizing the NCHRP Report NO. 5 $\overline{A}$ (single number) analysis method. The $\overline{A}$ value is related to the surface area and voidage of the coarse aggregate and expresses the relative coarseness of an aggregate gradation.

Overall, the data would indicate that a statistically significant change in gradation between stockpile and batcher may occur. However, the concrete produced in all cases during this study was judged "good" in the opinion of the experienced engineers. This indicates that with current handling procedures, segregation of No. 57 (one size) coarse aggregate is being adequately controlled so that quality of concrete is not substantially affected.

This study indicates that a more realistic control of gradation in No. 57 aggregates could be accomplished by using the average gradation from the job mix as a target, rather than the middle of the specification band. This would be similar to the procedures now being used to control bituminous concrete mixes. The mid-band appears to have limited significance in concrete production; also, incorporation of some material outside the AASHTO Specification band may be tolerated.

This study supports the NCHRP Report No. 5 comment that the $\bar{A}$ analysis method provides a more consistent measure of relative segregation than the limits of the percentages passing the individual sieves, and appears suitable as a field control procedure and for gradation acceptance.

## I. Introduction

It is an established fact that aggregates may segregate through handling, transporting, and stockpiling prior to incorporation into a concrete mix. In many instances, it has been considered expedient to accept aggregates for gradation at various points prior to batching such as the quarry stockpile, or concrete plant stockpile even though ASTM D-75, Sampling Aggregates, cautions against this practice. We can conclude that segregation may occur after acceptance when further handling of the aggregates is involved, and this, in turn, could influence cement efficiency.

A 1967 field study provided enough scattered evidence to indicate that sampling techniques and frequencies left doubt as to whether gradation results for job control could give a true picture of field conditions. For example, when results are evaluated singly, one sample increment from a high-coned stockpile containing as much as 1000 tons of aggregate could hardly be considered as representative. Sampling techniques on stockpiles vary from taking samples at the high, middle, and low points to sampling from either the clam bucket or front-end loader bucket. There is a marked lack of consistency of opinion among field inspectors in regard to sampling stockpiles.

Inspectors, recognizing fallacies under commonly practiced frequencies and procedures, have been reluctant to reject or order reprocessing of materials on the basis of failing aggregate gradation tests.

Generally, sampling and testing programs for controlling gradation in concrete aggregates has permitted additional handling after acceptance and prior to deposit of aggregates into the concrete mix. The foregoing raises some immediate questions:

How much segregation can be tolerated without adversely affecting the quality of the concrete mix? How can we develop realistic, workable field controls for aggregate gradation, whereby money spent in sampling, testing, and processing aggregates for gradation does not greatly exceed the return for the required control of quality in the concrete product?

NCHRP Report #5 "Effects of Different Methods of Stockpiling Aggregates" introduces a unique method of evaluating the effects of segregation by utilizing a single control, "$\bar{A}$ coarseness modulus", for coarse aggregates, rather than evaluating several sieve sizes as is presently done. This method of analysis was adopted for this gradation study. (See Appendix A).

The objectives of this study "Coarse Aggregates - Gradation Control" were to determine:

1. Do changes in gradation of No. 57 aggregates from quarry crusher to batcher under existing control procedures adversely affect concrete quality?

2. What areas should be further explored for future development of more realistic and practical gradation control procedures?

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the FHWA or any of the State agencies involved. This report does not constitute a standard, specification or regulation.

## II. Scope of Review

Eleven separate field studies were conducted; each involved sample increments at the stockpile and sample increments taken at the last practical point before entering the mix. In some instances, sample increments were also lifted at an intermediate point between the original stockpile and batcher points. The sampling plan is detailed in Figure A.

Aggregate sources were selected at random and samples were lifted by qualified State laboratory representatives. All sources were producing material to meet AASHTO Size No. 57, except one, which was producing Size No. 67. Each review was scheduled to include (1) five sample increments of coarse aggregate; (2) five sample increments of the same coarse aggregate prior to entry into the concrete batch (called batcher samples); (3) five samples of the fine aggregate (batcher sample only) being used with the particular coarse aggregate under review; (4) a repeat cycle of steps (1), (2), and (3) after an approximately 2 week interval; and (5) a second repeat cycle as described in (4). The coarse aggregates were tested for gradation and unit weight; $\overline{A}$ was computed. Fine aggregate was tested for gradation, and fineness modulus was computed. AASHTO T19 was used to determine unit weight; some States preferred the compacted weight procedure; others used the loose weight procedure. In either case, the same method was used throughout the particular study involved.

In order to avoid identifying the various contributors to this report, studies are numbered without reference to any particular State. Pictures representing studies are shown in Figure 1, 2, 3, . . 20. Figure 1 shows a typical batcher sample being taken.

## III. Evaluation of Results

The experiment is summarized in the following

Appendices:

Appendix A - The definition and use of $\overline{A}$ is described. Sample sizes used in the study met the requirements of NCHRP Report No. 5, Table 5.

Appendix B - Descriptions, pictures, and a brief resume of review results for each study are included.

Appendix C - All individual test results and computed statistical data are listed for each study.

Appendix D - Specification gradation limits and the average gradation test results (coarse aggregates only) for each cycle are illustrated graphically.

Concrete produced during the study was accepted as reasonably complying with the quality requirements of the specifying agency. All aggregates tested in this study were accepted and used in construction under job control procedures then in effect. This indicates that gradations found in the study were not of such nature as to adversely affect the quality of the concrete.

Appendix D illustrates graphically the relationship of the average stockpile and batcher gradations to the specification limits. These gradings generally follow the typical "S" curve. Both the average gradations and the $\bar{A}$ analysis indicates reasonable uniformity in the materials, however, few tended to group around the mid-band of the specifications. In fact, over 50 percent indicated appreciable percentages of material outside the specification band. This is not an unexpected finding since most traditional acceptance procedures would judge material represented by a sample that tested exactly on the upper or lower limit of the specification band as reasonably complying with specifications. Such a result would, if it were an unbiased estimate of the average, indicate that 50 percent of the material would fall outside the specification band.

The $\bar{A}$ value for each gradation was calculated as described in Appendix A. The test parameters including gradation results, $\bar{A}$, and unit weight for each individual sample are tabulated in Appendix C. This tabulation also includes the statistical analysis of each parameter.

The $\bar{A}$ values were checked against the criteria of ASTM E178, Dealing With Outlying Observations. Two values, one batcher sample increment in Study #2 and one plant sample increment in Study #3, were considered to be outliers and were eliminated from the analysis.

NCHRP Report #5 recommends that the acceptance criteria use the formula $\bar{A}' \pm 1.04\, \sigma'$ to determine the acceptability of the average of five measurements on test increments, where $\bar{A}'$ is the target $\bar{A}$ determined from historical data from the production process and $\sigma'$ is the estimate of the standard deviation from historical data. The factor 1.04 is obtained by dividing the standard z - score at the 99 percentile level (2.326) by the $\sqrt{5}$.

The formula $\bar{A} \pm 2.76\, \sigma'$ was suggested by NCHRP Report #5 for determining acceptance of the individual increments, where $\bar{A}$ is the average of the five individual $\bar{A}$ increments. This formula provides an outlier check in accordance with ASTM E 178, Section 6. It should be noted, however, that the constant factor in this formula is applicable only when the population standard deviation is known. Such is seldom the case in highway materials, and it was believed desirable in this study to analyze for outliers using the standard deviation calculated from the same sample. Outliers herein before noted were eliminated by the latter method.

Further, it is noted that the factor 1.04 is applicable to a distribution estimated from a sample with at least 30 degrees of freedom. Since this study has a smaller sample size (nominally 15 increments per frame, with scheduling difficulty or outlier elimination resulting in 14 increments in some instances) this factor was converted to the appropriate value of Student's t, resulting in a factor of 1.17 for 14 degrees of freedom and 1.185 for 13 degrees of freedom.

Using the above criteria, a range for acceptance was calculated and tabulated in Table I, Resulting in acceptance criteria to be applied to $\bar{A}_5$, the average of five measurements on test increments.

Table II indicates that the coarse aggregate unit weight changes do not vary greatly and could be excluded as an evaluation factor in these particular studies.

Table II also illustrates the variations in the Fineness Modulus of the fine aggregates at the batcher point. In Studies 4, 5 and 6 fine aggregate sample increments were taken both in the stockpile and at the batcher point. The variability of the Fineness Modulus of the Fine Aggregates is small. However, the average F.M's compared with the middle specification F.M.'s differ by as much as .33 with 9 out of 11 studies showing a difference greater than .11. Normally, where changes of .2 or more in F.M. occur, the concrete mix is reviewed to determine if any changes in the mix proportions are necessary. This would indicate that the same conclusions reached for coarse aggregate may also be applicable to the fine aggregate gradations, and introduces the possibility of applying the $\bar{A}$ principle to total solids in the mix, rather than just the coarse mix.

Table III compares the variability of key specification coarse aggregate gradation sieves vs. $\bar{A}$. Results indicate a much greater range of variability on the 1/2", No. 4 and No. 8 sieves than on the $\bar{A}$ computations. It raises the question as to whether the sensitivity of quality measurement by the analysis of individual screens is suitable for practical use in construction.

## IV. Conclusions and Recommendations

This study, utilizing the $\bar{A}$ analysis method, indicates that an adequate gradation control of No. 57 coarse aggregates is achieved if test data from actual material produced are used to establish a quality control target, thus supporting the recommendations of NCHRP Report #5. In general, it was found that coarse and fine aggregate gradations produced under current control methods were reasonably uniform, but the gradations did not necessarily follow the middle of the specification band. Average overall production tends to fall within the specification band, however, a percentage of material outside the specification band can be tolerated. Present control procedures do not usually attempt to alter gradations produced so long as specification requirements are reasonably met. Findings in this study support the NCHRP Report No. 5 recommendations for utilizing the coarseness modulus $\overline{A}$. This method utilizes a single gradation indicator which may be related to cement requirements and, hence, concrete quality. Gradation alone is too cumbersome to be readily used as such. It would be desirable to use the actual parameters from the aggregate production process to establish the criteria for concrete trial mix design, and as a quality control target for $\overline{A}$ in coarse aggregates and F.M. in fine aggregate. This would be similar to current practice for controlling uniformity of aggregate gradations for bituminous concrete mixes by requiring close adherence to an approved job mix formula within the broad specification band.

It should be possible to detect and predict the need for mix adjustments from changes in $\overline{A}$ and F.M. (or conversely avoid the need for mix adjustments by controlling homogeneity of gradation) before unsatisfactory or unworkable concrete is produced. Acceptable tolerances to be applied to the job mix gradations for coarse aggregate and fine aggregate ($\overline{A}$ and F.M.) should be established from historical data or tests showing the effect on cement demand for gradations throughout the range of the specification band. Control of aggregate gradations should be recognized and used as a process control, not as an acceptance criteria for measuring the quality of concrete.

A suggested method of controlling aggregate gradations for Portland Cement Concrete is outlined as follows:

A. Establish the point or points in the processing sequence where sample increments are to be taken, and the sample increment frequency to be used to provide (1) effective process control on aggregate production; and (2) a check on adequacy of subsequent handling procedure to prevent segregation. The procedures of ASTM D 75, Sampling Aggregates, are recommended.

B. Establish control charts for evaluation of $\overline{A}$ in coarse aggregates and F.M. in fine aggregates. Also determine: the target $\overline{A}$ and F.M.; the upper and lower control limits where gradation changes could indicate a change in cement demand or require complete redesign of the mix proportions or other appropriate action; and the upper and lower limits (caution zone) where action is initiated so that necessary field changes or process review may be implemented.

The target $\overline{A}$ and F.M. are established from the mix design. The control limits where gradation changes could require major adjustments are determined from historical data or laboratory testing. The caution zones are to be used in day to day quality assurance during production and are to be set using a modification of the concepts of NCHRP Report No. 5. The data should be checked for outliers using the applicable procedure from ASTM E 178, Dealing With Outlying Observations (rather then the formula $\bar{A}_5 \pm 2.76\ \sigma'$ as given by Report No.5). The caution zones are determined from the formula $\bar{A}_5 = \bar{A}' \pm (as)$ where:

$\bar{A}_5$ = the average of five measurements on individual increments

$\bar{A}'$ = the target $\bar{A}$.

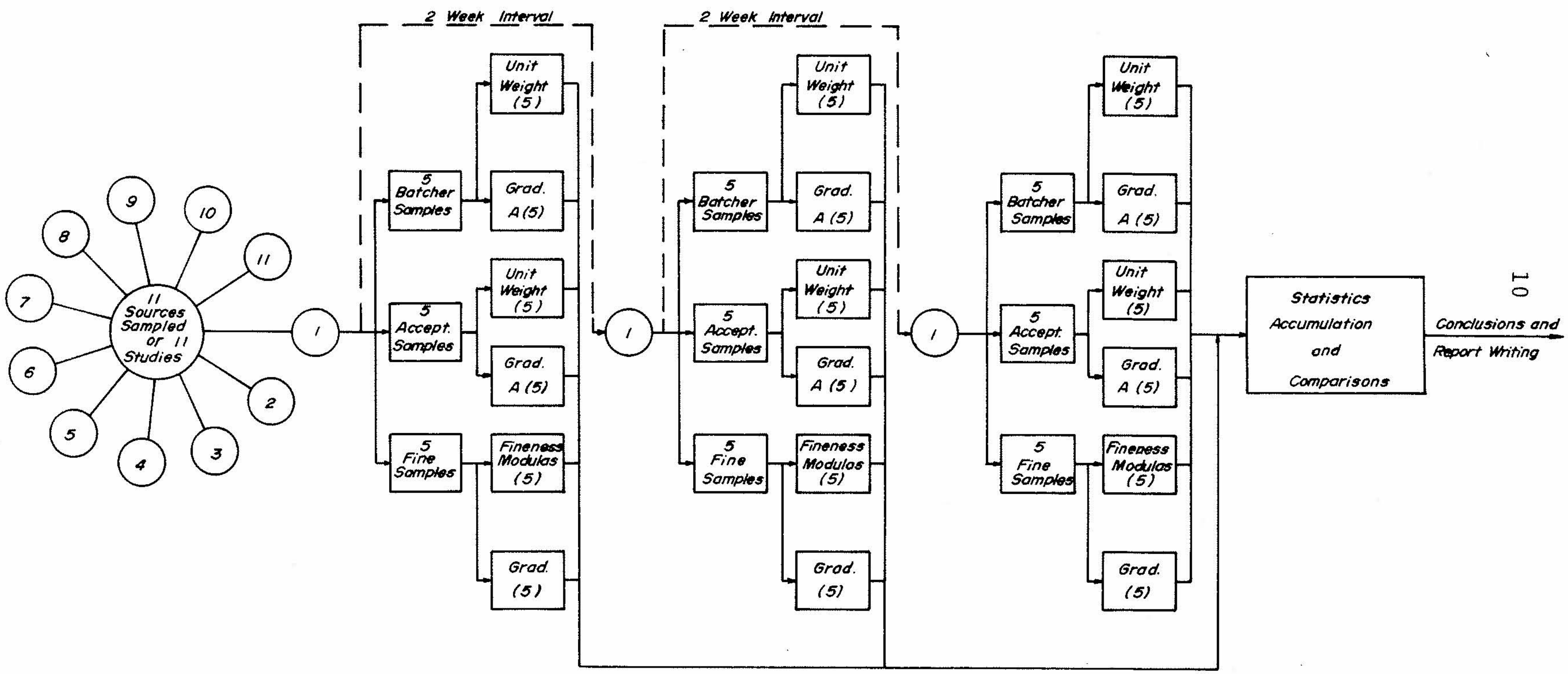
a = the 99 percentile value i.e., (1.04 When s is determined from a sample with at least 30 degrees of freedom or the appropriate value of Student's t when s is determined from a sample with less than 30 degrees of freedom.)

s = the estimated standard deviation of the production process.

C. Establish evaluation procedures based on test results plotted on control charts, which would include criteria for warnings to the producer or shutdowns of the operation. Note that the limits established from the concepts of NCHRP Report No. 5 become cautionary limits, and do not necessarily require stockpile rejection if not met.

# SAMPLING PLAN

*3 Cycles per source (study) yelded 15 acceptance * samples and 15 Batcher samples i.e., 5 per cycle=15. Also there were 15 fine aggregate samples taken.*




* *Acceptance samples are noted as stockpile samples in this report.*

FIG. A

TABLE I

**U.S. DOT FHWA - Region Three Aggregate Gradation Control Study**

SUMMARY - ACCEPTANCE CRITERIA

| Study | | $\bar{A}$ | s | N | Probable Error Of The Mean | Range $\bar{A} \pm 1.17_{14}, 1.185_{13}s$ |
|---|---|---|---|---|---|---|
| 1 | A | 2.14 | .065 | 15 | 2.106 to 2.174 | 2.064 to 2.216 |
| | B | 2.18 | .067 | 15 | 2.145 to 2.215 | 2.102 to 2.258 |
| 2 | A* | 2.19 | .043 | 14 | 2.167 to 2.213 | 2.139 to 2.241 |
| | B | 2.21 | .062 | 15 | 2.178 to 2.242 | 2.137 to 2.283 |
| 3 | A | 2.30 | .116 | 15 | 2.239 to 2.361 | 2.164 to 2.436 |
| | I* | 2.31 | .049 | 14 | 2.283 to 2.337 | 2.252 to 2.368 |
| | B | 2.35 | .094 | 15 | 2.301 to 2.399 | 2.240 to 2.460 |
| 4 | A | 1.93 | .073 | 14 | 1.890 to 1.970 | 1.843 to 2.016 |
| | B | 1.90 | .028 | 14 | 1.885 to 1.915 | 1.867 to 1.933 |
| 5 | A | 2.02 | .090 | 14 | 1.971 to 2.069 | 1.913 to 2.127 |
| | B | 1.98 | .077 | 14 | 1.938 to 2.022 | 1.889 to 2.071 |
| 6 | A | 2.04 | .057 | 14 | 2.009 to 2.071 | 1.972 to 2.108 |
| | B | 2.04 | .060 | 14 | 2.007 to 2.073 | 1.969 to 2.111 |
| 7 | A | 2.43 | .108 | 15 | 2.373 to 2.487 | 2.304 to 2.556 |
| | B | 2.54 | .078 | 15 | 2.499 to 2.581 | 2.449 to 2.631 |
| 8 | A | 2.09 | .174 | 15 | 1.999 to 2.181 | 1.886 to 2.294 |
| | I | 2.09 | .106 | 15 | 2.034 to 2.146 | 1.966 to 2.214 |
| | B | 2.31 | .231 | 15 | 2.189 to 2.431 | 2.040 to 2.580 |
| 9 | A | 2.44 | .182 | 15 | 2.345 to 2.535 | 2.227 to 2.653 |
| | B | 2.33 | .102 | 15 | 2.277 to 2.383 | 2.212 to 2.448 |
| 10 | A | 1.98 | .142 | 15 | 1.906 to 2.054 | 1.814 to 2.146 |
| | B | 2.21 | .159 | 15 | 2.127 to 2.293 | 2.024 to 2.396 |
| 11 | A | 2.31 | .131 | 15 | 2.241 to 2.379 | 2.157 to 2.463 |
| | B | 2.30 | .121 | 15 | 2.237 to 2.363 | 2.158 to 2.442 |
| Pooled | B | 2.18 | .184 | 147 | | |

A = Stockpile Sample
B = Batcher Sample
I = Intermediate Sample
* = One Outlier Excluded

$\bar{A}$ = Average A of Study frame, with N individual sample increments
s = Estimate of standard deviation of study frame
N = Individual sample increments in Study frame.

TABLE II - U. S. Department of Transportation, Federal Highway Administration - Region Three, Baltimore, Maryland
Aggregate Gradation Control Study
Summary - Coarse Aggregate Unit Weights and F.M. (Fineness Modulus) in Fine Aggregates

| | C. A. Unit Wgt | | | | | | F. A. Fineness Modulus (F.M.) (Batcher Samples Only) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stockpile Sample | | | Batcher Point | | | | | | |
| Study | Ave. Wgt | σ | $\bar{V}$ | Ave. Wgt | σ | $\bar{V}$ | Mid Spec F.M. | Ave. F.M. | σ | $\bar{V}$ |
| # 1 | 93.1 | .93 | 1.0 | 95.3 | 1.0 | 1.0 | 2.90 | 2.82 | .11 | 3.9 |
| # 2 | 110.1 | .93 | 0.8 | 110.1 | .93 | 0.8 | 2.90 | 2.69 | .04 | 1.5 |
| # 3 | 96.8 | 1.78 | 1.8 | 97.2 | 1.33 | 1.4 | 2.70 | 2.90 | .05 | 1.9 |
| # 4 | 94.8 | .80 | 0.8 | 94.8 | .45 | 0.5 | 2.87 | 2.77 | .04 | 1.4 |
| # 5 | 93.1 | .83 | 0.9 | 93.8 | .68 | 0.7 | 2.87 | 2.98 | .11 | 3.7 |
| # 6 | 75.9 | .54 | 0.7 | 75.0 | .50 | 0.7 | 2.87 | 2.63 | .04 | 1.5 |
| # 7 | 106.1 | .84 | 0.8 | 107.0 | .89 | 0.8 | 2.94 | 2.83 | .08 | 2.8 |
| # 8 | 98.6 | .52 | 0.5 | 99.6 | 1.31 | 1.3 | 3.09 | 3.24 | .10 | 3.1 |
| # 9 | 105.7 | .67 | 0.6 | 107.8 | .93 | 0.9 | 2.96 | 2.63 | .06 | 2.3 |
| #10 | 100.1 | 2.03 | 2.0 | 101.7 | 2.10 | 2.1 | 2.88 | 2.81 | .05 | 1.8 |
| #11 | 86.7 | 1.24 | 1.4 | 86.6 | 1.18 | 1.4 | 2.88 | 2.78 | .09 | 3.2 |

NOTE: Comparison of coarse aggregate unit weights between studies is not significant because the specific gravities of the materials used and the methods for measuring unit weight varied. Some States used the AASHO T19 compact weight method; others used the loose weight method. In either case the same method was used throughout the particular study involved.

Since the coefficients of variability in the coarse aggregate unit weights are small, the intermediate sampling points of studies #3 and #8 are not shown in this table.

See Appendix C for individual computations

**TABLE III - U. S. Dept. of Trans. - Fed. Hwy. Adm. - Region Three, Balto., Md.**
**Aggregate Gradation Control Study**
**Coarse Aggregate - Comparison of Variability - % Material Passing Key Specification Sieves vs. $\bar{A}$**

| Study | | ½" Sieve Accp | ½" Sieve Bat | #4 Sieve Accp | #4 Sieve Bat | #8 Sieve Accp | #8 Sieve Bat | $\bar{A}$ Accp | $\bar{A}$ Bat |
|---|---|---|---|---|---|---|---|---|---|
| # 1 | $\bar{X}$ | 42.0 | 40.7 | 2.6 | 3.7 | 1.5 | 2.3 | 2.14 | 2.18 |
| | $\sigma$ | 5.7 | 7.0 | .7 | .8 | .5 | .7 | .06 | .07 |
| | $\bar{V}$ | 13.6 | 17.1 | 28.3 | 21.4 | 35.2 | 31.0 | 3.0 | 3.1 |
| # 2 | $\bar{X}$ | 49.0 | 51.0 | 3.1 | 3.0 | 1.0 | 1.0 | 2.17 | 2.21 |
| | $\sigma$ | 3.5 | 4.8 | .5 | .8 | 0 | 0 | .06 | .06 |
| | $\bar{V}$ | 7.2 | 9.0 | 14.9 | 28.2 | 0 | 0 | 2.9 | 2.8 |
| # 3 | $\bar{X}$ | 53.2 | 56.1 | 6.6 | 7.9 | 1.6 | 2.0 | 2.30 | 2.35 |
| | $\sigma$ | 3.3 | 4.5 | 3.0 | 1.8 | .8 | .8 | .11 | .09 |
| | $\bar{V}$ | 6.2 | 8.0 | 45.4 | 22.7 | 50.3 | 41.9 | 5.0 | 4.0 |
| # 4 | $\bar{X}$ | 34.4 | 31.2 | .6 | .7 | .3 | .3 | 1.93 | 1.90 |
| | $\sigma$ | 6.1 | 2.9 | .45 | .3 | .3 | .14 | .07 | .03 |
| | $\bar{V}$ | 17.8 | 9.1 | 71.3 | 39.8 | 100.0 | 49.1 | 3.7 | 1.5 |
| # 5 | $\bar{X}$ | 40.6 | 37.5 | 2.4 | 2.9 | 0 | 0 | 2.02 | 1.98 |
| | $\sigma$ | 6.8 | 5.6 | .8 | .8 | 0 | 0 | .09 | .08 |
| | $\bar{V}$ | 16.8 | 15.0 | 34.9 | 27.7 | 0 | 0 | 4.4 | 3.8 |
| # 6 | $\bar{X}$ | 36.2 | 37.0 | 3.7 | 3.1 | 2.0 | 1.9 | 2.04 | 2.04 |
| | $\sigma$ | 3.9 | 4.5 | 1.2 | 1.0 | .4 | .4 | .06 | .06 |
| | $\bar{V}$ | 10.9 | 12.1 | 31.5 | 33.0 | 21.1 | 23.1 | 2.8 | 2.8 |
| # 7 | $\bar{X}$ | No | | 6.5 | 9.4 | 1.3 | 2.7 | 2.43 | 2.54 |
| | $\sigma$ | Specification | | 1.60 | 1.7 | .5 | 1.0 | .11 | .08 |
| | $\bar{V}$ | | | 24.7 | 17.9 | 36.6 | 37.8 | 4.5 | 3.1 |
| # 8 | $\bar{X}$ | 42.7 | 56.9 | 2.1 | 4.6 | 1.6 | 2.9 | 2.09 | 2.31 |
| | $\sigma$ | 14.5 | 12.0 | 2.2 | 3.8 | 2.2 | 2.7 | .17 | .22 |
| | $\bar{V}$ | 33.9 | 21.2 | 106.0 | 82.2 | 139.9 | 90.4 | 8.3 | 9.9 |
| # 9 | $\bar{X}$ | 65.5 | 56.8 | 5.1 | 4.8 | 1.4 | 2.3 | 2.45 | 2.33 |
| | $\sigma$ | 10.0 | 6.6 | 2.6 | 1.3 | .6 | .6 | .17 | .10 |
| | $\bar{V}$ | 15.3 | 11.7 | 51.9 | 27.5 | 45.2 | 26.4 | 7.1 | 4.4 |
| #10 | $\bar{X}$ | 39.5 | 46.8 | 2.4 | 5.4 | 1.3 | 3.4 | 1.98 | 2.21 |
| | $\sigma$ | 5.8 | 6.0 | 1.1 | 2.1 | .8 | 1.3 | .14 | .16 |
| | $\bar{V}$ | 14.8 | 12.8 | 46.0 | 39.0 | 58.7 | 38.6 | 7.1 | 7.2 |
| #11 | $\bar{X}$ | 50.4 | 49.6 | 4.6 | 4.2 | 2.5 | 2.3 | 2.31 | 2.30 |
| | $\sigma$ | 8.2 | 7.7 | 1.8 | 1.7 | .9 | 1.0 | .13 | .12 |
| | $\bar{V}$ | 16.2 | 15.6 | 39.0 | 40.1 | 37.7 | 41.8 | 5.7 | 5.2 |

$\bar{X}$ = **Mean**
$\sigma$ = **Standard Deviation**
$\bar{V}$ = **Coeff. Variability**

**Accp** - Stockpile Sample
**Bat** = **Batcher Sample**

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
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APPENDIX A
Aggregate Gradation Control Study
$\bar{A}$ Evaluation Procedures - NCHRP Report #5

## DEFINITION AND USE OF $\bar{A}$

$\bar{A}$ has been found to correlate well with factors associated with surface area, for example, the quantity of asphalt required for durability of bituminous paving mixtures, over a wide range of fine to coarse gradations. It can be shown that the area under the gradation curve on a semi-log plot is related to the surface area of the aggregate particles making up the gradation. This area can be defined by the base line and by ordinates having a height equal to the percentages passing the various sieves. $\bar{A}$ is a measure of this area and has a value equal to the sum of the heights of the 10 equally spaced ordinates plotted at the 1½ in., 3/4 in., 3/8 in., No.'s 4, 8, 16, 30, 50, 100 and 200 sieves. This value is conveniently found by adding the percentages which pass each of all 10 sieves, including those sieves which pass 100 percent of the aggregate, and dividing the total by 100.
(The amount of minus 8 material in the North Carolina No. 3 aggregate used in this study was so small that a gradation analysis on the No.'s 16, 30, 50, 100 and 200 sieves was not justified. It was found that multiplying the total minus 8 in each sample by three would produce a value approximately the same as would be calculated by passing the material through the nest of sieves.)
A batch of aggregate containing a large proportion of small particles has a high surface area and a high $\bar{A}$ value, whereas coarser aggregates have lower $\bar{A}$ values.

(1) Miller-Warden Associates, National Cooperative Highway Research Program Report 5, EFFECTS OF DIFFERENT METHODS OF STOCKPILING AGGREGATES INTERIM REPORT, 1964.

SUGGESTED TOLERANCES FOR MEASURED $\bar{A}$ VARIABILITY

It is necessary that guidelines be established for determining the limits of the range beyond which segregation could significantly affect the characteristics of a particular aggregate. A significant segregation effect may be defined as one which would change the gradation to an extent that would require adjustments in bitumen or cement content or would require changes in compactive effort to meet density or voids-requirements, or changes in blending proportions or screening set ups, or a host of other effects, as a result of excessive variations of percentages passing different sieve sizes. To be of maximum value, these changes in gradation must be expressed in terms of a single value combining all percentages, rather than independently using single percentages. Thus the $\bar{A}$ value is used.

In a previous research investigation conducted by Miller-Warden Associates, tolerance levels for different types of construction materials were established for four classification levels of criticality: critical, major, minor, and contractual. It is generally agreed that aggregate gradation falls into a classification of major when its effects on various types of construction units are considered. The tolerance guidelines previously developed appear to be appropriate for the purpose at hand. Several conditions must be stated at the outset for the application of these rules:

1. Five random increments of aggregate will be tested individually and an average $\bar{A}$ determined.

2. Total sample weight will be determined in accordance with Table 5 for the particular aggregate size involved. The sample should be taken in five approximately equal-sized increments so that the total weight of increments is equal to the total sample weight. The preferred method of securing sample increments is by defining a specific area on a conveyor belt and removing the total portion of aggregate from this area. This method is not practical in most cases, as stockpiled material is usually

picked up with a front-end loader or clam-bucket and loaded directly into trucks or bins. If hand-sampling must be employed, a sampling tool should be used which is at least four times wider than the largest maximum particle size and which is so constructed that none of the particles will overflow or roll from the tool. This device may be some type of scoop or shovel with built-up sides to prevent aggregate loss.

TABLE 5
TOTAL SAMPLE WEIGHT

| MAX. AGGREGATE SIZE | WEIGHT | RANGE OF ACCURACY ($\Delta$) |
|---|---|---|
| 3 in. | 500 | $\pm$ 3% |
| 2 in. | 400 | $\pm$ 2% |
| 1 in. | 250 | $\pm$ 1% |
| 1/2 in. | 80 | $\pm$ 0.5% |
| 3/8 in. | 60 | $\pm$ 0.5% |
| No. 4 | 8 | $\pm$ 0.5% |

3. An estimate of true standard deviation, $\sigma$, must be given. This estimate may be calculated from historical data, or it may be stated in terms of desired standard deviation. No attempt should be made to base a standard deviation on results of the five samples only, as these data are too limited to provide an accurate indication of the required value.

4. Statistical tolerances for acceptability will be applied to the individual measurement and to the sample average. Acceptance criteria will be stated accordingly.

5. The formula $\bar{A} \pm 1.04\sigma'$ will be used to determine the acceptability of the average of five measurements on test increments; $\bar{A}'$ is the desired value of $\bar{A}$, and $\sigma'$ is the estimate of the standard deviation of the FRAME ($\sigma'$). The formula $\bar{\bar{A}} \pm 2.76\sigma'$ will be used for determining acceptance of the individual increments. In this case, $\bar{\bar{A}}$ is the average of the five individual $\bar{A}$ measurements. If the group average is outside the calculated limits for averages or if a single increment is outside the calculated limits for individuals, the entire lot (stockpile) should be rejected as being too variable.

It is assumed that five sample increments have been properly secured and tested and that the following results have been obtained:

| SIEVE SIZE | TOTAL PERCENT PASSING | | | | |
| --- | --- | --- | --- | --- | --- |
| | NO. 1 | NO. 2 | NO. 3 | NO. 4 | NO. 5 |
| 1½ in. | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 3/4 in. | 80.0 | 73.7 | 75.7 | 80.3 | 69.5 |
| 3/8 in. | 18.6 | 13.7 | 12.8 | 15.9 | 11.6 |
| No. 4 | 2.3 | 0.9 | 1.5 | 1.2 | 1.3 |
| No. 8 | 1.1 | 0.5 | 0.5 | 0.5 | 0.8 |
| $\bar{A}$ | 2.042 | 1.898 | 1.915 | 1.989 | 1.848 |

In the example, the standard deviation, $\sigma'$, of $\bar{A}$ as calculated from a large FRAME had previously been determined to be 0.146. In the five increments tested, $\bar{A}$ runs from a low of 1.848 to a high 2.042 with an average of $\bar{\bar{A}} = 1.938$. Given the condition that the desired $\bar{A}$ value is 2.000, acceptability of the average would be calculated as being $2.000 \pm 1.04 \times 0.146$. Therefore, the average $\bar{A}$ must be between 1.848 and 2.152. A single test measurement is compared with the limits of $1.938 \pm 2.76 \times 0.146$. This means that individual values should fall between 1.535 and 2.341. In the example, both of these criteria for average and individual values are satisfied.

APPENDIX B U.S. Dept. of Trans. - Fed. Hwy. Adm. - Region Three, Balto., Md.

State Sampling and Testing Procedures - Study #1

Coarse Aggregate - #57 Limestone

Abrasion (LA) - 23%

Soundness - 2%

Specific Gravity - 2.55

Absorption - 2.3%

No clay lumps or coal

Trace of chert

Fine Aggregate

Specific Gravity - 2.54

Soundness - 5%

Absorption - 2.0%

Coarse aggregates are tested and approved for gradation at the quarry stockpiles (FIG. 2) Aggregates are loaded on dump trucks via a portable conveyor system shown in FIG. 2. Trucked aggregates are end dumped into a pit (left of building in FIG. 3) and transported by a conveyor system to the holding bins at the transit mix concrete plant; from the holding bins aggregates are discharged into weigh hoppers and then deposited into the mixer trucks. Study samples were taken from the quarry stockpiles and prior to material entering truck. (See FIG. 1)

STUDY RESULTS

Appendix D illustrates the #57 aggregates are graded on an "S" curve and the percentage of aggregates passing the 1" sieve favors the high side. (Specs 95-100% Actual 100%).

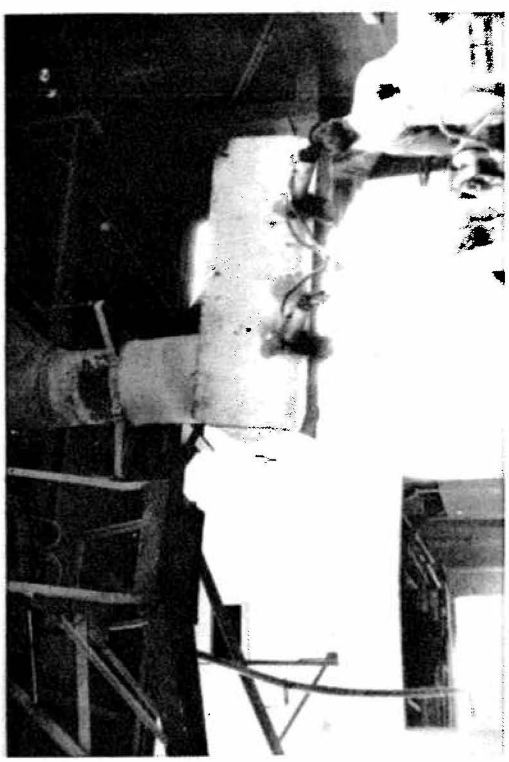

FIG. 1

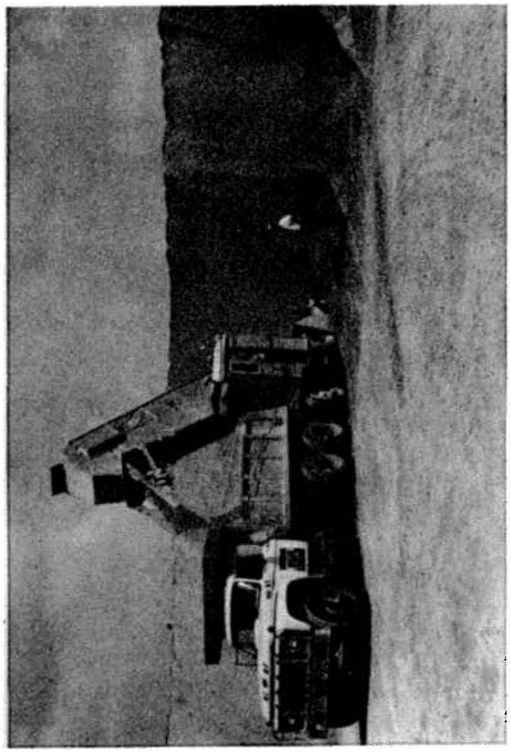

FIG. 2

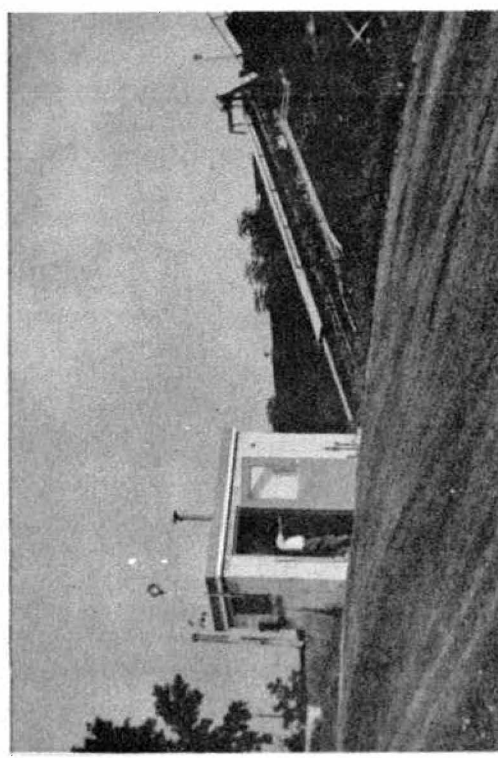

FIG. 3

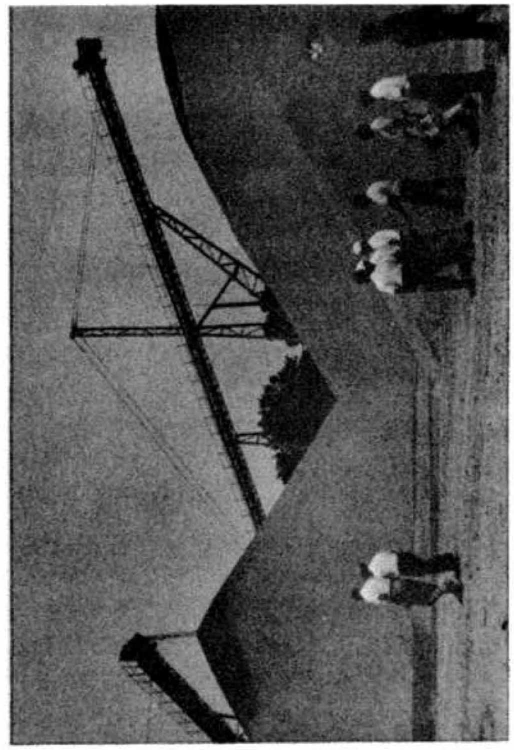

FIG. 4

APPENDIX B State Sampling and Testing Procedures - Study #2

Coarse Aggregate - #57 Gravel

Abrasion - 21%

Soundness - 5%

Specific Gravity - 2.60

Absorption - 2.00%

No clay lumps or coal

Trace of chert and shale

Fine Aggregate

Specific Gravity - 2.57

Soundness - 4%

Absorption - 1.73%

Coarse aggregates from the processing plant are deposited by conveyor into huge stockpiles as depicted in FIG. 4. These stockpiles are located over a reclaiming tunnel which houses a conveyor belt system. There are several hydraulically operated clam shell type gates located above the tunnel. These gates are controlled by means of a control panel; individual sizes and quantities of aggregates are deposited on the belt in order to blend a graded aggregate that will meet specifications. The producer utilizes a testing program whereby specific sizes composing each particular aggregate stockpile are known.

After the aggregate leaves the reclaiming tunnel it is transported via a conveyor system to the holding bin; it is then discharged to the weigh hoppers and eventually deposited into the transit mix concrete trucks. The concrete plant, conveyor system and holding bins are shown in FIG. 5. The State tests aggregates for gradation from the conveyor belt; this is the job control acceptance point. For this study samples were lifted from the conveyor belt (job control acceptance point) and prior to entry of aggregate into the mixer truck.

STUDY RESULTS

Appendix D illustrates the #57 aggregates are graded on an "S" curve but curve is flatter than in Study #1. As in Study #1 the percentage of aggregates passing the 1 inch sieve was 100%.

APPENDIX B State Sampling and Testing Procedures - Study #3

| Coarse Aggregate - #57 Granite | Fine Aggregate |
|---|---|
| Specific Gravity - 2.65 | Soundness - 5% |
| Abrasion - 21% | Specific Gravity - 2.64 |
| Absorption - 0.6% | Absorption - 0.3% |

Coarse aggregates are stockpiled and sampled at the quarry (FIG. 6). This is the job control acceptance point for both quality and gradation. The aggregates are trucked to the concrete plant where they are stockpiled in 8' layers by the end dumping method. The aggregates are removed from the stockpile with a front end loader, placed into a hopper as depicted in FIG. 7 and delivered by conveyor to the holding bins. From the holding bins aggregates are discharged into the weigh hoppers and then into the concrete mixer truck. Study samples were lifted; at the quarry stockpile, at the concrete plant stockpile, and prior to entry into the concrete mixer truck. The #5's and #7's are kept separated throughout the handling process (Quarry to concrete plant weigh hopper) and are weighed separately.

STUDY RESULTS

Appendix D again shows the "S" curve grading and also illustrates uniformity favoring the upper limits of the specifications.

The uniformity of aggregates in this study could be attributed to the handling of the #5 and #7 aggregates separately; they are blended into a #57 aggregate in the weigh hopper.

APPENDIX B State Sampling And Testing Procedures - Study #4

Coarse Aggregate - #57 Gravel

Specific Gravity - 2.60

Absorption - 1.1%

Soundness - 6%

Abrasion - 32%

Fine Aggregate

Specific Gravity - 2.65

Absorption - 1.2

Soundness - 3%

The deck barge shown in FIG. 8 is approved as a stockpiling area for coarse aggregates of this transmit mix concrete plant. Aggregates are sampled from the barge stockpile and tested for gradation; this is the job control acceptance point. Aggregates are then transported by clam shell to the holding bins. From the holding bins the aggregates are discharged into the weigh hoppers and then deposited into the concrete batch. Study samples were taken from the barge stockpiles and prior to entry into the concrete mixer truck (batcher sample).

STUDY RESULTS

As in Study #3 the grading of the aggregates follows an "S" curve, and are uniform. In this study the gradation favors the lower specification limits but all individual results meet specification requirements.

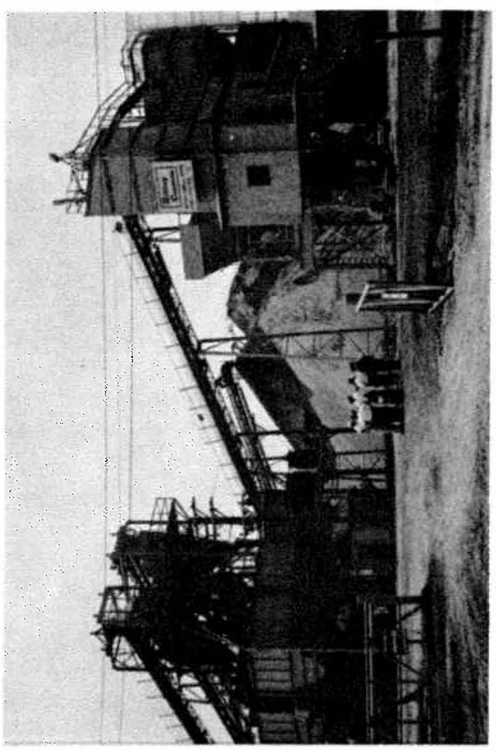

FIG. 5

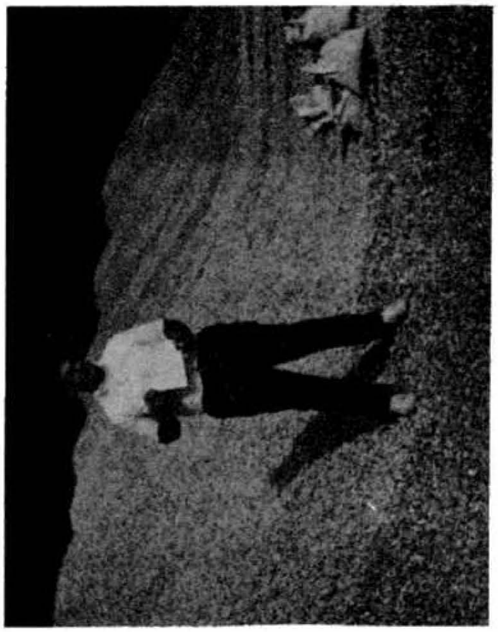

FIG. 6

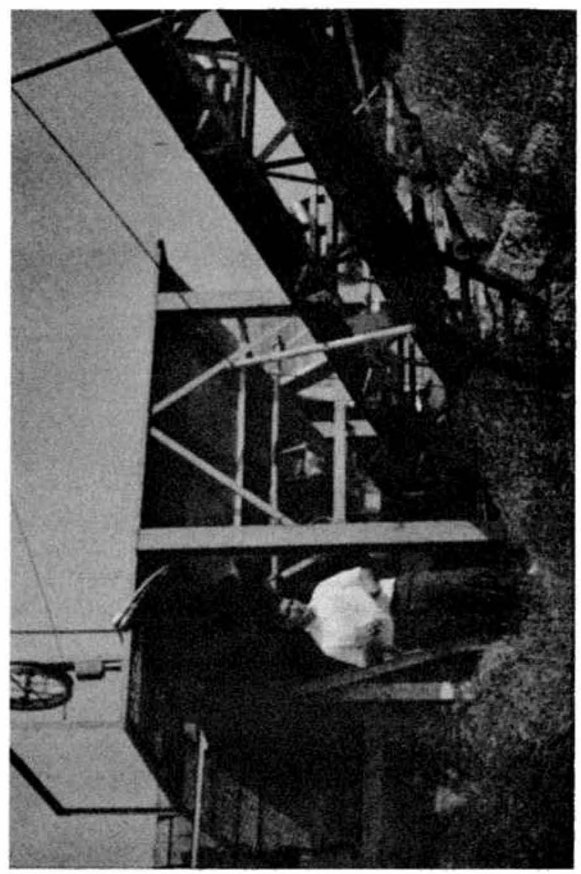

FIG. 7

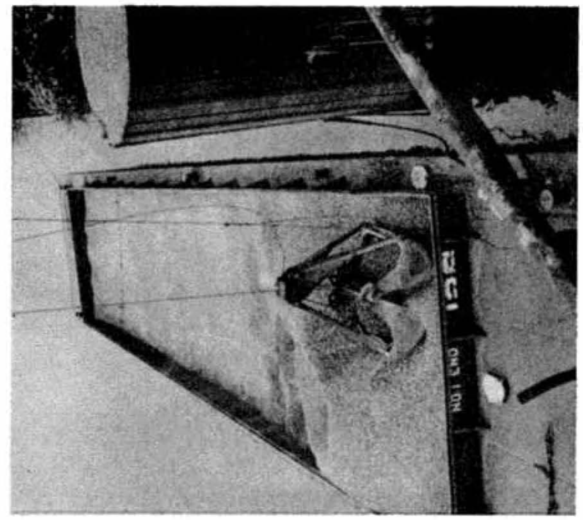

FIG. 8

APPENDIX B State Sampling and Testing Procedures - Study #5

Coarse Aggregate - #57 Limestone

Specific Gravity - 2.70

Absorption - 0.6

Abrasion - 19%

Soundness - 7%

Fine Aggregate

Specific Gravity - 2.60

Absorption - 1.1%

Soundness - 3%

The aggregates are trucked from the quarry to the transit mix concrete plant and end dumped into the partitioned bins as shown in FIG. 9 (clam bucket over center of stockpiles - partition shown on right side - half way point of picture). Second layer of stockpile is built by crane and clam bucket. The same crane and bucket transports aggregate to the holding bins, from which aggregates are discharged into the weigh hoppers and then into the mixer truck. Study samples were taken from the concrete plant stockpile and prior to entry into the mixer truck.

STUDY RESULTS

Appendix D illustrates the grading to be well within the specification limits.

FIG. 9

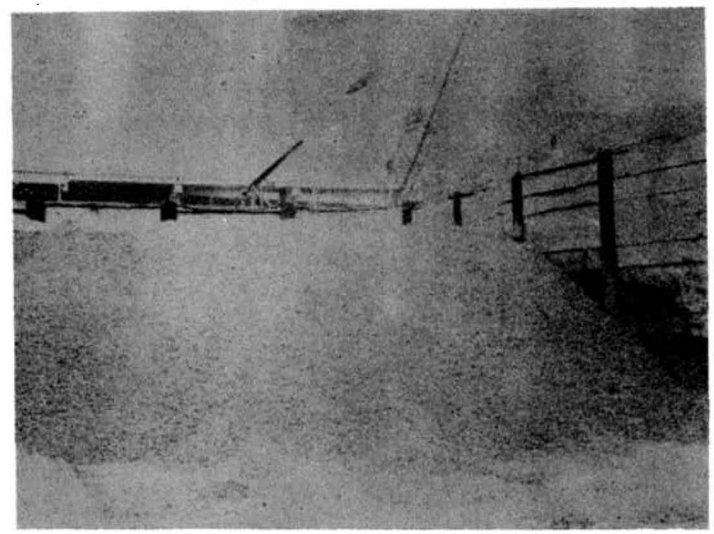

FIG. 10

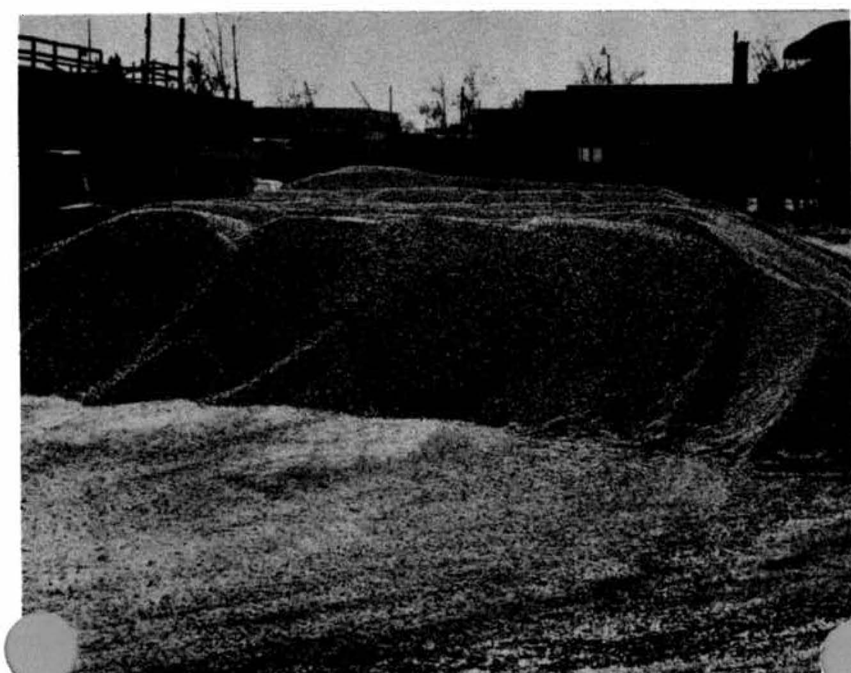

FIG. 11

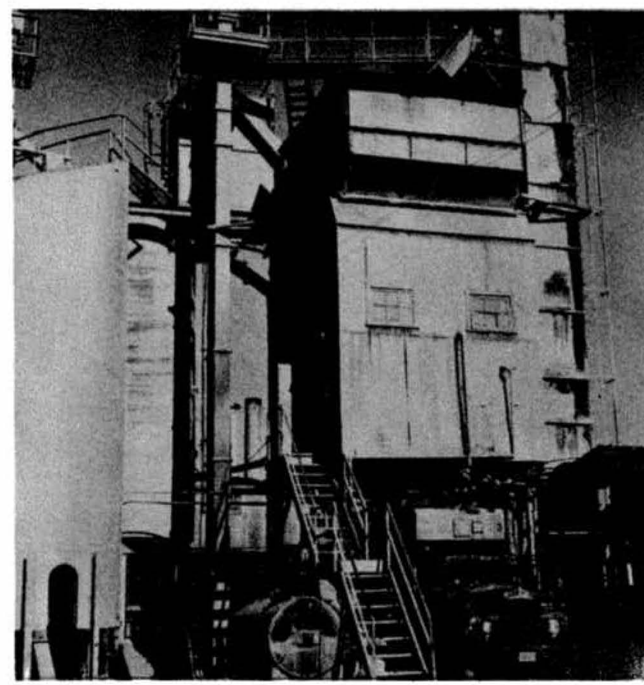

FIG. 12

APPENDIX B State Sampling and Testing Procedures - Study #6

Coarse Aggregate - #57 Slag

Specific Gravity - 2.32

Absorption - 3.9%

Soundness - 1%

Fine Aggregate

Specific Gravity - 2.60

Absorption - 1.5%

Soundness - 7%

Coarse aggregates are delivered by truck to the partitioned bins at the transit mix concrete plant. (FIG. 10 shows partitioned stockpiles). Material is dumped into the bin and a second layer is placed on top by means of a crane and clam bucket. Aggregates are tested for gradation from stockpile sample; this is the job control acceptance point. The same crane and bucket picks up aggregates and deposits them into holding bins, a point from which they are discharged into the weigh hoppers and then to the mixer truck. Study samples were lifted from the stockpile and prior to entry into concrete truck.

## STUDY RESULTS

Appendix D indicates "S" curve grading which is well within specification limits.

APPENDIX B State Sampling and Testing Procedures - Study #7

Coarse Aggregate - #67 Gravel

Abrasion - 35%

Specific Gravity - 2.58

Soundness - 4%

Absorption - 1%

Fine Aggregate

Soundness - 3%

Specific Gravity - 2.61

Absorption - 0.8%

Coarse aggregates are transported by truck and stored in stockpiles at the concrete plant (FIG. 11). Aggregates are picked up by a front end loader and deposited into a pit feeding a bucket conveyor system. This system feeds the holding bins, which deposit aggregates into the weigh hoppers. (FIG. 12 shows transit mix concrete plant - bucket conveyor at the right side of picture). Study samples were taken from stockpile (Job Control acceptance point) and prior to entry into the concrete batch (batcher sample).

STUDY RESULTS

Appendix D shows "S" curve grading; material passing larger sieve favors the lower limit of the specifications while material passing small sieves favors the middle and upper limits of the specifications. Grading is uniform but borderline on both the lower limit of the 3/4" sieve and upper limit of the #4 sieve.

APPENDIX B State Sampling and Testing Procedures - Study #8

| Coarse Aggregate - #57 Limestone | Fine Aggregate |
|---|---|
| Specific Gravity - 2.76 | Specific Gravity - 2.62 |
| Abrasion (LA) - 20% | |

The coarse aggregates are stockpiled at the quarry as shown in FIG. 13 (Stockpiles are approximately 5 ft. high); they are sampled and tested for gradation at this point. If the materials meets quality and gradation testing requirements they are approved for use. Aggregates are then transported to the concrete plant where they are stockpiled by the truck end dump method (See FIG. 14 - stockpile, conveyor system and batching plant shown) Front end loaders pick up aggregates from this stockpile and deposit them to a pit feeding the conveyor belt system. Aggregates are transported by the conveyor into the holding bins and the eventually to the weigh hoppers. This is a central mix concrete plant. For this study samples were lifted (1) at the quarry, (2) from the concrete plant stockpile and (3) as the material was discharged from the weigh hoppers into the central mixer.

STUDY RESULTS

Appendix D illustrates "S" curve grading favoring the high side of intermediate 3/4" sieve and the low side of the intermediate 3/8" sieve. It is interesting to note that the average of each group of 15 samples did meet requirements for materials passing specification sieves.

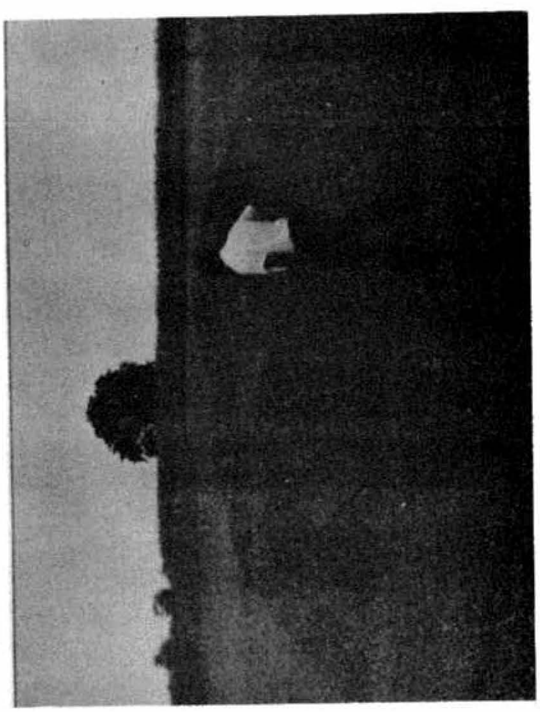

FIG. 13

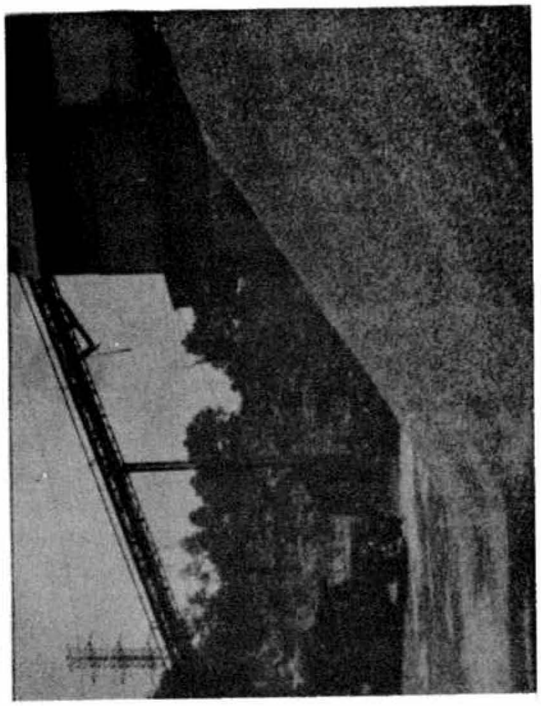

FIG. 14

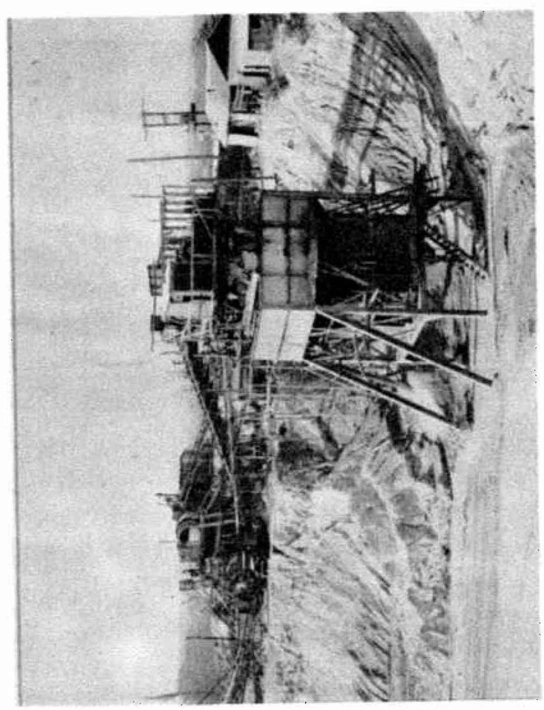

FIG. 15

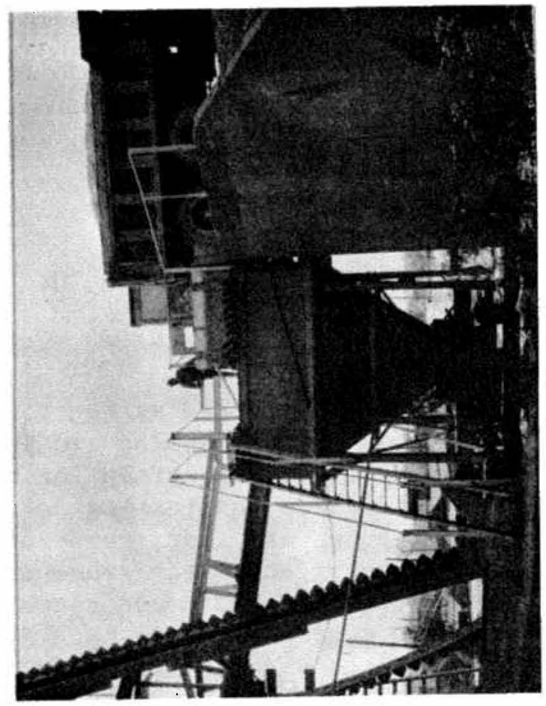

FIG. 16

APPENDIX B    State Sampling and Testing Procedures - Study #9

Coarse Aggregate - #57 Gravel

Specific Gravity - 2.62

Absorption - 0.6%

Abrasion - 33%

Soundness - 2%

Fine Aggregate

Specific Gravity - 2.59

Absorption - 0.9%

Soundness - 2%

The coarse aggregate is processed and then placed into the processing plant holding bins, from which dump trucks are loaded (FIG. 15). Trucks then transport material to hopper at transit mix concrete plant as depicted in FIG. 16. Bucket conveyor also shown in FIG. 16 transports aggregate to holding bins. As aggregates are discharged from the holding bin to the weigh hopper they are sampled by a sampling tray as shown in FIG. 17. This tray sample is the job control acceptance point for gradation. Study samples were taken as aggregates were discharged from the processing plant holding bins and from the sampling tray. For the purpose of this study the processing plant sample was considered as being the job control acceptance point and the sampling tray sample as the batcher point.

## STUDY RESULTS

Appendix D illustrates "S" curve, uniform grading with the upper limit line of the specifications being favored.

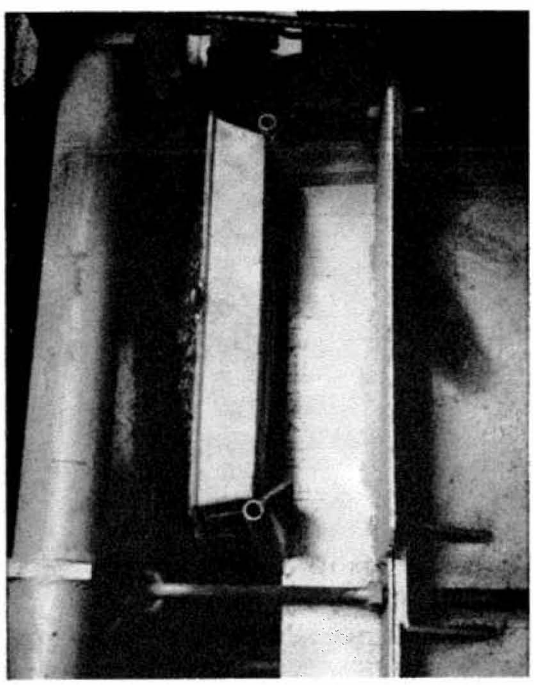

FIG. 17

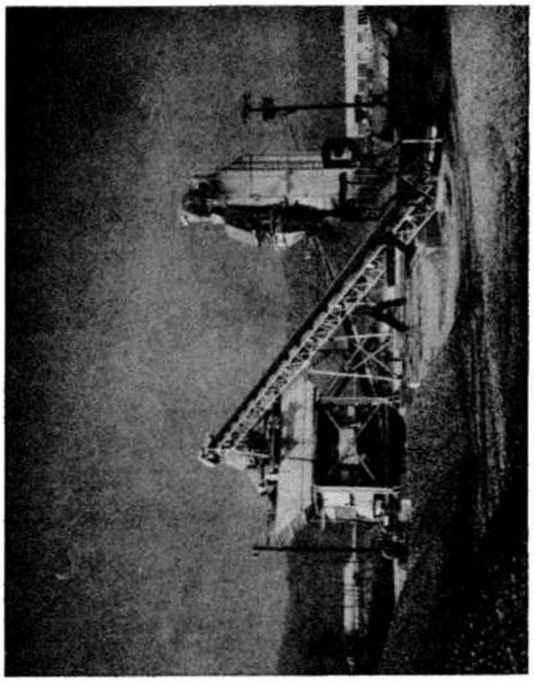

FIG. 18

FIG. 19

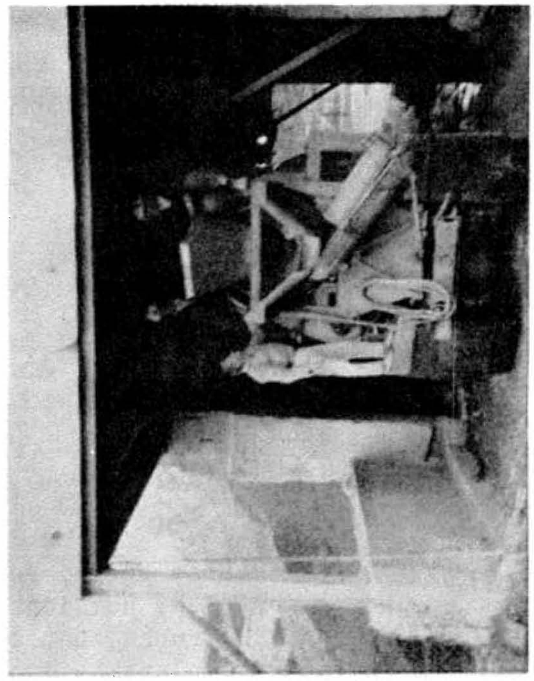

FIG. 20

APPENDIX B State Sampling and Testing Procedures - Study #10

Coarse Aggregate - #57 Gravel

Specific Gravity - 2.56

Absorption - 1.8%

Abrasion - 27%

Soundness - 7%

No Deleterious

Fine Aggregate

Specific Gravity - 2.61

Absorption - 1.5%

Soundness - 3%

FIG. 18 shows the whole transit mix concrete plant operation; stockpiled coarse aggregates on the left are picked up by front end loader and deposited into a pit at the lower right hand edge of the picture. From this pit both coarse and fine aggregates are transported independently by conveyor belt to separate holding bins located in the structure on the left. In this structure the aggregates are weighed separately in accordance with established mix proportions. From the weigh hoppers the blended aggregates (coarse and fine) are deposited on the second conveyor belt which carries the aggregates to the batching point (building on the right). Study samples were lifted from the first conveyor belt (State job control acceptance point) and at a point prior to entry into the concrete mixer truck.

STUDY RESULTS

Appendix D indicates averages of each group of 15 samples to be well within required limits for materials passing specification sieves.

APPENDIX B State Sampling and Testing Procedures - Study #11

Coarse Aggregate - #57 Limestone

Specific Gravity - 2.71

Absorption - 0.7%

Abrasion - 17%

Soundness - 2%

No Deleterious

Fine Aggregate

Specific Gravity - 2.60

Absorption - 1.5%

Soundness - 6%

FIG. 19 shows coarse aggregate stockpiles on the left and clam shell bucket sampling (State job control acceptance point); both are located at the transmit mix concrete plant. FIG. 20 is another view of the same concrete plant; it illustrates State personnel taking batcher sample prior to entry into concrete truck. Study samples were taken at the points described.

STUDY RESULTS

Appendix D indicates materials passing the 3/4" sieve favors the high side of the band and materials passing the smaller sieves (#8, #4, 3/4") favor the middle of the specification band.

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #1 - #57 LIMESTONE AGGREGATE

QS = Quarry Stockpile

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *95-100 | (63-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| QS-1 | | 100 | 94 | 49 | 19 | 4 | 2 | 2.23 | 93.2 |
| QS-2 | | 100 | 94 | 43 | 15 | 2 | 1 | 2.14 | 93.5 |
| QS-3 | | 100 | 95 | 54 | 19 | 3 | 2 | 2.23 | 93.6 |
| QS-4 | | 100 | 90 | 36 | 16 | 4 | 2 | 2.16 | 93.1 |
| QS-5 | | 100 | 94 | 37 | 11 | 3 | 2 | 2.14 | 92.0 |
| QS-6 (Cyc 2) | 100 | 99 | 89 | 35 | 9 | 2 | 1 | 2.03 | 92.4 |
| QS-7 | 100 | 99 | 88 | 37 | 11 | 2 | 1 | 2.04 | 92.2 |
| QS-8 | | 100 | 95 | 41 | 10 | 2 | 1 | 2.10 | 93.6 |
| QS-9 | | 100 | 94 | 37 | 12 | 2 | 1 | 2.11 | 93.2 |
| QS-10 | | 100 | 93 | 37 | 9 | 2 | 1 | 2.07 | 94.6 |
| QS-11 (Cyc 3) | | 100 | 96 | 43 | 10 | 2 | 1 | 2.11 | 91.6 |
| QS-12 | | 100 | 96 | 43 | 9 | 2 | 1 | 2.10 | 91.4 |
| QS-13 | | 100 | 97 | 47 | 14 | 3 | 2 | 2.20 | 93.6 |
| QS-14 | | 100 | 97 | 42 | 12 | 3 | 2 | 2.18 | 93.8 |
| QS-15 | | 100 | 97 | 49 | 15 | 3 | 2 | 2.21 | 94.0 |
| MEAN $\bar{X}$ | 100 | 99.9 | 93.9 | 42.0 | 12.7 | 2.6 | 1.5 | 2.14 | 93.1 |
| RANGE (R) | 0 | 1.0 | 9.0 | 19.0 | 10.0 | 2.0 | 1.0 | 0.20 | 3.2 |
| STD. DEV. (σ) | 0 | .35 | 2.87 | 5.71 | 3.43 | 0.74 | 0.52 | .065 | 0.93 |
| VAR. COEFF. | 0 | .35 | 3.05 | 13.59 | 26.96 | 28.34 | 35.21 | 3.025 | 1.00 |
| VARIANCE | 0 | .124 | 8.210 | 32.57 | 11.780 | 0.543 | .267 | .004 | .864 |
| SKEWNESS | | -3.07 | -0.80 | .53 | .57 | .68 | .12 | -.004 | -.248 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #1 - #57 LIMESTONE AGGREGATE

Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *95-100 | (63-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| Bat. 1 | | 100 | 95 | 45 | 16 | 5 | 3 | 2.25 | 94.4 |
| Bat. 2 | | 100 | 92 | 36 | 12 | 3 | 2 | 2.13 | 95.8 |
| Bat. 3 | | 100 | 93 | 39 | 14 | 4 | 3 | 2.20 | 96.8 |
| Bat. 4 | | 100 | 94 | 35 | 13 | 4 | 3 | 2.20 | 94.8 |
| Bat. 5 | | 100 | 94 | 39 | 14 | 4 | 3 | 2.21 | 95.2 |
| Bat. 6(Cyc 2) | | 100 | 91 | 38 | 14 | 4 | 3 | 2.18 | 94.5 |
| Bat. 7 | | 100 | 95 | 38 | 11 | 3 | 2 | 2.15 | 92.7 |
| Bat. 8 | | 100 | 91 | 32 | 9 | 3 | 1 | 2.06 | 96.3 |
| Bat. 9 | | 100 | 90 | 35 | 11 | 3 | 2 | 2.10 | 95.8 |
| Bat. 10 | | 100 | 92 | 39 | 12 | 3 | 2 | 2.13 | 94.6 |
| Bat. 11(Cyc 3) | | 100 | 97 | 53 | 18 | 5 | 3 | 2.29 | 95.2 |
| Bat. 12 | | 100 | 97 | 53 | 18 | 4 | 1 | 2.22 | 95.2 |
| Bat, 13 | | 100 | 97 | 52 | 19 | 5 | 3 | 2.30 | 96.3 |
| Bat. 14 | | 100 | 95 | 34 | 10 | 3 | 2 | 2.14 | 96.0 |
| Bat. 15 | | 100 | 95 | 42 | 14 | 3 | 2 | 2.18 | 95.1 |
| MEAN $\bar{X}$ | 100 | 100 | 93.9 | 40.7 | 13.7 | 3.7 | 2.3 | 2.18 | 95.2 |
| RANGE (R) | 0 | 0 | 7.0 | 21.0 | 10.0 | 2.0 | 2.0 | .24 | 4.1 |
| STD DEV($\sigma$) | 0 | 0 | 2.29 | 6.98 | 3.02 | .80 | .72 | .067 | 1.01 |
| VAR COEFF | 0 | 0 | 2.44 | 17.15 | 22.07 | 21.40 | 31.02 | 3.07 | 1.06 |
| VARIANCE | 0 | 0 | 5.27 | 48.67 | 9.10 | .64 | .52 | .004 | 1.01 |
| SKEWNESS | 0 | 0 | - .11 | .75 | .31 | .45 | - .51 | .09 | - .65 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #1 - FINE AGGREGATE

Samples Taken at Batcher Point Only.

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS. CYCLE - 1 | *100 | *95-100 | | *70-95 | *45-80 | *25-60 | *10-30 | *1-10 | *0-4 | MID-SPEC 2.90 |
| FA-1 | 100 | 98 | 93 | 88 | 70 | 35 | 13 | 6 | 3.7 | 2.90 |
| FA-2 | 100 | 97 | 91 | 86 | 68 | 33 | 12 | 6 | 3.8 | 2.98 |
| FA-3 | 100 | 98 | 93 | 88 | 69 | 34 | 12 | 6 | 3.6 | 2.93 |
| FA-4 | 100 | 97 | 92 | 87 | 68 | 34 | 12 | 6 | 3.8 | 2.96 |
| FA-5 | 100 | 98 | 93 | 88 | 69 | 34 | 12 | 6 | 3.6 | 2.93 |
| FA-6 (Cyc 2) | 100 | 98 | 94 | 89 | 72 | 41 | 14 | 6 | 3.0 | 2.80 |
| FA-7 | 100 | 98 | 94 | 90 | 74 | 42 | 14 | 5 | 3.2 | 2.77 |
| FA-8 | 100 | 99 | 96 | 92 | 75 | 38 | 13 | 6 | 3.7 | 2.77 |
| FA-9 | 100 | 98 | 93 | 89 | 73 | 40 | 14 | 5 | 2.9 | 2.81 |
| FA-10 | 100 | 97 | 93 | 88 | 71 | 39 | 13 | 5 | 3.0 | 2.88 |
| FA-11 (Cyc 3) | | 100 | 96 | 89 | 70 | 41 | 21 | 7 | 3.0 | 2.72 |
| FA-12 | | 100 | 96 | 89 | 70 | 42 | 21 | 7 | 3.0 | 2.71 |
| FA-13 | 100 | 99 | 96 | 90 | 71 | 44 | 23 | 8 | 3.1 | 2.65 |
| FA-14 | | 100 | 95 | 87 | 67 | 39 | 20 | 8 | 3.2 | 2.79 |
| FA-15 | 100 | 99 | 95 | 88 | 70 | 45 | 24 | 8 | 3.3 | 2.66 |
| MEAN $\bar{X}$ | 100 | 98.4 | 94.0 | 88.5 | 70.5 | 38.7 | 15.9 | 6.3 | 3.33 | 2.82 |
| RANGE (R) | 0 | 3.0 | 5.0 | 6.0 | 8.0 | 12.0 | 12.0 | 3.0 | .9 | .33 |
| STD DEV ($\sigma$) | 0 | 1.06 | 1.60 | 1.46 | 2.26 | 3.92 | 4.49 | 1.05 | .33 | .11 |
| VAR COEFF | 0 | 1.07 | 1.70 | 1.65 | 3.21 | 10.12 | 28.27 | 16.52 | 10.06 | 3.82 |
| VARIANCE | 0 | 1.11 | 2.57 | 2.12 | 5.12 | 15.35 | 20.12 | 1.10 | .11 | .01 |
| SKEWNESS | 0 | .28 | - .0 | .52 | .45 | - .08 | .68 | .41 | .22 | - - .004 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #2 - #57 GRAVEL

BS - Belt Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *95-100 | (63-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| BS-1 | | 100 | 90 | 52 | 27 | 3 | 1 | 2.23 | 110.2 |
| BS-2 | | 100 | 87 | 50 | 26 | 3 | 1 | 2.19 | 110.4 |
| BS-3 | | 100 | 89 | 53 | 30 | 4 | 1 | 2.26 | 111.4 |
| BS-4 | | 100 | 89 | 49 | 26 | 3 | 1 | 2.21 | 111.0 |
| BS-5 | | 100 | 86 | 46 | 22 | 2 | 1 | 2.13 | 109.6 |
| BS-6(Cyc. 2) | 100 | 99 | 88 | 52 | 26 | 3 | 1 | 2.20 | 109.6 |
| BS-7 | 100 | 99 | 73 | 42 | 21 | 3 | 1 | 2.00 * | 109.4 |
| BS-8 | | 100 | 86 | 46 | 21 | 3 | 1 | 2.13 | 109.4 |
| BS-9 | 100 | 99 | 89 | 50 | 24 | 3 | 1 | 2.19 | 110.0 |
| BS-10 | | 100 | 89 | 53 | 25 | 3 | 1 | 2.20 | 107.6 |
| BS-11(Cyc. 3) | | 100 | 91 | 49 | 23 | 4 | 1 | 2.21 | 110.7 |
| BS-12 | | 100 | 90 | 50 | 23 | 3 | 1 | 2.19 | 111.0 |
| BS-13 | | 100 | 86 | 47 | 22 | 3 | 1 | 2.14 | 110.4 |
| BS-14 | | 100 | 91 | 53 | 26 | 3 | 1 | 2.23 | 110.5 |
| BS-15 | | 100 | 86 | 43 | 20 | 3 | 1 | 2.12 | 110.7 |
| MEAN $\bar{\bar{X}}$ | 100.0 | 99.8 | 87.3 | 49.0 | 24.1 | 3.1 | 1.0 | 2.19 | 110.1 |
| RANGE (R) | 0 | 1.0 | 18.0 | 11.0 | 10.0 | 2.0 | 0 | 0.26 | 3.8 |
| STD DEV (σ) | 0 | .41 | 4.35 | 3.55 | 2.75 | .46 | 0 | .043 | .93 |
| VAR COEFF | 0 | .41 | 4.98 | 7.24 | 11.39 | 14.93 | 0 | 2.92 | .84 |
| VARIANCE | 0 | .17 | 18.95 | 12.57 | 7.55 | .21 | 0 | .004 | .87 |
| SKEWNESS | 0 | - .94 | - 2.26 | - .56 | .31 | .28 | 0 | - 1.23 | - 1.16 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #2 - #57 GRAVEL

Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *95-100 | (63-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| Bat. 1 | | 100 | 92 | 57 | 31 | 4 | 1 | 2.30 | 111.2 |
| Bat. 2 | | 100 | 94 | 56 | 30 | 3 | 1 | 2.30 | 110.6 |
| Bat. 3 | | 100 | 90 | 52 | 26 | 3 | 1 | 2.22 | 110.2 |
| Bat. 4 | | 100 | 90 | 48 | 21 | 3 | 1 | 2.17 | 110.2 |
| Bat. 5 | | 100 | 92 | 51 | 24 | 2 | 1 | 2.21 | 110.2 |
| Bat. 6(Cyc. 2) | | 100 | 93 | 60 | 29 | 3 | 1 | 2.28 | 110.2 |
| Bat. 7 | | 100 | 84 | 41 | 18 | 2 | 1 | 2.07 | 107.4 |
| Bat. 8 | | 100 | 91 | 49 | 21 | 2 | 1 | 2.17 | 110.0 |
| Bat. 9 | | 100 | 90 | 48 | 20 | 2 | 1 | 2.15 | 109.4 |
| Bat. 10 | | 100 | 89 | 50 | 25 | 3 | 1 | 2.20 | 108.8 |
| Bat. 11(Cyc. 3) | | 100 | 89 | 49 | 22 | 3 | 1 | 2.17 | 110.6 |
| Bat. 12 | | 100 | 90 | 57 | 29 | 5 | 1 | 2.27 | 110.4 |
| Bat. 13 | | 100 | 93 | 52 | 24 | 3 | 1 | 2.23 | 110.6 |
| Bat. 14 | | 100 | 87 | 47 | 24 | 4 | 1 | 2.18 | 110.4 |
| Bat. 15 | | 100 | 89 | 49 | 24 | 3 | 1 | 2.19 | 110.8 |
| MEAN $\bar{X}$ | 100 | 100 | 90.2 | 51.1 | 24.5 | 3.0 | 1.0 | 2.21 | 110.1 |
| RANGE (R) | 0 | 0 | 10.0 | 19.0 | 13.0 | 3.0 | 0 | .23 | 3.8 |
| STD DEV (σ) | 0 | 0 | 2.54 | 4.83 | 3.87 | .85 | 0 | .062 | .93 |
| VAR COEFF | 0 | 0 | 2.82 | 9.46 | 15.78 | 28.17 | 0 | 2.82 | .84 |
| VARIANCE | 0 | 0 | 6.46 | 23.35 | 14.98 | .71 | 0 | .004 | .87 |
| SKEWNESS | 0 | 0 | - .67 | .05 | .16 | .66 | 0 | - .20 | - 1.40 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY # 2 - FINE AGGREGATE

Samples Taken at Batcher Point Only.

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS CYCLE - 1 | *100 | *95-100 | -- | *70-95 | *45-80 | *25-60 | *10-30 | *1-10 | *0-4 | MID-SPEC 2.90 |
| FA-1 | | 100 | 99 | 91 | 73 | 49 | 16 | 5 | 2.6 | 2.66 |
| FA-2 | | 100 | 99 | 92 | 73 | 50 | 16 | 5 | 2.7 | 2.64 |
| FA-3 | | 100 | 98 | 90 | 72 | 49 | 16 | 5 | 2.7 | 2.68 |
| FA-4 | | 100 | 98 | 90 | 73 | 52 | 18 | 5 | 2.7 | 2.62 |
| FA-5 | | 100 | 98 | 90 | 72 | 50 | 18 | 6 | 2.9 | 2.64 |
| FA-6 (Cyc 2) | | 100 | 99 | 92 | 72 | 45 | 15 | 5 | 2.5 | 2.71 |
| FA-7 | 100 | 99 | 98 | 91 | 70 | 45 | 15 | 5 | 2.6 | 2.75 |
| FA-8 | | 100 | 98 | 91 | 71 | 46 | 15 | 5 | 2.6 | 2.72 |
| FA-9 | | 100 | 99 | 93 | 73 | 45 | 15 | 5 | 2.7 | 2.69 |
| FA-10 | | 100 | 99 | 93 | 71 | 44 | 14 | 4 | 2.5 | 2.74 |
| FA-11 (Cyc 3) | | 100 | 98 | 90 | 70 | 46 | 15 | 5 | 2.5 | 2.74 |
| FA-12 | | 100 | 98 | 89 | 69 | 46 | 16 | 5 | 2.6 | 2.75 |
| FA-13 | | 100 | 99 | 93 | 73 | 46 | 15 | 5 | 2.7 | 2.68 |
| FA-14 | | 100 | 99 | 93 | 74 | 47 | 15 | 5 | 3.0 | 2.66 |
| FA-15 | | 100 | 98 | 91 | 71 | 46 | 16 | 5 | 3.1 | 2.71 |
| MEAN $\bar{X}$ | 100.0 | 99.9 | 98.5 | 91.3 | 71.8 | 47.1 | 15.7 | 5.0 | 2.7 | 2.69 |
| RANGE (R) | 0 | 1.0 | 1.0 | 4.0 | 5.0 | 8.0 | 4.0 | 2.0 | .6 | .13 |
| STD DEV ($\sigma$) | 0 | .26 | .52 | 1.33 | 1.42 | 2.34 | 1.11 | .38 | .18 | .042 |
| VAR COEFF | 0 | .26 | .52 | 1.46 | 1.98 | 4.98 | 7.10 | 7.56 | 6.65 | 1.59 |
| VARIANCE | 0 | .067 | .267 | 1.78 | 2.03 | 5.50 | 1.24 | .14 | .032 | .001 |
| SKEWNESS | 0 | - 3.89 | .48 | .06 | - .37 | .64 | .91 | | | - .14 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

**STUDY #3 - #57 GRANITE AGGREGATE**

QS = Quarry Stockpile

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| QS-1 | | 100 | 82.5 | 49.2 | 28.2 | 3.2 | 0.5 | 2.15 | 93.4 |
| QS-2 | | 100 | 89.4 | 59.2 | 42.4 | 10.8 | 3.4 | 2.53 | 94.9 |
| QS-3 | | 100 | 85.5 | 53.2 | 38.0 | 10.0 | 2.4 | 2.41 | 97.2 |
| QS-4 | | 100 | 85.8 | 53.8 | 41.6 | 13.6 | 3.2 | 2.51 | 97.8 |
| QS-5 | | 100 | 82.6 | 49.6 | 26.4 | 4.5 | 1.1 | 2.17 | 94.9 |
| QS-6 (Cyc 2) | | 100 | 81.5 | 49.8 | 27.9 | 3.4 | 0.8 | 2.15 | 96.8 |
| QS-7 | | 100 | 79.8 | 50.8 | 36.0 | 8.4 | 1.9 | 2.30 | 98.8 |
| QS-8 | | 100 | 85.4 | 52.2 | 40.6 | 7.6 | 1.4 | 2.38 | 99.6 |
| QS-9 | | 100 | 82.0 | 52.5 | 34.4 | 8.1 | 1.6 | 2.29 | 98.6 |
| QS-10 | | 100 | 91.2 | 58.8 | 31.2 | 5.0 | 1.4 | 2.32 | 99.4 |
| QS-11 (Cyc 3) | | 100 | 84.6 | 53.6 | 32.2 | 5.4 | 1.4 | 2.26 | 96.2 |
| QS-12 | | 100 | 86.2 | 55.8 | 33.5 | 5.8 | 1.4 | 2.30 | 95.9 |
| QS-13 | | 100 | 90.0 | 56.6 | 31.4 | 4.2 | 1.0 | 2.29 | 96.4 |
| QS-14 | | 100 | 84.0 | 48.8 | 27.6 | 4.4 | 1.2 | 2.20 | 96.0 |
| QS-15 | | 100 | 89.0 | 54.1 | 30.8 | 5.3 | 1.6 | 2.30 | 95.9 |
| MEAN $\bar{X}$ | 100 | 100 | 85.3 | 53.2 | 33.5 | 6.6 | 1.6 | 2.30 | 96.8 |
| RANGE (R) | 0 | 0 | 11.4 | 10.4 | 16.0 | 10.4 | 2.9 | .38 | 6.2 |
| STD. DEV (б) | 0 | 0 | 3.40 | 3.32 | 5.25 | 3.02 | .82 | .116 | 1.78 |
| VAR COEFF. | 0 | 0 | 3.98 | 6.24 | 15.68 | 45.46 | 50.32 | 5.05 | 1.84 |
| VARIANCE | 0 | 0 | 11.53 | 11.01 | 27.56 | 9.13 | .66 | .013 | 3.18 |
| SKEWNESS | 0 | 0 | .22 | .36 | .36 | .81 | .94 | .48 | |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #3 - #57 GRANITE AGGREGATE

PS = Concrete Plant Stock Pile

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| PS-1 | | 100 | 79.2 | 50.6 | 39.5 | 7.8 | 1.0 | 2.30 | 97.0 |
| PS-2 | | 100 | 77.3 | 50.4 | 38.4 | 9.5 | 1.2 | 2.29 | 96.6 |
| PS-3 | | 100 | 83.2 | 53.2 | 38.6 | 8.4 | 1.5 | 2.35 | 95.4 |
| PS-4 | | 100 | 80.0 | 51.6 | 34.9 | 7.2 | 2.5 | 2.30 | 97.2 |
| PS-5 | | 100 | 82.9 | 52.9 | 43.0 | (15.0) | 4.0 | 2.53 * | 98.8 |
| PS-6 (Cyc 2) | | 100 | 89.3 | 56.0 | 34.9 | 5.8 | 1.4 | 2.34 | 96.8 |
| PS-7 | | 100 | 84.5 | 55.6 | 35.2 | 5.2 | 0.6 | 2.27 | 96.4 |
| PS-8 | | 100 | 82.2 | 51.4 | 31.7 | 5.2 | 1.0 | 2.22 | 95.5 |
| PS-9 | | 100 | 85.2 | 56.7 | 37.8 | 7.0 | 0.6 | 2.32 | 96.6 |
| PS-10 | | 100 | 85.1 | 57.5 | 38.2 | 8.2 | 2.3 | 2.38 | 96.6 |
| PS-11 (Cyc 3) | | 100 | 83.4 | 54.3 | 40.4 | 8.0 | 1.6 | 2.37 | 95.9 |
| PS-12 | | 100 | 85.0 | 55.6 | 35.8 | 5.2 | 1.6 | 2.31 | 96.4 |
| PS-13 | | 100 | 84.8 | 53.2 | 32.2 | 3.6 | 0.8 | 2.23 | 95.9 |
| PS-14 | | 100 | 88.6 | 56.0 | 35.1 | 6.4 | 1.6 | 2.35 | 95.9 |
| PS-15 | | 100 | 85.6 | 54.2 | 33.5 | 5.3 | 0.8 | 2.27 | 96.4 |
| MEAN $\bar{X}$ | 100 | 100 | 83.8 | 53.9 | 36.6 | 7.2 | 1.5 | 2.31 | 96.5 |
| RANGE (R) | 0 | 0 | 12.0 | 7.1 | 11.3 | 11.4 | 3.4 | .31 | 3.4 |
| STD. DEV. σ | 0 | 0 | 3.22 | 2.27 | 3.15 | 2.68 | .89 | .049 | .82 |
| VAR COEFF | 0 | 0 | 3.84 | 4.21 | 8.59 | 37.33 | 59.41 | 3.20 | .85 |
| VARIANCE | 0 | 0 | 10.34 | 5.16 | 9.90 | 7.20 | .79 | .005 | .68 |
| SKEWNESS | 0 | 0 | -.24 | -.12 | .23 | 1.43 | 1.39 | 1.19 | 1.20 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #3 - #57 GRANITE AGGREGATE

BAT = Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | Ā | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| BAT-1 | | 100 | 85.0 | 53.6 | 38.0 | 9.1 | 1.9 | 2.38 | 99.0 |
| BAT-2 | | 100 | 86.0 | 58.1 | 37.8 | 9.6 | 3.0 | 2.42 | 98.3 |
| BAT-3 | | 100 | 86.7 | 58.6 | 36.5 | 7.7 | 1.6 | 2.36 | 98.8 |
| BAT-4 | | 100 | 92.4 | (64.6) | 41.2 | 10.0 | 3.4 | 2.54 | 98.8 |
| BAT-5 | | 100 | 87.4 | 60.4 | 40.2 | (10.4) | 2.6 | 2.46 | 98.3 |
| BAT-6 Cyc2 | | 100 | 79.6 | 52.2 | 37.2 | 9.2 | 0.8 | 2.28 | 97.2 |
| BAT-7 | | 100 | 82.0 | 52.9 | 35.2 | 7.6 | 1.6 | 2.30 | 96.0 |
| BAT-8 | | 100 | 76.2 | 48.4 | 33.7 | 5.5 | 0.8 | 2.18 | 98.8 |
| BAT-9 | | 100 | 86.6 | 55.2 | 34.2 | 5.2 | 1.7 | 2.31 | 95.9 |
| BAT-10 | | 100 | 85.0 | 50.9 | 32.4 | 6.4 | 1.6 | 2.29 | 95.9 |
| BAT-11 Cyc3 | | 100 | 85.4 | 55.8 | 30.6 | 5.2 | 1.0 | 2.24 | 96.0 |
| BAT-12 | | 100 | 86.4 | 56.4 | 38.6 | 9.7 | 2.8 | 2.43 | 96.0 |
| BAT-13 | | 100 | 82.8 | 54.3 | 37.6 | 9.1 | 2.8 | 2.38 | 96.5 |
| BAT-14 | | 100 | 84.4 | 56.8 | 35.3 | 6.7 | 1.7 | 2.31 | 95.9 |
| BAT-15 | | 100 | 91.7 | (64.0) | 35.6 | 7.6 | 2.9 | 2.44 | 96.0 |
| MEAN X | 100 | 100 | 85.2 | 56.1 | 36.3 | 7.9 | 2.01 | 2.35 | 97.2 |
| RANGE (R) | 0 | 0 | 16.2 | 16.2 | 10.6 | 5.2 | 2.6 | .36 | 3.1 |
| STD. DEV. σ | 0 | 0 | 4.09 | 4.52 | 2.85 | 1.80 | .84 | .094 | 1.33 |
| VAR COEFF | 0 | 0 | 4.80 | 8.05 | 7.86 | 22.75 | 41.89 | 4.00 | 1.36 |
| VARIANCE | 0 | 0 | 16.74 | 20.44 | 8.12 | 3.26 | .71 | .009 | 1.76 |
| SKEWNESS | 0 | 0 | -.26 | .33 | -.18 | -.24 | .07 | .07 | .28 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

**STUDY #3 - FINE AGGREGATE** Samples Taken at Batcher Point Only

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS CYCLE -1 | *100 | *94-100 | | *80-100 | *65-85 | *30-60 | *8-26 | *2-10 | *0-5 | MID-SPEC 2.70 |
| FA-1 | 100.0 | 99.2 | | 85.2 | 65.8 | 38.3 | 15.9 | 3.6 | 0.8 | 2.92 |
| FA-2 | 100.0 | 99.4 | | 87.2 | 68.8 | 39.8 | 13.3 | 2.6 | 0.7 | 2.89 |
| FA-3 | 100.0 | 99.4 | | 87.0 | 68.8 | 42.8 | 15.2 | 3.10 | 0.8 | 2.84 |
| FA-4 | 100.0 | 99.2 | | 86.1 | 66.8 | 38.2 | 12.6 | 2.7 | 0.8 | 2.94 |
| FA-5 | 100.0 | 99.1 | | 86.2 | 66.5 | 38.7 | 12.3 | 2.5 | 0.7 | 2.95 |
| FA-6 Cyc2 | 100.0 | 99.1 | | 85.4 | 64.4 | 34.0 | 13.0 | 2.7 | 0.9 | 3.01 |
| FA-7 | | 99.2 | | 86.2 | 68.7 | 41.1 | 14.6 | 3.6 | 1.2 | 2.87 |
| FA-8 | | 99.3 | | 86.6 | 69.1 | 40.2 | 14.5 | 3.3 | 1.1 | 2.87 |
| FA-9 | | 98.9 | | 86.5 | 69.6 | 42.6 | 14.7 | 3.6 | 1.1 | 2.84 |
| FA-10 | | 99.3 | | 86.4 | 66.2 | 36.5 | 12.9 | 2.9 | 1.0 | 2.96 |
| FA-11 Cyc 3 | | 97.9 | | 85.5 | 67.1 | 39.4 | 14.6 | 3.1 | 0.9 | 2.92 |
| FA-12 | | 99.1 | | 85.7 | 66.9 | 39.9 | 14.5 | 3.0 | 0.6 | 2.91 |
| FA-13 | | 97.9 | | 85.1 | 67.6 | 39.6 | 14.4 | 3.0 | 0.7 | 2.92 |
| FA-14 | | 98.1 | | 87.0 | 69.8 | 44.6 | 14.3 | 2.9 | 0.7 | 2.83 |
| FA-15 | | 99.3 | | 88.0 | 70.8 | 42.8 | 14.6 | 2.9 | 0.7 | 2.82 |
| MEAN X | 100 | 99.0 | | 86.3 | 67.8 | 39.9 | 14.1 | 3.03 | .85 | 2.90 |
| RANGE (R) | 0 | 1.5 | | 2.9 | 6.4 | 10.6 | 3.6 | 1.1 | .60 | .19 |
| STD DEV σ | 0 | .53 | | .82 | 1.75 | 2.69 | 1.03 | .36 | .18 | .05 |
| VAR COEFF | 0 | .54 | | .95 | 2.58 | 6.74 | 7.29 | 11.80 | 21.35 | 1.88 |
| VARIANCE | 0 | .28 | | .67 | 3.06 | 7.24 | 1.06 | .13 | .03 | .002 |
| SKEWNESS | 0 | -.89 | | .12 | -.12 | -.28 | -.28 | .36 | .56 | .20 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #4 - #57 GRAVEL AGGREGATE

PS - Concrete Plant Stockpile Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| PS-1 | 100.0 | 96.2 | 66 | 30.2 | 20 | 0.6 | 0.2 | 1.87 | 93.7 |
| PS-2 | 100.0 | 98.1 | 69 | 34.9 | 23 | 0.5 | 0.1 | 1.93 | 96.5 |
| PS-3 | 100.0 | 99.4 | 69 | 31.1 | 21 | 1.0 | 0.5 | 1.93 | 95.1 |
| PS-4 | 100.0 | 97.6 | 68 | 31.9 | 21 | 0.4 | 0.1 | 1.90 | 94.9 |
| PS-5 | 100.0 | 98.2 | 68 | 31.5 | 21 | 0.7 | 0.3 | 1.91 | 94.4 |
| PS-6(Cyc 2) | 100.0 | 96.9 | 69 | 36.2 | 24 | 0.5 | 0.1 | 1.94 | 94.8 |
| PS-7 | 100.0 | 97.6 | 69 | 34.9 | 23 | 0.6 | 0.1 | 1.93 | 94.6 |
| PS-8 | 100.0 | 98.3 | 73 | 42.5 | 28 | 0.4 | 0.2 | 2.02 | 95.8 |
| PS-9 | 100.0 | 97.6 | 69 | 34.9 | 23 | 0.6 | 0.1 | 1.93 | 94.9 |
| PS-10 | 100.0 | 98.6 | 72 | 40.5 | 27 | 2.0 | 1.2 | 2.05 | 95.2 |
| PS-11(Cyc 3) | HOLIDAY | | | | | | | | |
| PS-12 | 100.0 | 99.1 | 66 | 26.0 | 17 | 0.7 | 0.1 | 1.84 | 94.5 |
| PS-13 | 100.0 | 96.5 | 67 | 33.0 | 22 | 0.4 | 0.2 | 1.90 | 94.1 |
| PS-14 | 100.0 | 99.2 | 76 | 48.6 | 32 | 0.3 | 0.1 | 2.09 | 95.9 |
| PS-15 | 100.0 | 99.2 | 66 | 26.2 | 18 | 0.1 | 0.0 | 1.84 | 93.8 |
| MEAN $\bar{X}$ | 100 | 98.0 | 69.1 | 34.5 | 22.9 | .63 | .24 | 1.93 | 94.9 |
| RANGE (R) | 0 | 3.2 | 10.0 | 22.6 | 15.0 | 1.9 | 1.1 | .25 | 2.8 |
| STD DEV (6) | 0 | 1.03 | 2.87 | 6.15 | 3.98 | .45 | .30 | .073 | .80 |
| VAR COEFF | 0 | 1.05 | 4.15 | 17.84 | 17.40 | 71.26 | 128.47 | 3.79 | .84 |
| VARIANCE | 0 | 1.05 | 8.23 | 37.80 | 15.82 | .20 | .09 | .005 | .64 |
| SKEWNESS | 0 | - .33 | .97 | .69 | .70 | 1.91 | 2.22 | .73 | .42 |

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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #4 - # 57 GRAVEL AGGREGATE

Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | * 25-60 | (16-43) | *0-10 | *0-5 | | | |
| Bat. 1 | 100.0 | 96.6 | 65 | 27.3 | 18 | 0.6 | 0.5 | | 1.85 | 94.7 |
| Bat. 2 | 100.0 | 95.7 | 65 | 29.2 | 20 | 0.9 | 0.3 | | 1.87 | 95.4 |
| Bat. 3 | 100.0 | 98.2 | 67 | 28.1 | 19 | 0.7 | 0.4 | | 1.88 | 94.4 |
| Bat. 4 | 100.0 | 98.7 | 69 | 33.0 | 22 | 0.4 | 0.1 | | 1.92 | 94.2 |
| Bat. 5 | 100.0 | 97.7 | 67 | 30.2 | 20 | 0.7 | 0.4 | | 1.89 | 95.4 |
| Bat. 6 (Cyc 2) | 100.0 | 97.0 | 68 | 32.5 | 22 | 0.8 | 0.5 | | 1.92 | 94.6 |
| Bat. 7 | 100.0 | 98.7 | 68 | 30.5 | 20 | 0.3 | 0.1 | | 1.89 | 94.9 |
| Bat. 8 | 100.0 | 98.6 | 70 | 36.7 | 24 | 1.0 | 0.1 | | 1.95 | 95.2 |
| Bat. 9 | 100.0 | 97.9 | 68 | 34.6 | 22 | 1.1 | 0.4 | | 1.92 | 95.6 |
| Bat. 10 | 100.0 | 99.0 | 70 | 35.1 | 23 | 0.4 | 0.2 | | 1.94 | 94.9 |
| Bat. 11 (Cyc 3) | HOLIDAY | | | | | | | | | |
| Bat. 12 | 100.0 | 95.1 | 66 | 30.5 | 20 | 1.2 | 0.4 | | 1.88 | 94.7 |
| Bat. 13 | 100.0 | 98.9 | 69 | 30.1 | 20 | 0.5 | 0.2 | | 1.90 | 94.9 |
| Bat. 14 | 100.0 | 96.4 | 68 | 31.5 | 20 | 0.5 | 0.3 | | 1.89 | 94.2 |
| Bat. 15 | 100.0 | 98.4 | 67 | 27.8 | 19 | 0.6 | 0.2 | | 1.87 | 94.4 |
| MEAN $\bar{X}$ | 100 | 97.6 | 67.6 | 31.2 | 20.6 | .69 | .29 | | 1.90 | 94.8 |
| RANGE (R) | 0 | 3.9 | 5.0 | 9.4 | 6.0 | .9 | .4 | | .10 | 1.4 |
| STD DEV (6) | 0 | 1.27 | 1.60 | 2.85 | 1.69 | .28 | .14 | | .028 | .45 |
| VAR COEFF | 0 | 1.30 | 2.36 | 9.13 | 8.20 | 39.81 | 49.14 | | 1.50 | .47 |
| VARIANCE | 0 | 1.60 | 2.55 | 8.12 | 2.86 | .08 | .02 | | .0008 | .20 |
| SKEWNESS | 0 | - .63 | - .19 | .39 | .43 | .37 | - .03 | | .29 | 1.56 |

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AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #4 - FINE AGGREGATE

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | #100.0 | *90-100 | | *70-92 | *50-80 | *30-65 | *10-30 | *1-8 | *0-3 | MID-SPEC 2.870 |
| FA-1 | 100.0 | 97.6 | | 84.1 | 71.8 | 52.7 | 17.2 | 3.9 | | 2.727 |
| FA-2 | 100.0 | 97.9 | | 87.0 | 71.5 | 52.0 | 13.0 | 2.3 | | 2.763 |
| FA-3 (Cyc 2) | 100.0 | 97.5 | | 78.8 | 65.8 | 49.9 | 25.2 | 3.4 | | 2.794 |
| FA-4 | 100.0 | 97.6 | | 84.4 | 66.6 | 50.6 | 23.9 | 2.8 | | 2.741 |
| FA-5 (Cyc 3) | 100.0 | 95.8 | | 84.3 | 66.7 | 47.7 | 19.8 | 5.1 | | 2.806 |
| FA-6 | 100.0 | 96.5 | | 84.6 | 67.7 | 47.8 | 18.6 | 3.2 | | 2.816 |
| MEAN X̄ | 100 | 97.1 | | 83.9 | 68.3 | 50.1 | 19.6 | 3.45 | | 2.77 |
| RANGE (R) | 0 | 2.1 | | 8.2 | 6.0 | 5.0 | 12.9 | 2.8 | | .09 |
| STD DEV(6) | 0 | .82 | | 2.70 | 2.63 | 2.08 | 4.48 | .97 | | .036 |
| VAR COEFF | 0 | .84 | | 3.22 | 3.84 | 4.16 | 22.82 | 28.21 | | 1.31 |
| VARIANCE | 0 | .67 | | 7.31 | 6.91 | 4.34 | 20.04 | .95 | | .001 |
| SKEWNESS | 0 | - .92 | | - .83 | .42 | - .05 | - .03 | .50 | | - .14 |

NOTE: For each cycle, a sample was taken from the stockpile and from the batch (a batcher sample). F.A. 1, 3, and 5 are batcher samples. F.A. 2, 4, and 6 are stockpile samples.

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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #5 - #57 **LIMESTONE AGGREGATE** PS - Concrete Plant Stockpile Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| PS-1 | 100.0 | 97.7 | 75 | 47.1 | 32 | 2.9 | 0 | 2.10 | 93.6 |
| PS-2 | 100.0 | 98.1 | 70 | 37.6 | 25 | 1.8 | 0 | 1.97 | 93.7 |
| PS-3 | 100.0 | 99.0 | 77 | 51.7 | 35 | 2.6 | 0 | 2.15 | 92.1 |
| PS-4 | 100.0 | 98.4 | 77 | 50.9 | 35 | 4.6 | 0 | 2.17 | 92.8 |
| PS-5 | 100.0 | 97.4 | 73 | 43.4 | 29 | 2.1 | 0 | 2.04 | 91.2 |
| PS-6(Cyc. 2) | HOLIDAY | | | | | | | | |
| PS-7 | 100.0 | 96.2 | 67 | 31.7 | 21 | 1.8 | 0 | 1.90 | 93.1 |
| PS-8 | 100.0 | 98.4 | 71 | 37.1 | 25 | 1.8 | 0 | 1.98 | 93.8 |
| PS-9 | 100.0 | 96.0 | 69 | 36.1 | 24 | 1.8 | 0 | 1.95 | 94.5 |
| PS-10 | 100.0 | 98.3 | 74 | 44.0 | 30 | 3.2 | 0 | 2.07 | 93.4 |
| PS-11(Cyc. 3) | 100.0 | 97.4 | 74 | 44.5 | 30 | 2.7 | 0 | 2.07 | 93.3 |
| PS-12 | 100.0 | 97.4 | 70 | 37.9 | 25 | 2.1 | 0 | 1.97 | 93.2 |
| PS-13 | 100.0 | 96.5 | 67 | 32.8 | 22 | 1.7 | 0 | 1.91 | 93.1 |
| PS-14 | 100.0 | 98.0 | 68 | 30.5 | 21 | 1.5 | 0 | 1.90 | 92.1 |
| PS-15 | 100.0 | 97.5 | 73 | 43.8 | 30 | 3.0 | 0 | 2.06 | 93.3 |
| MEAN $\bar{X}$ | 100 | 97.6 | 71.8 | 40.6 | 27.4 | 2.4 | 0 | 2.02 | 93.1 |
| RANGE (R) | 0 | 3.0 | 10.0 | 21.2 | 14.0 | 3.1 | 0 | .27 | 3.3 |
| STD DEV ($\sigma$) | 0 | .88 | 3.42 | 6.83 | 4.80 | .84 | 0 | .090 | .83 |
| VAR COEFF | 0 | .90 | 4.77 | 16.81 | 17.50 | 34.94 | 0 | 4.46 | .89 |
| VARIANCE | 0 | .77 | 11.72 | 46.71 | 23.03 | .70 | 0 | .008 | .69 |
| SKEWNESS | 0 | -.53 | .06 | .09 | .16 | 1.16 | 0 | .16 | -.63 |

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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #5 - #57 **LIMESTONE AGGREGATE** — Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| | 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | |
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| Bat. 1 | 100.0 | 96.9 | 71 | 39.3 | 27 | 3.8 | 0 | 2.02 | 94.5 |
| Bat. 2 | 100.0 | 97.0 | 75 | 48.3 | 33 | 3.8 | 0 | 2.12 | 93.4 |
| Bat. 3 | 100.0 | 97.7 | 71 | 39.8 | 27 | 3.5 | 0 | 2.01 | 94.2 |
| Bat. 4 | 100.0 | 96.6 | 69 | 37.3 | 25 | 2.6 | 0 | 1.97 | 94.8 |
| Bat. 5 | 100.0 | 92.9 | 65 | 31.1 | 21 | 2.5 | 0 | 1.88 | 93.2 |
| Bat. 6(Cyc. 2 | HOLIDAY | | | | | | | | |
| Bat. 7 | 100.0 | 97.1 | 69 | 35.1 | 24 | 1.9 | 0 | 1.95 | 94.9 |
| Bat. 8 | 100.0 | 97.1 | 71 | 40.5 | 27 | 3.6 | 0 | 2.02 | 94.6 |
| Bat. 9 | 100.0 | 96.8 | 72 | 42.4 | 29 | 3.5 | 0 | 2.04 | 93.0 |
| Bat. 10 | 100.0 | 97.3 | 73 | 44.5 | 30 | 3.0 | 0 | 2.06 | 93.2 |
| Bat. 11(Cyc. 3) | 100.0 | 95.4 | 71 | 40.7 | 28 | 4.0 | 0 | 2.03 | 93.2 |
| Bat. 12 | 100.0 | 95.0 | 65 | 29.4 | 20 | 1.9 | 0 | 1.87 | 93.6 |
| Bat. 13 | 100.0 | 96.2 | 68 | 34.3 | 24 | 2.7 | 0 | 1.95 | 93.2 |
| Bat. 14 | 100.0 | 94.4 | 66 | 31.1 | 21 | 1.5 | 0 | 1.88 | 94.2 |
| Bat. 15 | 100.0 | 95.6 | 66 | 31.7 | 22 | 2.5 | 0 | 1.90 | 93.7 |
| MEAN $\bar{X}$ | 100 | 96.1 | 69.4 | 37.5 | 25.6 | 2.9 | 0 | 1.98 | 93.8 |
| RANGE (R) | 0 | 4.8 | 10.0 | 18.9 | 13.0 | 2.5 | 0 | .25 | 1.9 |
| STD DEV (σ) | 0 | 1.34 | 3.11 | 5.65 | 3.82 | .81 | 0 | .077 | .68 |
| VAR COEFF | 0 | 1.39 | 4.47 | 15.04 | 14.93 | 27.68 | 0 | 2.80 | .72 |
| VARIANCE | 0 | 1.79 | 9.65 | 31.89 | 14.57 | .65 | 0 | .003 | .46 |
| SKEWNESS | 0 | - 1.01 | - .014 | .18 | .18 | - .23 | 0 | .05 | .46 |

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AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #5 - FINE AGGREGATE

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS CYCLE - 1 | *100 | *90-100 | | *70-92 | *50-80 | *30-65 | *10-30 | *1-8 | *0-3 | MID-SPEC 2.870 |
| FA-1 | 100.0 | 93.2 | | 75.0 | 61.1 | 47.3 | 14.2 | 2.9 | | 3.06 |
| FA-2 | 100.0 | 93.9 | | 72.2 | 57.8 | 44.0 | 15.0 | 3.2 | | 3.14 |
| FA-3 (Cyc. 2) | 100.0 | 94.8 | | 78.4 | 65.4 | 52.8 | 17.3 | 3.1 | | 2.88 |
| FA-4 | 100.0 | 93.4 | | 75.5 | 62.7 | 49.7 | 14.7 | 2.9 | | 3.01 |
| FA-5 (Cyc. 3) | 100.0 | 94.6 | | 76.3 | 62.7 | 52.6 | 21.6 | 3.1 | | 2.89 |
| FA-6 | 100.0 | 92.7 | | 75.6 | 62.3 | 53.0 | 24.3 | 3.1 | | 2.89 |
| MEAN $\bar{X}$ | 100 | 93.8 | | 75.5 | 62.0 | 49.9 | 17.8 | 3.05 | | 2.98 |
| RANGE (R) | 0 | 2.1 | | 6.2 | 7.6 | 9.0 | 10.1 | .3 | | .26 |
| STD DEV($\sigma$) | 0 | .82 | | 2.01 | 2.49 | 3.66 | 4.18 | .12 | | .11 |
| VAR COEFF | 0 | .88 | | 2.66 | 4.02 | 7.33 | 23.41 | 4.02 | | 3.65 |
| VARIANCE | 0 | .67 | | 4.04 | 6.22 | 13.38 | 17.47 | .02 | | .01 |
| SKEWNESS | 0 | - .18 | | - .23 | - .37 | - .51 | .50 | - .27 | | .32 |

NOTE: For each cycle, a sample was taken from the stockpile and from the batch (a batcher sample). F. A. 1, 3, and 5 are batcher samples. F. A. 2, 4, and 6 are stockpile samples.

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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #6 - #57 SLAG AGGREGATE — PS = Concrete Plant Stock Pile Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | | |
| PS-1 | 100.0 | 97.6 | 69 | 35.0 | 25 | 4.7 | 2.2 | | 2.05 | 75.4 |
| PS-2 | 100.0 | 96.4 | 67 | 31.7 | 22 | 2.9 | 2.2 | | 1.98 | 75.7 |
| PS-3 | 100.0 | 98.9 | 72 | 41.1 | 28 | 4.3 | 2.0 | | 2.10 | 76.0 |
| PS-4 | 100.0 | 98.1 | 69 | 33.2 | 23 | 3.2 | 1.7 | | 2.00 | 76.7 |
| PS-5 | 100.0 | 97.6 | 69 | 33.9 | 23 | 2.1 | 1.0 | | 1.97 | 76.2 |
| PS-6 (Cyc-2) | 100.0 | 98.1 | 70 | 35.8 | 25 | 4.9 | 2.1 | | 2.06 | 75.3 |
| PS-7 | 100.0 | 98.1 | 69 | 34.3 | 23 | 2.2 | 1.8 | | 2.00 | 75.8 |
| PS-8 | 100.0 | 97.4 | 69 | 34.5 | 23 | 2.1 | 1.3 | | 1.98 | 76.2 |
| PS-9 | 100.0 | 97.8 | 74 | 45.8 | 31 | 4.8 | 2.3 | | 2.17 | 76.5 |
| PS-10 | 100.0 | 98.1 | 69 | 35.0 | 24 | 3.4 | 2.0 | | 2.02 | 75.8 |
| PS-11 (Cyc-3) | HOLIDAY | | | | | | | | | |
| PS-12 | 100.0 | 95.9 | 68 | 34.6 | 24 | 4.7 | 2.4 | | 2.04 | 76.6 |
| PS-13 | 100.0 | 98.7 | 69 | 34.2 | 23 | 2.9 | 2.2 | | 2.01 | 75.3 |
| PS-14 | 100.0 | 98.0 | 72 | 40.6 | 28 | 4.1 | 2.4 | | 2.11 | 75.4 |
| PS-15 | 100.0 | 98.8 | 69 | 32.2 | 23 | 5.6 | 2.4 | | 2.05 | 75.0 |
| MEAN $\bar{X}$ | 100.0 | 97.8 | 69.6 | 35.8 | 24.6 | 3.7 | 2.0 | | 2.04 | 75.9 |
| RANGE (R) | 0 | 3.0 | 7.0 | 14.1 | 9.0 | 3.5 | 1.4 | | .20 | 1.7 |
| STD. DEV ($\sigma$) | 0 | .84 | 1.82 | 3.93 | 2.59 | 1.17 | .42 | | .057 | .54 |
| VAR COEFF | 0 | .86 | 2.62 | 10.95 | 10.51 | 31.54 | 21.12 | | 2.80 | .71 |
| VARIANCE | 0 | .71 | 3.32 | 15.42 | 6.71 | 1.37 | .18 | | .003 | .29 |
| SKEWNESS | 0 | -.72 | .99 | 1.02 | 1.18 | -.04 | -1.07 | | .72 | |

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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #6 - #57 SLAG AGGREGATES

BAT = Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | | |
| BAT-1 | 100.0 | 98.0 | 69 | 34.7 | 23 | 2.0 | 1.6 | | 1.99 | 74.6 |
| BAT-2 | 100.0 | 98.9 | 71 | 35.8 | 25 | 3.7 | 2.4 | | 2.07 | 74.9 |
| BAT-3 | 100.0 | 98.7 | 69 | 34.2 | 23 | 2.9 | 2.2 | | 2.01 | 75.2 |
| BAT-4 | 100.0 | 97.5 | 71 | 39.3 | 27 | 2.8 | 2.1 | | 2.07 | 75.9 |
| BAT-5 | 100.0 | 96.8 | 70 | 37.3 | 26 | 4.1 | 2.0 | | 2.06 | 75.4 |
| BAT-6 (Cyc2) | 100.0 | 98.9 | 73 | 41.3 | 28 | 2.2 | 1.8 | | 2.10 | 74.5 |
| BAT-7 | 100.0 | 97.3 | 67 | 29.5 | 20 | 1.4 | 1.1 | | 1.92 | 75.0 |
| BAT-8 | 100.0 | 98.0 | 70 | 38.0 | 25 | 1.7 | 1.1 | | 2.00 | 75.4 |
| BAT-9 | 100.0 | 96.3 | 71 | 40.8 | 28 | 5.2 | 1.9 | | 2.10 | 75.7 |
| BAT-10 | 100.0 | 95.5 | 70 | 38.7 | 27 | 4.3 | 2.2 | | 2.08 | 75.0 |
| BAT-11 (Cyc3) | HOLIDAY | | | | | | | | | |
| BAT-12 | 100.0 | 97.7 | 66 | 28.0 | 19 | 2.8 | 2.1 | | 1.94 | 74.8 |
| BAT-13 | 100.0 | 99.5 | 75 | 45.1 | 30 | 3.1 | 1.3 | | 2.12 | 74.5 |
| BAT-14 | 100.0 | 97.2 | 71 | 38.5 | 26 | 3.3 | 2.0 | | 2.07 | 74.9 |
| BAT-15 | 100.0 | 98.5 | 70 | 35.7 | 24 | 2.9 | 2.3 | | 2.04 | 74.2 |
| MEAN $\bar{X}$ | 100 | 97.8 | 70.2 | 37.0 | 25.1 | 3.1 | 1.86 | | 2.04 | 75.0 |
| RANGE (R) | 0 | 4.0 | 9.0 | 17.1 | 11.0 | 3.8 | 1.3 | | .20 | 1.7 |
| STD. DEV (σ) | 0 | 1.11 | 2.22 | 4.49 | 3.07 | 1.03 | .43 | | .050 | .49 |
| VAR COEFF | 0 | 1.13 | 3.17 | 12.14 | 12.26 | 32.99 | 23.10 | | 2.96 | .66 |
| VARIANCE | 0 | 1.23 | 4.95 | 20.17 | 9.43 | 1.06 | .185 | | .0037 | .24 |
| SKEWNESS | 0 | -.42 | .14 | -.[illegible] | -.4[illegible] | .15 | -.[illegible] | | -.66 | |

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AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #6 - FINE AGGREGATE

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE 1 | *100.0 | *90-100 | | *70-92 | *50-80 | *30-65 | *10-30 | *1-8 | *0-3 | MID-SPEC 2.870 |
| FA-1 | 100.0 | 97.6 | | 87.3 | 75.9 | 56.5 | 14.4 | 1.6 | | 2.667 |
| FA-2 | 100.0 | 98.5 | | 88.1 | 75.9 | 58.0 | 14.7 | 1.7 | | 2.630 |
| FA-3(Cyc2) | | 98.4 | | 86.8 | 75.5 | 59.9 | 14.8 | 2.1 | | 2.625 |
| FA-4 | | 99.0 | | 89.9 | 78.7 | 60.3 | 14.4 | 1.6 | | 2.561 |
| FA-5(Cyc3) | | 98.0 | | 87.9 | 77.0 | 58.7 | 14.4 | 1.6 | | 2.624 |
| FA-6 | | 98.2 | | 87.8 | 76.2 | 56.8 | 14.5 | 2.0 | | 2.645 |
| MEAN $\bar{X}$ | 100 | 98.3 | | 88.0 | 76.5 | 58.4 | 14.5 | 1.77 | | 2.62 |
| RANGE (R) | 0 | 1.4 | | 3.1 | 3.2 | 3.8 | .4 | .5 | | .11 |
| STD DEV 6 | 0 | .49 | | 1.06 | 1.17 | 1.57 | .17 | .22 | | .035 |
| VAR COEFF | 0 | .49 | | 1.20 | 1.53 | 2.68 | 1.20 | 12.74 | | 1.35 |
| VARIANCE | 0 | .24 | | 1.12 | 1.38 | 2.45 | .03 | .05 | | .001 |
| SKEWNESS | 0 | | | .73 | .91 | .02 | .56 | .52 | | -.71 |

NOTE: For each cycle, a sample was taken from the stockpile and from the batch (a batcher sample). F. A. 1, 3, and 5 are batcher samples. F. A. 2, 4, and 6 are stockpile samples.

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #7 - #67 GRAVEL AGGREGATE

PS - Concrete Plant Stockpile Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE 1 | | *100 | *90-100 | | *20-55 | *0-10 | *0-5 | | |
| PS-1 | | 100 | 90 | | 41 | 8 | 1 | 2.42 | 106.3 |
| PS-2 | | 100 | 94 | | 51 | 7 | 1 | 2.55 | 106.3 |
| PS-3 | | 100 | 94 | | 50 | 8 | 2 | 2.58 | 106.0 |
| PS-4 | | 100 | 93 | | 48 | 9 | 2 | 2.56 | 106.0 |
| PS-5 | | 100 | 94 | | 48 | 8 | 1 | 2.53 | 106.3 |
| PS-6 (Cyc. 2) | | 100 | 93 | | 38 | 6 | 1 | 2.40 | 105.2 |
| PS-7 | | 100 | 90 | | 28 | 6 | 2 | 2.30 | 105.2 |
| PS-8 | | 100 | 91 | | 34 | 4 | 1 | 2.32 | 106.0 |
| PS-9 | | 100 | 92 | | 32 | 5 | 2 | 2.35 | 104.5 |
| PS-10 | | 100 | 90 | | 32 | 4 | 2 | 2.32 | 104.9 |
| PS-11 (Cyc. 3) | | 100 | 92 | | 52 | 8 | 1 | 2.55 | 106.4 |
| PS-12 | | 99 | 88 | | 47 | 7 | 1 | 2.45 | 107.4 |
| PS-13 | | 99 | 89 | | 50 | 7 | 1 | 2.49 | 106.9 |
| PS-14 | | 99 | 87 | | 34 | 5 | 1 | 2.29 | 106.7 |
| PS-15 | | 100 | 87 | | 36 | 5 | 1 | 2.31 | 107.3 |
| MEAN $\bar{X}$ | | 99.8 | 90.9 | | 41.4 | 6.5 | 1.33 | 2.43 | 106.1 |
| RANGE (R) | | 1.0 | 7.0 | | 24.0 | 5.0 | 1.0 | .29 | 2.9 |
| STD DEV (6) | | .41 | 2.46 | | 8.36 | 1.60 | .49 | .108 | .84 |
| VAR COEFF | | .41 | 2.71 | | 20.18 | 24.70 | 36.60 | 4.47 | .80 |
| VARIANCE | | .17 | 6.07 | | 69.83 | 2.55 | .24 | .012 | .71 |
| SKEWNESS | | - .94 | - .22 | | - .11 | - .14 | .64 | .07 | - .22 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #7 - #67 GRAVEL AGGREGATE

Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | | *100 | *90-100 | | *20-55 | *0-10 | *0-5 | | | |
| Bat. 1 | | 99 | 94 | | 49 | 10 | 2 | | 2.59 | 106.0 |
| Bat. 2 | | 99 | 92 | | 50 | 10 | 3 | | 2.61 | 106.3 |
| Bat. 3 | | 99 | 95 | | (57) | (12) | 2 | | 2.70 | 106.0 |
| Bat. 4 | | 100 | 93 | | 41 | 8 | 2 | | 2.48 | 106.0 |
| Bat. 5 | | 100 | 92 | | 42 | 10 | 3 | | 2.53 | 106.6 |
| Bat. 6 (Cyc. 2) | | 100 | (89) | | 31 | 8 | 5 | | 2.43 | 106.9 |
| Bat. 7 | | 100 | 91 | | 28 | 8 | 5 | | 2.42 | 106.6 |
| Bat. 8 | | 100 | 91 | | 38 | 7 | 3 | | 2.45 | 106.9 |
| Bat. 9 | | 100 | 91 | | 44 | 9 | 3 | | 2.53 | 107.3 |
| Bat. 10 | | 100 | 93 | | 43 | 7 | 3 | | 2.52 | 106.3 |
| Bat. 11(Cyc. 3) | | 99 | 90 | | 46 | 9 | 2 | | 2.51 | 107.9 |
| Bat. 12 | | 99 | 91 | | 55 | (12) | 2 | | 2.64 | 107.8 |
| Bat. 13 | | 99 | 90 | | 51 | 9 | 2 | | 2.56 | 107.7 |
| Bat. 14 | | 99 | (88) | | 50 | (12) | 2 | | 2.56 | 109.1 |
| Bat. 15 | | 100 | 92 | | 50 | 10 | 2 | | 2.58 | 107.5 |
| MEAN $\bar{X}$ | | 99.5 | 91.5 | | 45.0 | 9.4 | 2.7 | | 2.54 | 107.0 |
| RANGE (R) | | 1.0 | 7.0 | | 29.0 | 5.0 | 3.0 | | .28 | 3.1 |
| STD DEV (6) | | .52 | 1.85 | | 8.18 | 1.68 | 1.03 | | .078 | .89 |
| VAR COEFF | | .52 | 2.02 | | 18.17 | 17.89 | 37.78 | | 3.07 | .83 |
| VARIANCE | | .27 | 3.41 | | 66.86 | 2.83 | 1.07 | | .006 | .79 |
| SKEWNESS | | | .04 | | -.57 | .24 | 1.22 | | .20 | .67 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #7 - FINE AGGREGATE — Samples taken at Batcher Point only.

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS CYCLE - 1 | *100 | *95-100 | | (70-90) | *45-80 | (27-53) | *10-30 | *2-10 | *0-3 | MID-SPEC 2.94 |
| FA-1 | 100 | 100 | | 84 | 70 | 50 | 20 | 5 | 1.7 | 2.71 |
| FA-2 | 100 | 100 | | 84 | 68 | 48 | 18 | 4 | 1.4 | 2.78 |
| FA-3 | 100 | 100 | | 85 | 69 | 48 | 18 | 5 | 1.8 | 2.75 |
| FA-4 | 100 | 100 | | 85 | 70 | 50 | 18 | 4 | 1.5 | 2.73 |
| FA-5 | 100 | 100 | | 86 | 71 | 51 | 19 | 5 | 1.8 | 2.68 |
| FA-6 (Cyc. 2) | 100 | 100 | | 84 | 66 | 42 | 14 | 3 | 1.4 | 2.91 |
| FA-7 | 100 | 100 | | 84 | 66 | 43 | 12 | 3 | 1.3 | 2.92 |
| FA-8 | 100 | 99 | | 84 | 67 | 46 | 18 | 5 | 2.0 | 2.81 |
| FA-9 | 100 | 100 | | 85 | 66 | 43 | 15 | 3 | 1.3 | 2.88 |
| FA-10 | 100 | 100 | | 84 | 65 | 43 | 14 | 3 | 1.2 | 2.91 |
| FA-11 (Cyc. 3) | 100 | 100 | | 85 | 69 | 46 | 14 | 3 | 1.5 | 2.83 |
| FA-12 | 100 | 100 | | 83 | 67 | 45 | 15 | 4 | 1.4 | 2.86 |
| FA-13 | 100 | 100 | | 85 | 69 | 47 | 15 | 3 | 1.2 | 2.81 |
| FA-14 | 100 | 100 | | 83 | 66 | 43 | 14 | 3 | 1.4 | 2.91 |
| FA-15 | 100 | 100 | | 83 | 66 | 43 | 14 | 4 | 1.7 | 2.90 |
| MEAN $\bar{X}$ | 100 | 99.9 | | 84.3 | 67.7 | 45.9 | 15.9 | 3.8 | 1.51 | 2.83 |
| RANGE (R) | 0 | 1.0 | | 3.0 | 6.0 | 9.0 | 8.0 | 2.0 | .8 | .24 |
| STD DEV(6) | 0 | .26 | | .88 | 1.88 | 3.02 | 2.39 | .86 | .24 | .081 |
| VAR COEFF | 0 | .26 | | 1.05 | 2.77 | 6.58 | 15.04 | 22.68 | 15.96 | 2.87 |
| VARIANCE | 0 | .07 | | .78 | 3.52 | 9.12 | 5.70 | .74 | .06 | .006 |
| SKEWNESS | 0 | - 3.89 | | | .27 | .29 | .23 | .35 | .50 | - .36 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #8 - #57 LIMESTONE AGGREGATE

QS - Quarry Stockpile

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE -1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | | |
| QS-1 | 100 | 100 | 78.7 | 14.7 | 2.7 | 1.0 | 0.6 | | 1.84 | 99.1 |
| QS-2 | 100 | 99.6 | 78.7 | 20.8 | 4.0 | 1.0 | 0.7 | | 1.85 | 98.9 |
| QS-3 | 100 | 100 | 84.3 | 26.6 | 5.8 | 1.1 | 0.7 | | 1.93 | 98.6 |
| QS-4 | 100 | 100 | 92.6 | 51.1 | 14.6 | 1.0 | 0.6 | | 2.10 | 99.0 |
| QS-5 | 100 | 100 | 87.2 | 29.1 | 6.6 | 0.8 | 0.6 | | 1.96 | 98.3 |
| QS-6 (Cyc. 2) | 100 | 100 | 92.1 | 45.9 | 11.8 | 1.4 | 1.0 | | 2.08 | 98.8 |
| QS-7 | 100 | 100 | 88.0 | 33.3 | 6.0 | 1.0 | 0.6 | | 1.97 | 97.9 |
| QS-8 | 100 | 100 | 91.2 | 43.9 | 12.2 | 0.9 | 0.5 | | 2.06 | 99.2 |
| QS-9 | 100 | 100 | 88.5 | 45.5 | 11.7 | 1.0 | 0.6 | | 2.03 | 99.1 |
| QS-10 | 100 | 100 | 92.4 | 51.6 | 16.2 | 1.1 | 0.7 | | 2.12 | 98.9 |
| QS-11 (Cyc. 3) | 100 | 100 | 95.8 | 62.8 | 27.1 | 3.0 | 2.1 | | 2.32 | 98.8 |
| QS-12 | 100 | 100 | 93.4 | 51.3 | 20.6 | 9.4 | 9.2 | | 2.47 | 97.8 |
| QS-13 | 100 | 100 | 94.3 | 58.9 | 17.7 | 3.1 | 1.9 | | 2.21 | 99.1 |
| QS-14 | 100 | 100 | 92.8 | 48.4 | 15.6 | 2.4 | 1.7 | | 2.16 | 98.0 |
| QS-15 | 100 | 100 | 94.9 | 57.0 | 20.6 | 2.8 | 2.0 | | 2.24 | 97.8 |
| MEAN $\bar{X}$ | 100 | 100 | 89.7 | 42.7 | 12.9 | 2.1 | 1.6 | | 2.09 | 98.6 |
| RANGE (R) | 0 | .4 | 17.1 | 48.1 | 24.4 | 8.6 | 8.7 | | .63 | 1.4 |
| STD DEV (6) | 0 | 0 | 5.44 | 14.50 | 7.01 | 2.19 | 2.19 | | .174 | .52 |
| VAR COEFF | 0 | 0 | 6.07 | 33.93 | 54.44 | 106.12 | 139.90 | | 8.31 | .52 |
| VARIANCE | 0 | 0 | 29.58 | 210.20 | 49.17 | 4.81 | 4.80 | | .030 | .27 |
| SKEWNESS | 0 | 0 | - .91 | - .50 | .25 | 2.43 | 2.77 | | .48 | - .48 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
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## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #8 - #57 LIMESTONE AGGREGATE

PS - Concrete Plant Stockpile Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | Ā | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| PS-1 | 100.0 | 100.0 | 81.8 | 30.8 | 10.3 | 2.0 | 1.2 | 1.98 | 99.5 |
| PS-2 | 100.0 | 100.0 | 84.7 | 32.1 | 8.5 | 0.8 | 0.5 | 1.95 | 98.7 |
| PS-3 | 100.0 | 100.0 | 93.4 | 50.9 | 17.8 | 3.1 | 2.1 | 2.21 | 98.9 |
| PS-4 | 100.0 | 100.0 | 94.7 | 53.8 | 17.6 | 1.5 | 0.8 | 2.16 | 98.7 |
| PS-5 | 100.0 | 100.0 | 90.6 | 34.9 | 11.3 | 1.5 | 0.9 | 2.06 | 100.0 |
| PS-6 (Cyc. 2) | 100.0 | 100.0 | 88.0 | 44.6 | 11.6 | 0.7 | 0.3 | 2.01 | 97.1 |
| PS-7 | 100.0 | 100.0 | 93.5 | 55.1 | 17.3 | 1.2 | 0.5 | 2.13 | 99.2 |
| PS-8 | 100.0 | 100.0 | 86.2 | 32.1 | 8.2 | 1.1 | 0.4 | 1.97 | 97.6 |
| PS-9 | 100.0 | 100.0 | 86.1 | 30.3 | 9.2 | 0.9 | 0.5 | 1.98 | 98.7 |
| PS-10 | 100.0 | 100.0 | 90.4 | 46.6 | 14.8 | 1.3 | 1.0 | 2.09 | 99.0 |
| PS-11 (Cyc. 3) | 100.0 | 100.0 | 94.0 | 55.1 | 20.6 | 2.6 | 1.8 | 2.23 | 98.0 |
| PS-12 | 100.0 | 100.0 | 92.6 | 50.4 | 17.1 | 1.8 | 1.1 | 2.15 | 98.2 |
| PS-13 | 100.0 | 100.0 | 90.1 | 39.6 | 10.0 | 0.7 | 0.4 | 2.02 | 96.4 |
| PS-14 | 100.0 | 100.0 | 92.0 | 60.6 | 26.2 | 3.8 | 2.5 | 2.29 | 98.3 |
| PS-15 | 100.0 | 100.0 | 93.6 | 49.8 | 15.7 | 1.5 | 0.9 | 2.13 | 97.6 |
| MEAN $\bar{X}$ | 100 | 100 | 90.1 | 44.4 | 14.4 | 1.6 | .99 | 2.09 | 98.4 |
| RANGE (R) | 0 | 0 | 12.9 | 30.3 | 18.0 | 3.1 | 2.2 | .34 | 3.6 |
| STD DEV (6) | 0 | 0 | 3.92 | 10.32 | 5.15 | .91 | .66 | .106 | .94 |
| VAR COEFF | 0 | 0 | 4.35 | 23.22 | 35.71 | 55.62 | 66.83 | 5.05 | .96 |
| VARIANCE | 0 | 0 | 15.35 | 106.55 | 26.50 | .82 | .44 | .011 | .89 |
| SKEWNESS | 0 | 0 | - .63 | .08 | .58 | 1.01 | .95 | .26 | - .40 |

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BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #8 - #57 LIMESTONE AGGREGATE

Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| Bat. 1 | 100.0 | 100.0 | 92.0 | 52.9 | 20.7 | 3.6 | 2.5 | 2.24 | 100.3 |
| Bat. 2 | 100.0 | 100.0 | 92.9 | 53.3 | 19.6 | 2.3 | 1.9 | 2.20 | 100.2 |
| Bat. 3 | 100.0 | 100.0 | 93.5 | 61.0 | 27.5 | 4.0 | 2.6 | 2.33 | 99.7 |
| Bat. 4 | 100.0 | 100.0 | 82.9 | 35.0 | 10.6 | 2.3 | 1.8 | 2.01 | 100.2 |
| Bat. 5 | 100.0 | 100.0 | 93.0 | 52.4 | 21.4 | 3.2 | 2.4 | 2.25 | 100.4 |
| Bat. 6 (Cyc. 2) | 100.0 | 100.0 | 93.3 | 65.1 | 27.2 | 1.9 | 1.1 | 2.26 | 97.8 |
| Bat. 7 | 100.0 | 100.0 | 97.0 | 69.7 | 35.3 | 8.5 | 5.3 | 2.59 | 99.9 |
| Bat. 8 | 100.0 | 100.0 | 96.2 | 56.5 | 15.2 | 1.6 | 1.0 | 2.16 | 97.9 |
| Bat. 9 | 100.0 | 100.0 | 96.4 | 72.7 | 36.2 | 6.0 | 1.0 | 2.42 | 99.4 |
| Bat. 10 | 100.0 | 100.0 | 95.0 | 54.7 | 22.0 | 2.1 | 1.3 | 2.23 | 99.2 |
| Bat. 11 (Cyc. 3) | 100.0 | 100.0 | 96.8 | 74.4 | 40.6 | 12.7 | 8.7 | 2.82 | 101.4 |
| Bat. 12 | 100.0 | 100.0 | 95.7 | 65.9 | 28.6 | 6.7 | 4.2 | 2.44 | 100.3 |
| Bat. 13 | 100.0 | 100.0 | 93.8 | 60.1 | 30.2 | 11.9 | 8.9 | 2.60 | 102.1 |
| Bat. 14 | 100.0 | 100.0 | 89.4 | 38.1 | 8.6 | 1.0 | 0.8 | 2.01 | 98.0 |
| Bat. 15 | 100.0 | 100.0 | 91.7 | 41.2 | 10.3 | 1.3 | 1.0 | 2.06 | 97.8 |
| MEAN $\bar{X}$ | 100 | 100 | 93.3 | 56.9 | 23.6 | 4.6 | 3.0 | 2.31 | 99.6 |
| RANGE (R) | 0 | 0 | 14.1 | 39.4 | 32.0 | 11.7 | 8.1 | .80 | 4.3 |
| STD DEV (6) | 0 | 0 | 3.59 | 12.04 | 9.84 | 3.79 | 2.68 | .231 | 1.31 |
| VAR COEFF | 0 | 0 | 3.85 | 21.17 | 41.68 | 82.20 | 90.43 | 10.00 | 1.31 |
| VARIANCE | 0 | 0 | 12.91 | 144.91 | 96.76 | 14.34 | 7.20 | .053 | 1.72 |
| SKEWNESS | 0 | 0 | - 1.47 | - .31 | .03 | 1.00 | 1.26 | .58 | - .03 |

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BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #8 - FINE AGGREGATE

Samples taken at Batcher Point only.

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *95-100 | | (73-83) | (50-65) | (26-47) | *5-30 | *1-7 | *0-4 | MID-SPEC 3.090 |
| FA-1 | 100.0 | 95.6 | | 84.0 | 57.1 | 22.6 | 7.6 | 3.8 | 2.6 | 3.29 |
| FA-2 | 99.2 | 95.4 | | 85.0 | 60.7 | 24.5 | 8.9 | 4.0 | 2.7 | 3.21 |
| FA-3 | 100.0 | 96.7 | | 86.0 | 62.8 | 28.6 | 11.1 | 5.6 | 3.6 | 3.09 |
| FA-4 | 99.7 | 96.4 | | 86.0 | 61.9 | 26.6 | 9.6 | 4.4 | 3.1 | 3.15 |
| FA-5 | 100.0 | 97.1 | | 88.4 | 64.3 | 28.0 | 10.6 | 5.4 | 3.6 | 3.06 |
| FA-6 (Cyc 2) | 99.2 | 95.9 | | 84.7 | 60.4 | 24.2 | 9.2 | 4.7 | 3.4 | 3.21 |
| FA-7 | 100.0 | 95.7 | | 83.9 | 58.1 | 22.1 | 8.6 | 4.2 | 2.9 | 3.27 |
| FA-8 | 100.0 | 97.5 | | 88.2 | 63.1 | 24.7 | 8.7 | 5.2 | 3.6 | 3.13 |
| FA-9 | 100.0 | 96.7 | | 85.9 | 59.8 | 20.9 | 7.6 | 4.1 | 3.1 | 3.25 |
| FA-10 | 100.0 | 96.8 | | 85.2 | 59.9 | 24.1 | 8.6 | 4.8 | 3.5 | 3.21 |
| FA-11(Cyc 3) | 100.0 | 94.7 | | 81.7 | 54.9 | 20.3 | 5.9 | 3.1 | 2.3 | 3.39 |
| FA-12 | 100.0 | 96.4 | | 84.9 | 57.6 | 17.3 | 4.7 | 2.3 | 1.6 | 3.37 |
| FA-13 | 100.0 | 95.6 | | 83.4 | 59.4 | 22.2 | 7.2 | 3.9 | 2.8 | 3.28 |
| FA-14 | 100.0 | 95.9 | | 85.8 | 58.3 | 21.2 | 7.4 | 3.5 | 2.5 | 3.28 |
| FA-15 | 100.0 | 96.3 | | 82.4 | 55.4 | 20.6 | 6.5 | 3.6 | 2.6 | 3.35 |
| MEAN $\bar{X}$ | 99.9 | 96.2 | | 85.0 | 59.6 | 23.2 | 8.1 | 4.2 | 2.93 | 3.24 |
| RANGE (R) | 0.8 | 2.8 | | 6.7 | 9.4 | 11.3 | 6.4 | 3.3 | 2.0 | .33 |
| STD DEV(6) | .28 | .73 | | 1.85 | 2.75 | 3.06 | 1.71 | .89 | .57 | .098 |
| VAR COEFF | .28 | .76 | | 2.17 | 4.61 | 13.21 | 20.99 | 21.25 | 19.56 | 3.05 |
| VARIANCE | .08 | .53 | | 3.41 | 7.56 | 9.38 | 2.92 | .79 | .33 | .009 |
| SKEWNESS | | | | .12 | - .02 | .11 | - .17 | - .20 | - .54 | - .16 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #9 - #57 GRAVEL AGGREGATE — PP = Sample From Processing Plant

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE -1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| PP-1 | 100 | 98 | 85 | 57 | 37 | 3 | 1 | 2.28 | 105.8 |
| PP-2 | 100 | 99 | 87 | 57 | 36 | 2 | 1 | 2.28 | 106.0 |
| PP-3 | 100 | 99 | 93 | 72 | 50 | 5 | 1 | 2.51 | 104.0 |
| PP-4 | 100 | 99 | 87 | 63 | 44 | 4 | 1 | 2.38 | 105.8 |
| PP-5 | 100 | 99 | 90 | 61 | 43 | 6 | 2 | 2.45 | 105.4 |
| PP-6 (Cyc 2) | 100 | 100 | 93 | 74 | 52 | 5 | 1 | 2.53 | 106.0 |
| PP-7 | 100 | 100 | 95 | 79 | 62 | 11 | 3 | 2.77 | 105.6 |
| PP-8 | 100 | 100 | 97 | 83 | 65 | 9 | 1 | 2.74 | 106.2 |
| PP-9 | 100 | 99 | 92 | 73 | 52 | 7 | 2 | 2.57 | 106.8 |
| PP-10 | 100 | 100 | 96 | 77 | 54 | 8 | 1 | 2.61 | 106.8 |
| PP-11(Cyc 3) | 100 | 97 | 83 | 52 | 30 | 3 | 2 | 2.22 | 105.6 |
| PP-12 | 100 | 99 | 89 | 61 | 38 | 3 | 1 | 2.33 | 105.4 |
| PP-13 | 100 | 99 | 86 | 53 | 29 | 3 | 1 | 2.21 | 105.4 |
| PP-14 | 100 | 99 | 92 | 65 | 42 | 4 | 2 | 2.44 | 105.2 |
| PP-15 | 100 | 98 | 84 | 56 | 34 | 3 | 1 | 2.24 | 106.0 |
| MEAN $\bar{X}$ | 100 | 99.0 | 89.9 | 65.5 | 44.5 | 5.1 | 1.4 | 2.44 | 105.7 |
| RANGE (R) | 0 | 3.0 | 14.0 | 31.0 | 36.0 | 9.0 | 2.0 | .56 | 2.8 |
| STD DEV (6) | 0 | .84 | 4.48 | 10.04 | 11.02 | 2.63 | .63 | .182 | .67 |
| VAR COEFF | 0 | .85 | 4.98 | 15.32 | 24.74 | 51.93 | 45.18 | 7.48 | .64 |
| VARIANCE | 0 | .71 | 20.07 | 100.84 | 121.41 | 6.92 | .40 | .033 | .45 |
| SKEWNESS | 0 | -.77 | .01 | .25 | .32 | .83 | 1.14 | .31 | -.22 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #9 - #57 GRAVEL AGGREGATE BAT = Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | | |
| BAT-1 | 100 | 98 | 90 | 67 | 45 | 4 | 2 | | 2.45 | 107.4 |
| BAT-2 | 100 | 98 | 84 | 59 | 40 | 4 | 2 | | 2.34 | 107.2 |
| BAT-3 | 100 | 98 | 84 | 56 | 35 | 4 | 2 | | 2.29 | 107.6 |
| BAT-4 | 100 | 98 | 88 | 63 | 44 | 4 | 2 | | 2.42 | 106.6 |
| BAT-5 | 100 | 96 | 82 | 56 | 35 | 5 | 3 | | 2.31 | 108.2 |
| BAT-6 (Cyc2 | 100 | 95 | 74 | 48 | 33 | 5 | 3 | | 2.21 | 107.2 |
| BAT-7 | 100 | 98 | 84 | 55 | 37 | 4 | 2 | | 2.31 | 106.4 |
| BAT-8 | 100 | 97 | 82 | 58 | 40 | 5 | 2 | | 2.33 | 108.6 |
| BAT-9 | 100 | 96 | 83 | 66 | 51 | 9 | 3 | | 2.52 | 110.0 |
| BAT-10 | 100 | 98 | 88 | 67 | 51 | 6 | 1 | | 2.48 | 108.0 |
| BAT-11 Cyc3 | 100 | 95 | 78 | 51 | 33 | 4 | 2 | | 2.21 | 108.2 |
| BAT-12 | 100 | 98 | 82 | 52 | 33 | 4 | 2 | | 2.25 | 107.0 |
| BAT-13 | 100 | 96 | 76 | 46 | 28 | 5 | 3 | | 2.18 | 108.8 |
| BAT-14 | 100 | 98 | 84 | 56 | 38 | 5 | 3 | | 2.36 | 107.2 |
| BAT-15 | 100 | 98 | 82 | 52 | 33 | 4 | 3 | | 2.28 | 108.0 |
| MEAN $\bar{X}$ | 100 | 97.1 | 82.7 | 56.8 | 38.4 | 4.8 | 2.3 | | 2.33 | 107.8 |
| RANGE (R) | 0 | 3.0 | 16.0 | 21.0 | 23.0 | 5.0 | 2.0 | | .34 | 3.6 |
| STD DEV (б) | 0 | 1.19 | 4.32 | 6.63 | 6.80 | 1.32 | .62 | | .102 | .93 |
| VAR COEFF | 0 | 1.22 | 5.22 | 11.68 | 17.71 | 27.50 | 26.45 | | 4.36 | .86 |
| VARIANCE | 0 | 1.41 | 18.64 | 44.03 | 46.26 | 1.74 | .38 | | .010 | .87 |
| SKEWNESS | 0 | -.72 | -.33 | .18 | .56 | 2.08 | -.25 | | .35 | .74 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #9 - #57 FINE AGGREGATE

Samples Taken at Batcher Point Only

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS CYCLE - 1 | *100 | *95-100 | | (70-90) | *45-80 | *20-60 | *10-30 | *1-8 | *0-3 | MID-SPEC 2.955 |
| FA-1 | 100 | 97 | | 88 | 78 | 54 | 12 | 4 | 2.4 | 2.67 |
| FA-2 | 100 | 98 | | 89 | 79 | 56 | 14 | 4 | 2.8 | 2.60 |
| FA-3 | 100 | 97 | | 87 | 76 | 53 | 13 | 5 | 2.6 | 2.69 |
| FA-4 | 100 | 97 | | 87 | 76 | 52 | 13 | 5 | 2.6 | 2.70 |
| FA-5 | 100 | 98 | | 88 | 78 | 52 | 11 | 4 | 2.4 | 2.69 |
| FA-6 Cyc2 | 100 | 99 | | 91 | 81 | 59 | 11 | 4 | 2.0 | 2.55 |
| FA-7 | 100 | 97 | | 87 | 78 | 59 | 15 | 5 | 3.2 | 2.59 |
| FA-8 | 100 | 97 | | 89 | 79 | 58 | 12 | 4 | 2.4 | 2.61 |
| FA-9 | 100 | 98 | | 88 | 78 | 57 | 15 | 5 | 3.2 | 2.59 |
| FA-10 | 100 | 99 | | 87 | 77 | 57 | 15 | 5 | 3.1 | 2.62 |
| FA-11 Cyc3 | 100 | 98 | | 87 | 79 | 56 | 12 | 5 | 3.0 | 2.63 |
| FA-12 | 100 | 98 | | 84 | 74 | 55 | 13 | 3 | 0.8 | 2.75 |
| FA-13 | 100 | 98 | | 89 | 80 | 57 | 11 | 4 | 2.6 | 2.61 |
| FA-14 | 100 | 98 | | 89 | 80 | 57 | 12 | 4 | 2.8 | 2.60 |
| FA-15 | 100 | 98 | | 89 | 81 | 61 | 13 | 5 | 3.0 | 2.53 |
| MEAN X̄ | 100 | 97.8 | | 87.9 | 78.3 | 56.2 | 12.8 | 4.4 | 2.6 | 2.63 |
| RANGE (R) | 0 | 2.0 | | 7.0 | 7.0 | 9.0 | 4.0 | 2.0 | 2.4 | .22 |
| STD DEV 6 | 0 | .68 | | 1.58 | 1.94 | 2.62 | 1.42 | .63 | .60 | .059 |
| VAR COEFF | 0 | .69 | | 1.80 | 2.48 | 4.67 | 11.13 | 14.37 | 23.25 | 2.28 |
| VARIANCE | 0 | .46 | | 2.49 | 3.78 | 6.89 | 2.03 | .40 | .36 | .003 |
| SKEWNESS | 0 | .43 | | -.49 | -.45 | -.11 | .33 | -.44 | -1.60 | .34 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #10 - #57 GRAVEL AGGREGATE — BS- Belt Sample (Job Control)

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| BS-1 | 100 | | 85.0 | 48 | 27.1 | 4.0 | 3.0 | 2.25 | 100.0 |
| BS-2 | 100 | | 67.2 | 32 | 11.6 | 1.8 | 0.9 | 1.83 | 98.3 |
| BS-3 | 100 | | 82.4 | 48 | 27.1 | 3.0 | 1.7 | 2.18 | 97.2 |
| BS-4 | 100 | | 74.1 | 38 | 16.9 | 2.1 | 1.2 | 1.97 | 98.3 |
| BS-5 | 100 | | 72.9 | 40 | 19.2 | 2.1 | 1.2 | 1.98 | 98.2 |
| BS-6 Cyc2 | 100 | | 73.9 | 43 | 25.0 | 2.6 | 0.8 | 2.04 | 102.0 |
| BS-7 | 100 | | 72.2 | 38 | 17.6 | 1.5 | 0.7 | 1.93 | 100.6 |
| BS-8 | 99.5 | | 61.4 | 32 | 14.3 | 1.6 | 1.0 | 1.80 | 101.2 |
| BS.9 | 100 | | 73.5 | 38 | 15.9 | 1.7 | 1.0 | 1.94 | 100.1 |
| BS-10 | 100 | | 63.5 | 30 | 9.5 | 0.6 | 0.4 | 1.75 | 96.9 |
| BS-11 Cyc3 | 100 | | 72.5 | 42 | 24.6 | 3.7 | 1.6 | 2.06 | 102.8 |
| BS-12 | 100 | | 75.0 | 45 | 25.1 | 4.7 | 3.0 | 2.14 | 102.9 |
| BS-13 | 100 | | 62.1 | 33 | 17.5 | 2.3 | 1.4 | 1.86 | 103.0 |
| BS-14 | 100 | | 75.3 | 45 | 24.6 | 2.5 | 1.2 | 2.06 | 100.3 |
| BS-15 | 100 | | 70.8 | 41 | 21.4 | 1.4 | 0.6 | 1.95 | 99.7 |
| MEAN $\bar{X}$ | 100.0 | | 72.1 | 39.5 | 19.8 | 2.4 | 1.3 | 1.98 | 100.1 |
| RANGE (R) | 0.5 | | 23.6 | 18.0 | 17.6 | 4.1 | 2.6 | .50 | 6.1 |
| STD DEV $\sigma$ | 0 | | 6.63 | 5.84 | 5.66 | 1.09 | .77 | .142 | 2.03 |
| VAR COEFF | 0 | | 9.19 | 14.78 | 28.53 | 45.98 | 58.69 | 7.16 | 2.03 |
| VARIANCE | 0 | | 43.95 | 34.12 | 32.00 | 1.19 | .59 | .020 | 4.11 |
| SKEWNESS | 0 | | .07 | -.14 | -.24 | .58 | 1.17 | .17 | |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

SAMPLE #10 - #57 GRAVEL AGGREGATE

BAT = Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE -1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | | |
| BAT-1 | 100.0 | INDIVIDUAL RESULTS NOT AVAILABLE- SIEVE IS NOT INVOLVED IN $\bar{A}$ COMPUTATION | 83.2 | 49 | 28.6 | 6.6 | 3.9 | | 2.30 | 97.8 |
| BAT-2 | 100 | | 79.7 | 44 | 22.8 | 3.2 | 1.8 | | 2.11 | 101.8 |
| BAT-3 | 100 | | 83.7 | 53 | 35.0 | 8.5 | 5.0 | | 2.42 | 100.8 |
| BAT-4 | 100 | | 88.3 | 58 | 40.0 | 9.1 | 4.7 | | 2.51 | 100.1 |
| BAT-5 | 100 | | 88.9 | 56 | 34.5 | 5.8 | 3.2 | | 2.39 | 106.2 |
| BAT-6 Cyc2 | 100 | | 76.1 | 45 | 25.7 | 7.6 | 5.5 | | 2.26 | 105.7 |
| BAT-7 | 100 | | 79.7 | 48 | 28.9 | 7.7 | 5.6 | | 2.33 | 102.2 |
| BAT-8 | 100 | | 71.4 | 36 | 14.5 | 3.3 | 2.9 | | 1.98 | 101.2 |
| BAT-9 | 100 | | 76.6 | 42 | 20.9 | 3.0 | 2.2 | | 2.07 | 101.2 |
| BAT-10 | 100 | | 75.0 | 41 | 19.8 | 3.1 | 2.3 | | 2.05 | 101.7 |
| BAT-11 Cyc3 | 100 | | 69.3 | 40 | 22.0 | 3.4 | 2.1 | | 2.01 | 102.0 |
| BAT-12 | 100 | | 76.8 | 47 | 27.2 | 5.1 | 2.9 | | 2.18 | 100.7 |
| BAT-13 | 100 | | 76.5 | 48 | 29.3 | 5.1 | 3.0 | | 2.20 | 101.7 |
| BAT-14 | 100 | | 79.2 | 50 | 29.9 | 5.7 | 3.4 | | 2.25 | 101.8 |
| BAT-15 | 100 | | 76.0 | 45 | 26.0 | 3.8 | 1.9 | | 2.11 | 100.0 |
| MEAN $\bar{X}$ | 100 | 96.6 | 78.7 | 46.8 | 27.0 | 5.4 | 3.4 | | 2.21 | 101.7 |
| RANGE (R) | 0 | | 19.6 | 22.0 | 25.5 | 6.1 | 3.8 | | .54 | 8.4 |
| STD DEV (σ) | 0 | | 5.52 | 5.98 | 6.55 | 2.11 | 1.30 | | .159 | 2.06 |
| VAR COEFF | 0 | | 7.01 | 12.77 | 24.24 | 39.02 | 38.62 | | 7.17 | 2.03 |
| VARIANCE | 0 | | 30.42 | 35.74 | 42.84 | 4.44 | 1.68 | | .025 | 4.25 |
| SKEWNESS | 0 | | .33 | .17 | .10 | .33 | .49 | | .16 | .51 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #10 - FINE AGGREGATE

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE | | | | | | | | | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | |
| *SPECS CYCLE 1 | *100 | *95-100 | | *80-95 | *50-85 | (27-53) | *5-25 | *0-9 | *0-3 | MID-SPEC 2.88 |
| FA-1 | 100 | 99.6 | | 85.1 | 71.6 | 52.2 | 12.3 | 2.8 | | 2.76 |
| FA-2 | 100 | 99.0 | | 85.1 | 71.8 | 52.7 | 12.4 | 2.7 | | 2.76 |
| FA-3 | 100 | 98.7 | | 85.1 | 71.8 | 50.9 | 9.4 | 2.6 | | 2.82 |
| FA-4 | 100 | 98.6 | | 83.6 | 69.8 | 50.2 | 11.6 | 2.7 | | 2.84 |
| FA-5 | 100 | 98.5 | | 84.2 | 70.6 | 51.8 | 12.4 | 3.2 | | 2.79 |
| FA-6 Cyc2 | 100 | 99.4 | | 85.1 | 69.6 | 53.7 | 16.2 | 3.5 | | 2.72 |
| FA-7 | 100 | 99.3 | | 84.0 | 68.1 | 51.6 | 14.8 | 3.1 | | 2.79 |
| FA-8 | 100 | 99.5 | | 84.8 | 68.3 | 51.6 | 14.5 | 2.9 | | 2.78 |
| FA-9 | 100 | 99.4 | | 84.8 | 69.3 | 52.5 | 15.4 | 3.7 | | 2.75 |
| FA-10 | 100 | 99.4 | | 83.6 | 66.6 | 50.1 | 14.3 | 3.2 | | 2.82 |
| FA-11 Cyc3 | 100 | 99.3 | | 85.3 | 68.8 | 45.2 | 11.9 | 2.0 | | 2.88 |
| FA-12 | 100 | 99.2 | | 86.4 | 70.4 | 46.3 | 12.4 | 2.1 | | 2.83 |
| FA-13 | 100 | 99.7 | | 87.0 | 71.4 | 47.7 | 12.9 | 2.1 | | 2.79 |
| FA-14 | 100 | 99.3 | | 85.2 | 68.6 | 45.6 | 12.7 | 2.2 | | 2.86 |
| FA-15 | 100 | 99.2 | | 84.8 | 68.3 | 45.2 | 11.9 | 2.0 | | 2.89 |
| MEAN $\bar{X}$ | 100 | 99.2 | | 84.9 | 69.7 | 49.8 | 13.0 | 2.7 | | 2.81 |
| RANGE (R) | 0 | 1.2 | | 3.4 | 5.2 | 8.5 | 6.8 | 1.7 | | .17 |
| STD DEV σ | 0 | .36 | | .92 | 1.58 | 2.99 | 1.74 | .55 | | .049 |
| VAR COEFF | 0 | .36 | | 1.08 | 2.27 | 6.00 | 13.35 | 20.38 | | 1.75 |
| VARIANCE | 0 | .13 | | .84 | 2.49 | 8.94 | 3.01 | .31 | | .002 |
| SKEWNESS | 0 | -1.46 | | .52 | -.10 | -.47 | .05 | .13 | | .13 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #11 - #57 LIMESTONE AGGREGATE

CBS - Clam Sample (Job Control)

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| CBS-1 | 100 | 100 | 92.3 | 49.1 | 23.9 | 2.8 | 1.5 | 2.23 | 84.2 |
| CBS-2 | 100 | 99.8 | 93.5 | 48.6 | 23.8 | 3.0 | 1.5 | 2.25 | 84.8 |
| CBS-3 | 100 | 100 | 93.4 | 58.0 | 35.8 | 7.3 | 3.0 | 2.45 | 87.8 |
| CBS-4 | 100 | 100 | 92.9 | 52.8 | 29.7 | 3.8 | 1.9 | 2.32 | 86.0 |
| CBS-5 | 100 | 99.8 | 92.1 | 53.9 | 29.3 | 3.5 | 1.5 | 2.29 | 85.4 |
| CBS-6 (Cyc. 2) | 100 | 99.8 | 93.4 | 58.5 | 35.1 | 6.9 | 4.2 | 2.48 | 88.0 |
| CBS-7 | 100 | 99.8 | 93.5 | 61.1 | 38.6 | 7.7 | 4.4 | 2.53 | 88.2 |
| CBS-8 | 100 | 99.7 | 91.5 | 52.5 | 29.5 | 4.8 | 2.9 | 2.34 | 87.0 |
| CBS-9 | 100 | 99.9 | 93.3 | 58.2 | 34.0 | 5.5 | 3.1 | 2.42 | 87.0 |
| CBS-10 | 100 | 99.9 | 93.2 | 58.7 | 36.6 | 6.7 | 3.0 | 2.45 | 88.2 |
| CBS-11 (Cyc. 3) | 100 | 99.9 | 83.2 | 45.3 | 26.4 | 4.6 | 2.8 | 2.23 | 87.6 |
| CBS-12 | 100 | 99.8 | 88.1 | 45.5 | 26.0 | 4.3 | 2.8 | 2.27 | 87.2 |
| CBS-13 | 100 | 99.7 | 87.7 | 40.8 | 21.9 | 2.9 | 1.8 | 2.18 | 86.2 |
| CBS-14 | 100 | 99.9 | 87.2 | 37.5 | 19.6 | 2.9 | 1.9 | 2.15 | 87.0 |
| CBS-15 | 100 | 99.9 | 84.4 | 35.2 | 17.6 | 2.5 | 1.6 | 2.09 | 86.0 |
| MEAN $\bar{X}$ | 100 | 99.9 | 90.6 | 50.4 | 28.5 | 4.6 | 2.5 | 2.31 | 86.7 |
| RANGE (R) | 0 | 0.3 | 10.3 | 25.9 | 21.0 | 5.2 | 2.9 | .44 | 4.0 |
| STD DEV (6) | 0 | .10 | 3.56 | 8.17 | 6.51 | 1.80 | .95 | .131 | 1,24 |
| VAR COEFF | 0 | .10 | 3.92 | 16.22 | 22.82 | 39.02 | 37.71 | 5.65 | 1.43 |
| VARIANCE | 0 | .01 | 12.66 | 66.75 | 42.38 | 3.24 | .91 | .017 | 1.54 |
| SKEWNESS | 0 | - 66.67 | - .88 | - .42 | - .03 | .44 | .53 | .08 | - .52 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #11 - #57 LIMESTONE AGGREGATE

Bat - Batcher Sample

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 1½" | 1" | 3/4" | ½" | 3/8" | No. 4 | No. 8 | $\bar{A}$ | UNIT WEIGHT #/CU. FT. |
|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *90-100 | (60-82) | *25-60 | (16-43) | *0-10 | *0-5 | | |
| Bat. 1 | 100 | 99.9 | 91.8 | 54.9 | 32.0 | 5.2 | 3.0 | 2.38 | 88.0 |
| Bat. 2 | 100 | 99.8 | 92.1 | 57.9 | 34.0 | 4.9 | 2.6 | 2.39 | 88.0 |
| Bat. 3 | 100 | 99.8 | 89.5 | 41.6 | 20.0 | 2.3 | 1.5 | 2.16 | 86.2 |
| Bat. 4 | 100 | 100.0 | 93.9 | 58.7 | 32.4 | 3.7 | 2.2 | 2.37 | 85.8 |
| Bat. 5 | 100 | 99.8 | 94.3 | 62.9 | 38.7 | 5.0 | 2.7 | 2.46 | 87.4 |
| Bat. 6 (Cyc. 2) | 100 | 100.0 | 90.2 | 44.0 | 21.5 | 2.5 | 1.6 | 2.19 | 84.8 |
| Bat. 7 | 100 | 99.7 | 88.8 | 45.5 | 25.2 | 4.4 | 2.0 | 2.24 | 86.6 |
| Bat. 8 | 100 | 100.0 | 92.1 | 49.7 | 25.9 | 2.6 | 1.3 | 2.24 | 85.0 |
| Bat. 9 | 100 | 99.8 | 89.5 | 46.2 | 24.2 | 3.2 | 1.8 | 2.22 | 85.8 |
| Bat. 10 | 100 | 99.9 | 89.8 | 49.5 | 29.8 | 5.5 | 2.6 | 2.33 | 87.0 |
| Bat. 11 (Cyc. 3) | 100 | 99.9 | 93.6 | 56.2 | 33.0 | 7.6 | 4.6 | 2.48 | 88.2 |
| Bat. 12 | 100 | 99.9 | 93.9 | 55.9 | 32.8 | 7.1 | 4.0 | 2.46 | 88.4 |
| Bat. 13 | 100 | 99.9 | 89.8 | 42.4 | 21.4 | 2.7 | 1.5 | 2.18 | 85.6 |
| Bat. 14 | 100 | 100.0 | 88.8 | 42.8 | 23.0 | 3.3 | 1.9 | 2.21 | 86.6 |
| Bat. 15 | 100 | 100.0 | 86.7 | 36.3 | 18.5 | 2.7 | 1.4 | 2.12 | 85.8 |
| MEAN $\bar{X}$ | 100 | 99.9 | 91.0 | 49.6 | 27.5 | 4.2 | 2.3 | 2.30 | 86.6 |
| RANGE (R) | 0 | 0.3 | 7.6 | 26.6 | 20.2 | 5.3 | 3.3 | 0.36 | 3.6 |
| STD DEV (6) | 0 | .10 | 2.29 | 7.74 | 6.12 | 1.68 | .97 | .121 | 1.18 |
| VAR COEFF | 0 | .10 | 2.52 | 15.59 | 22.27 | 40.16 | 41.81 | 5.25 | 1.36 |
| VARIANCE | 0 | .01 | 5.26 | 59.90 | 37.50 | 2.82 | .94 | .014 | 1.38 |
| SKEWNESS | 0 | 74.50 | - .02 | .06 | .14 | .64 | 1.01 | .20 | .12 |

APPENDIX C - US DEPARTMENT OF TRANSPORTATION - FEDERAL HIGHWAY ADMINISTRATION
REGION THREE
BALTIMORE, MARYLAND

## AGGREGATE GRADATION CONTROL STUDY - TEST RESULTS

STUDY #11 - FINE AGGREGATE

Samples taken at Batcher Point only.

| SAMPLE NUMBER | PERCENT PASSING - SIEVE SIZE 3/8" | #4 | #6 | #8 | #16 | #30 | #50 | #100 | #200 | FINENESS MODULUS (F.M.) |
|---|---|---|---|---|---|---|---|---|---|---|
| *SPECS CYCLE - 1 | *100 | *95-100 | | *80-95 | *50-85 | (27-53) | *5-25 | *0-9 | *0-3 | MID-SPEC 2.88 |
| FA-1 | 100.0 | 97.2 | | 77.6 | 60.0 | 44.0 | 13.5 | 2.0 | | 3.06 |
| FA-2 | 100 | 99.6 | | 85.9 | 65.7 | 42.9 | 13.6 | 2.3 | | 2.90 |
| FA-3 | 100 | 99.9 | | 87.6 | 69.6 | 44.9 | 14.4 | 2.1 | | 2.82 |
| FA-4 | 100 | 99.6 | | 88.0 | 71.6 | 48.3 | 16.8 | 2.6 | | 2.73 |
| FA-5 | 99.6 | 98.1 | | 85.2 | 69.8 | 48.9 | 15.8 | 2.3 | | 2.80 |
| FA-6 (Cyc. 2) | 100 | 99.8 | | 88.2 | 71.6 | 51.3 | 15.1 | 1.9 | | 2.72 |
| FA-7 | 100 | 100.0 | | 87.6 | 69.6 | 50.8 | 13.4 | 1.7 | | 2.77 |
| FA-8 | 100 | 100.0 | | 87.5 | 70.0 | 50.5 | 13.8 | 1.8 | | 2.76 |
| FA-9 | 100 | 99.8 | | 88.2 | 71.9 | 51.3 | 14.4 | 1.7 | | 2.73 |
| FA-10 | 100 | 100.0 | | 87.5 | 71.3 | 50.8 | 14.5 | 1.8 | | 2.74 |
| FA-11(Cyc. 3) | 100 | 99.7 | | 88.0 | 72.4 | 51.6 | 15.2 | 2.2 | | 2.71 |
| FA-12 | 100 | 99.6 | | 87.2 | 70.2 | 50.9 | 14.5 | 2.1 | | 2.76 |
| FA-13 | 100 | 99.8 | | 88.9 | 72.1 | 52.7 | 14.0 | 2.3 | | 2.70 |
| FA-14 | 100 | 100.0 | | 87.2 | 71.1 | 50.4 | 14.7 | 2.2 | | 2.74 |
| FA-15 | 100 | 99.6 | | 87.4 | 69.9 | 50.4 | 14.3 | 2.2 | | 2.76 |
| MEAN $\bar{X}$ | 100 | 99.5 | | 86.8 | 69.8 | 49.3 | 14.5 | 2.1 | | 2.78 |
| RANGE (R) | .4 | 2.8 | | 11.3 | 12.4 | 9.8 | 3.4 | .9 | | .36 |
| STD DEV(6) | .10 | .79 | | 2.70 | 3.16 | 2.99 | .91 | .26 | | .098 |
| VAR COEFF | .10 | .79 | | 3.11 | 4.53 | 6.07 | 6.28 | 12.48 | | 3.55 |
| VARIANCE | .01 | .63 | | 7.30 | 10.00 | 8.95 | .83 | .07 | | .009 |
| SKEWNESS | 60.11 | - 1.88 | | - 2.58 | - 2.00 | - 1.04 | .89 | .07 | | 1.70 |

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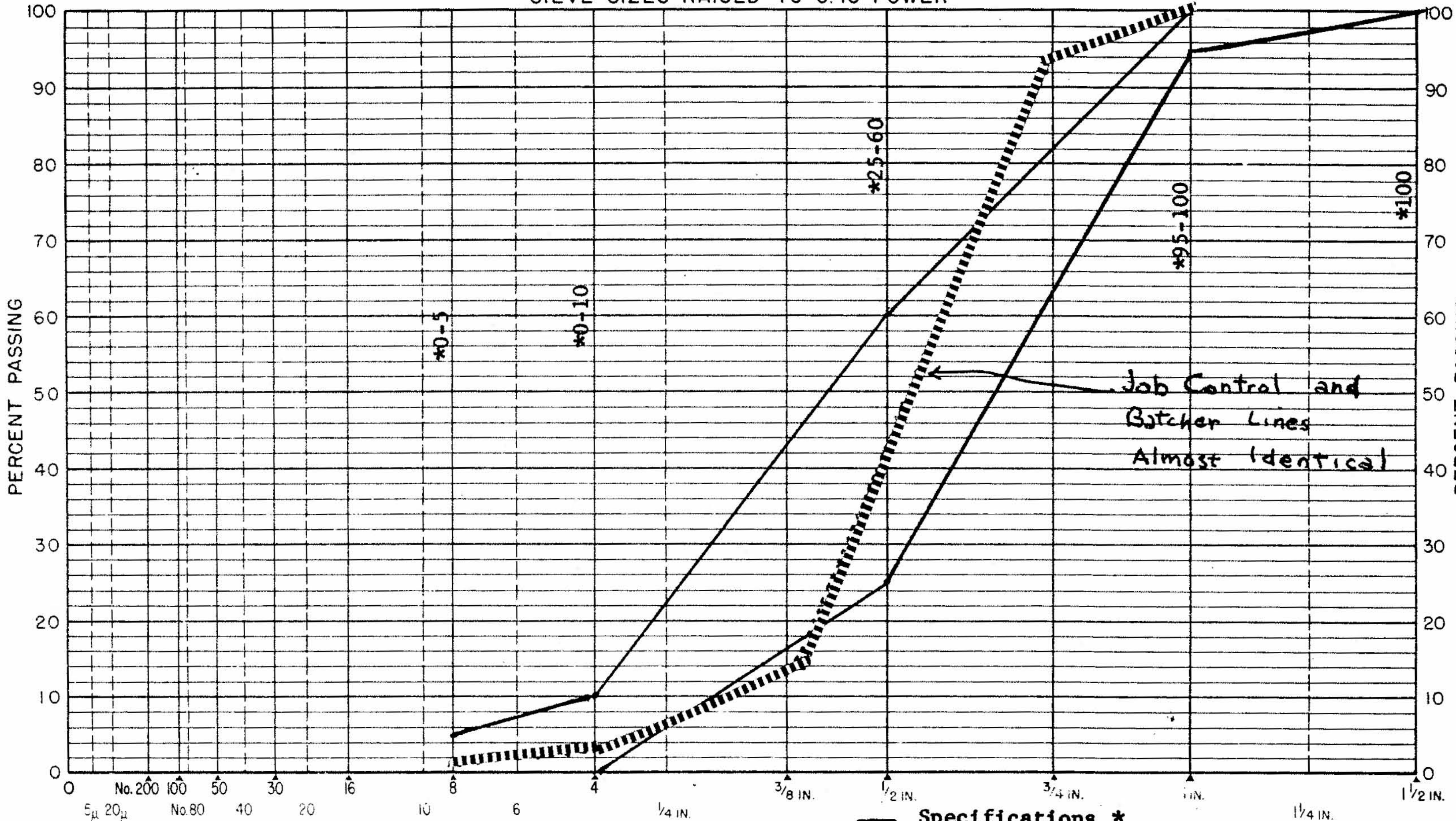
APPENDIX D

# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER




— Specifications *
ııııııı Job Control Acceptance (Quarry Stockpile)
--- Batcher

▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #1 - #57 Limestone Aggregate**

| Sheet No. |
| --- |
| Date |

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(2-62)

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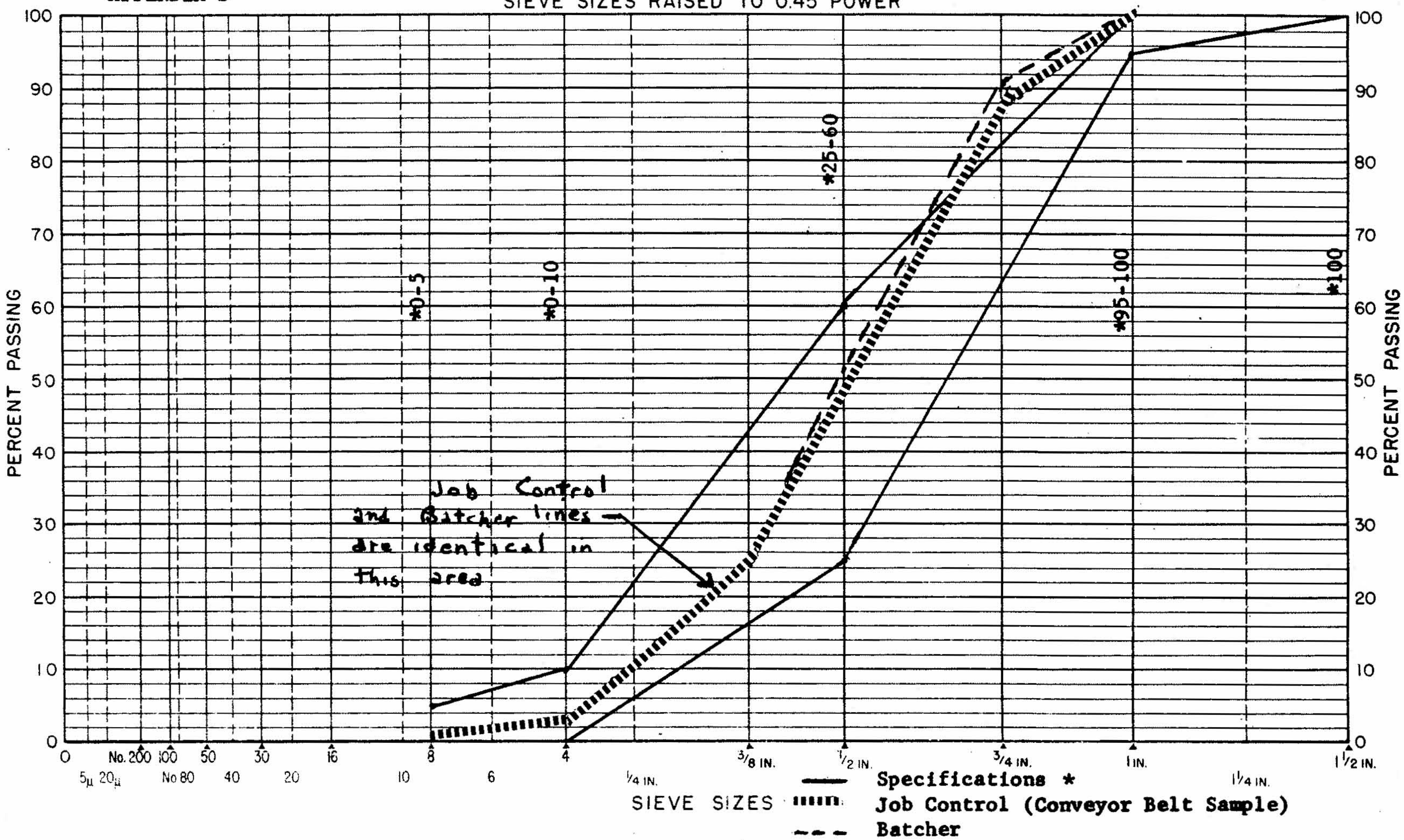
**APPENDIX D**

# GRADATION CHART
SIEVE SIZES RAISED TO 0.45 POWER




▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #2 - #57 Gravel Aggregate**

Sheet No.

Date

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U.S. DEPARTMENT OF COMMERCE
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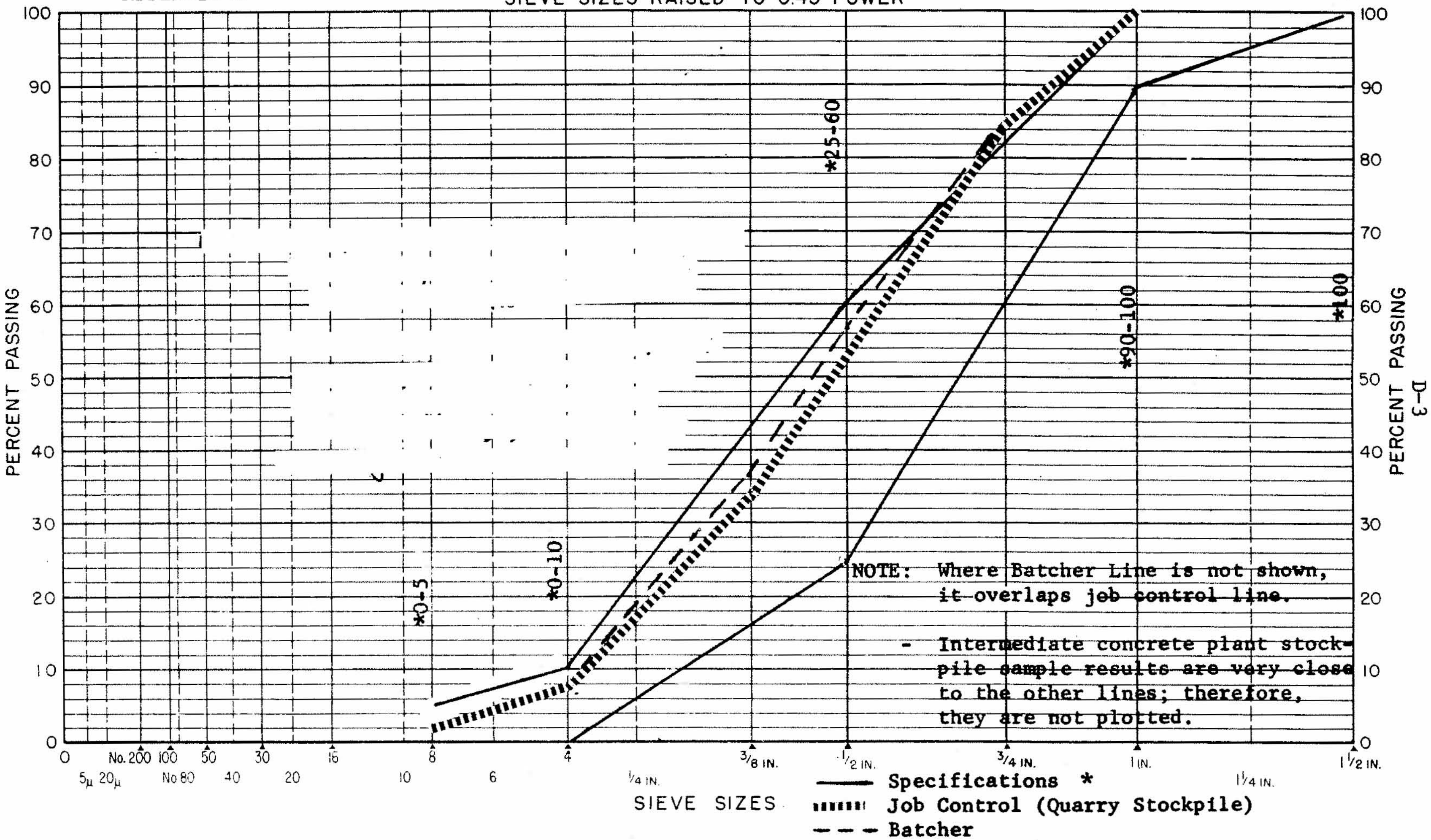
# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER

**APPENDIX D**




▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #3 - #57 Granite Aggregate**

Sheet No.

Date

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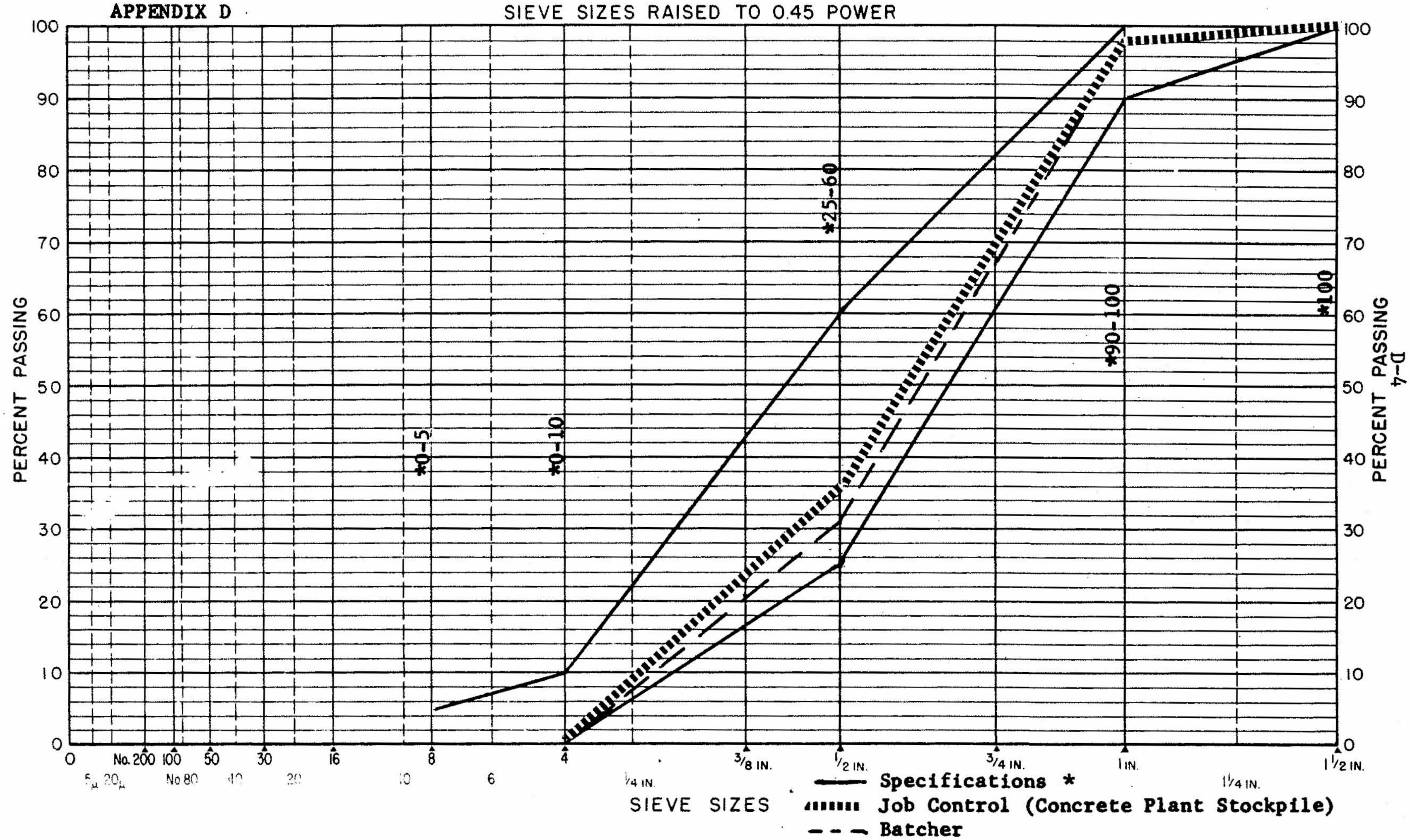
U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER

APPENDIX D




D-4

▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #4 - #57 Gravel Aggregate**

Sheet No.

Date

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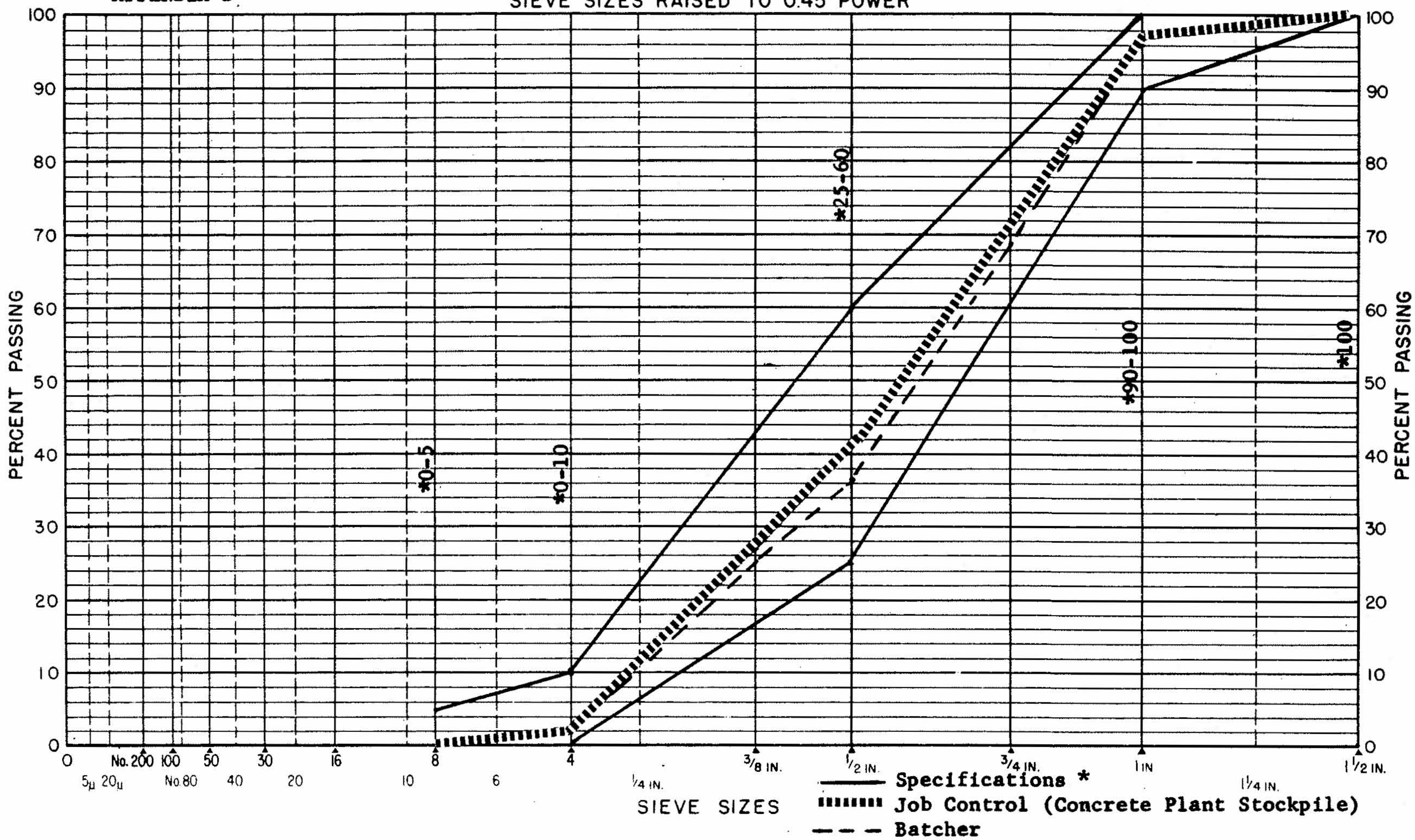
BUREAU OF PUBLIC ROADS

APPENDIX D

# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER






▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #5 - #57 Limestone Aggregate**

Sheet No.

Date

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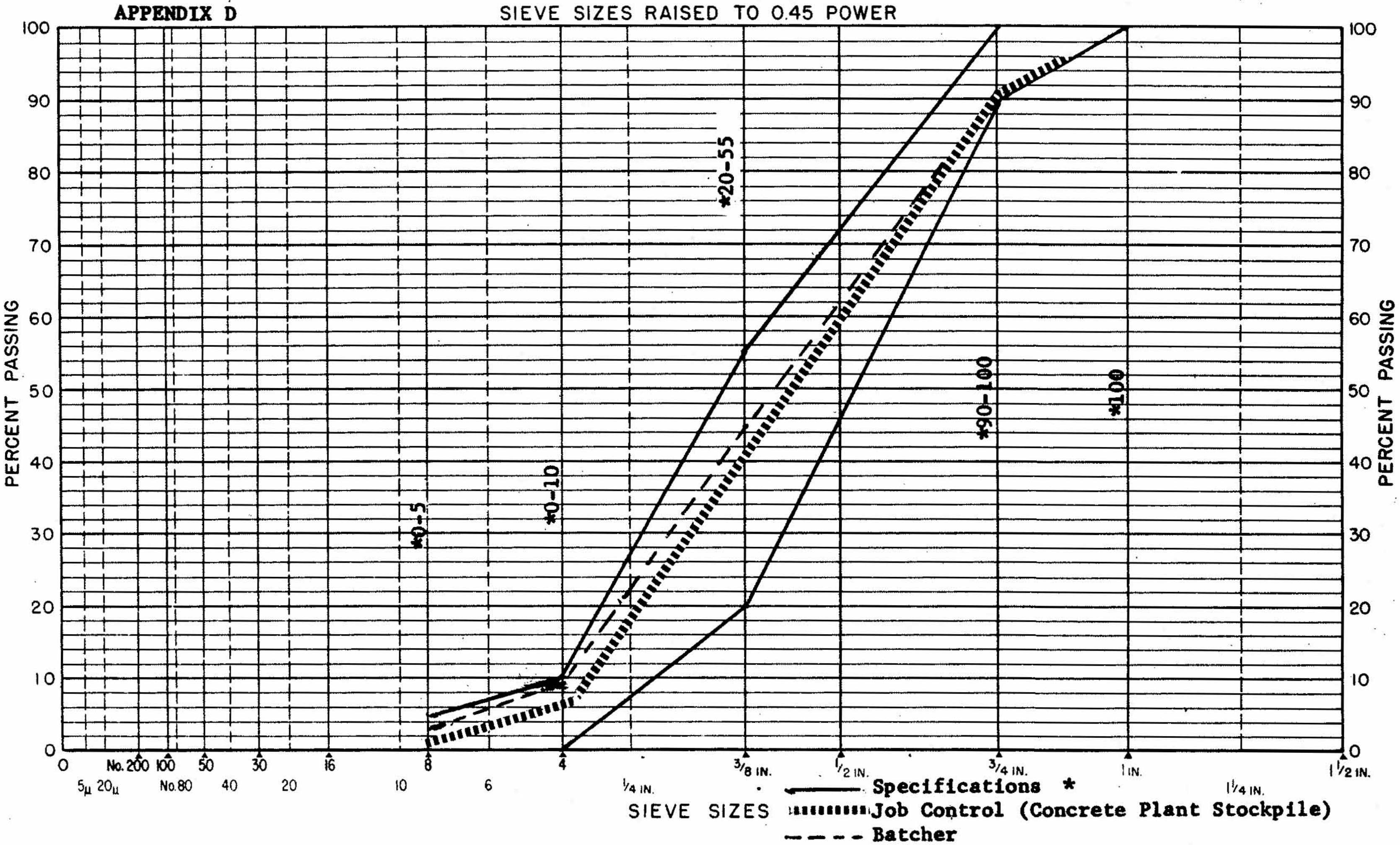
## GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER

**APPENDIX D**




D-6

▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Idenification of gradations:

**Study #7 - #67 Gravel Aggregate**

| Sheet No. |
|---|
| Date |

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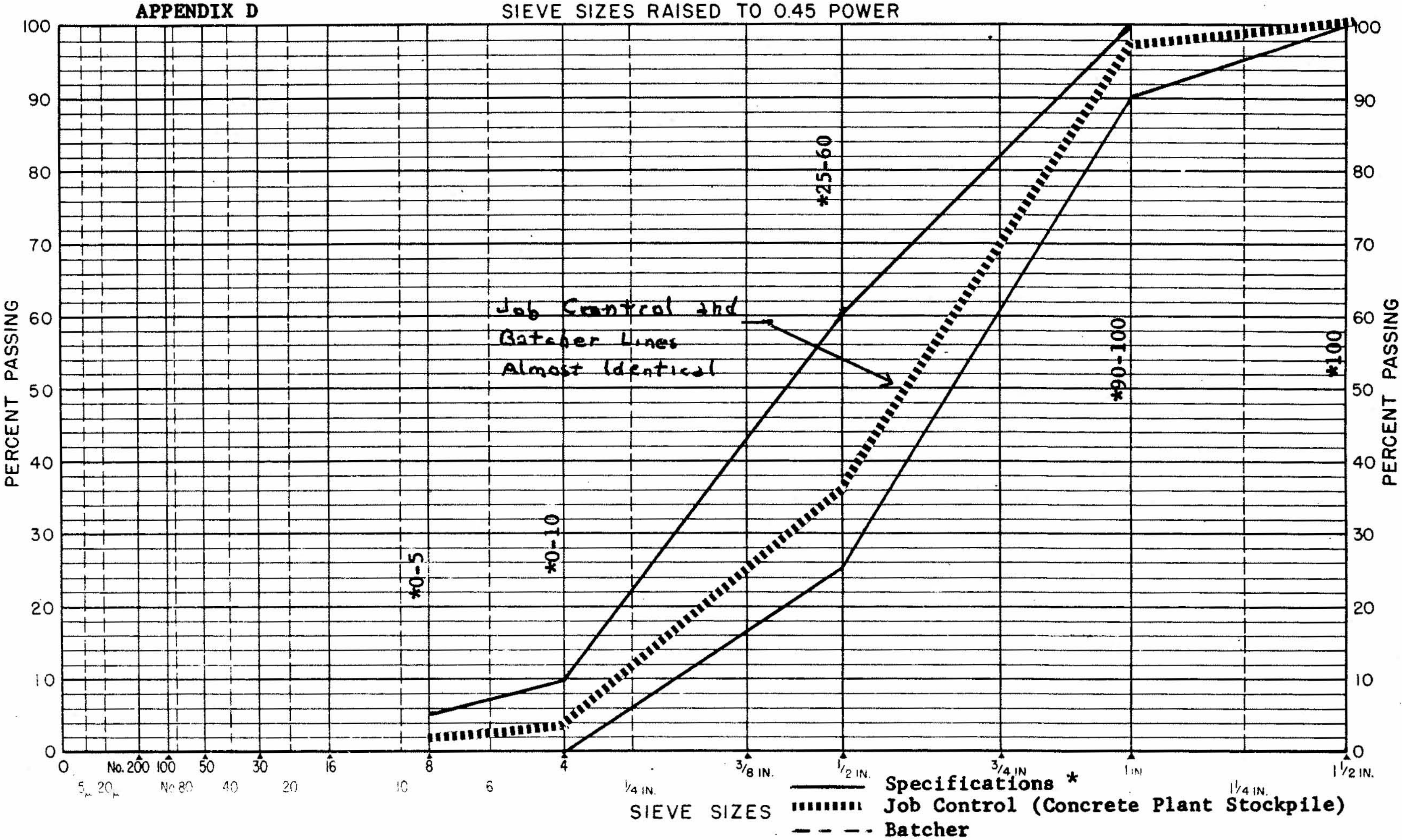
APPENDIX D

# GRADATION CHART
SIEVE SIZES RAISED TO 0.45 POWER




▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations: **Study #6 - #57 Slag Aggregate**

Sheet No.

Date



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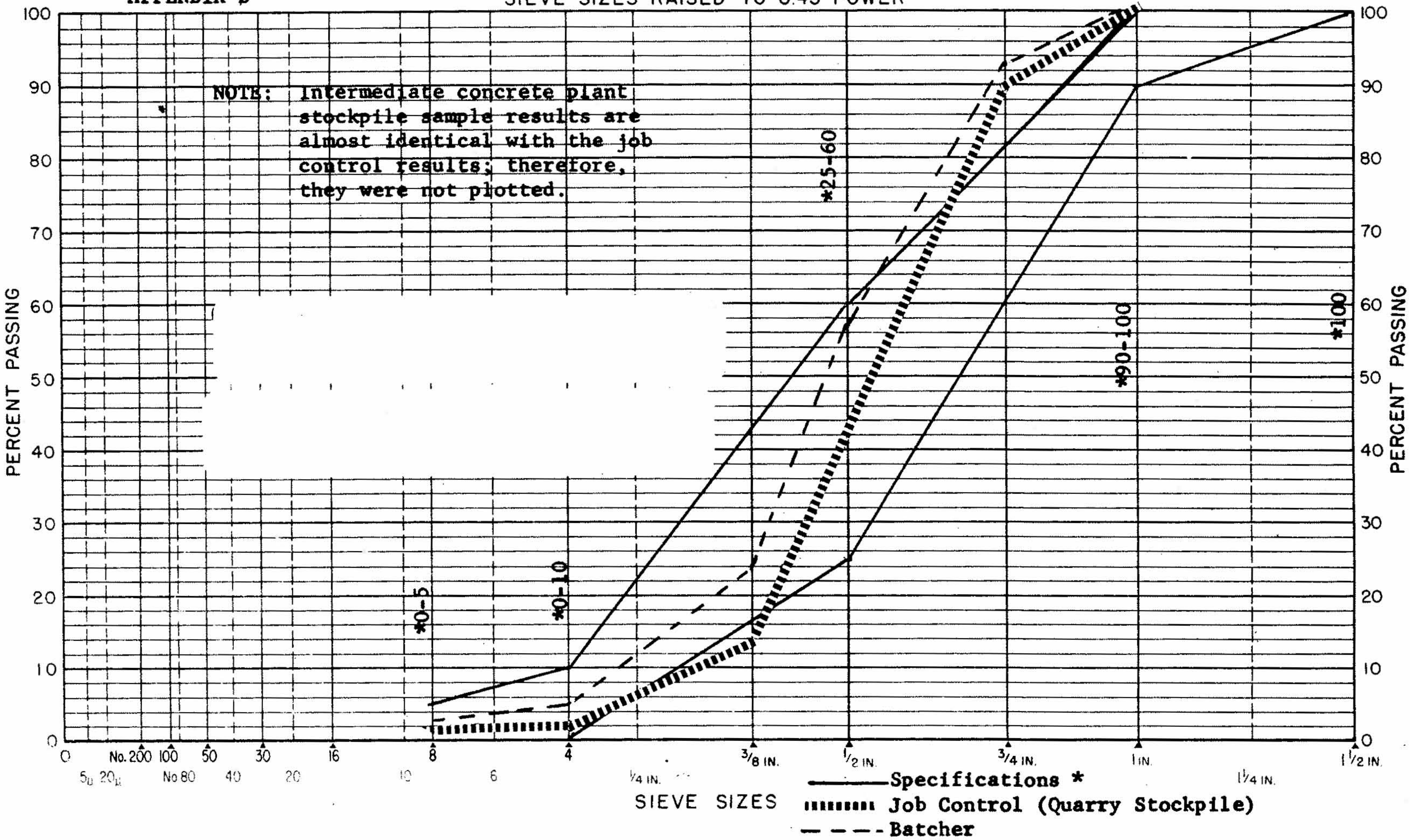
# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER

APPENDIX D






▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #8 - #57 Limestone Aggregate**

Sheet No.

Date

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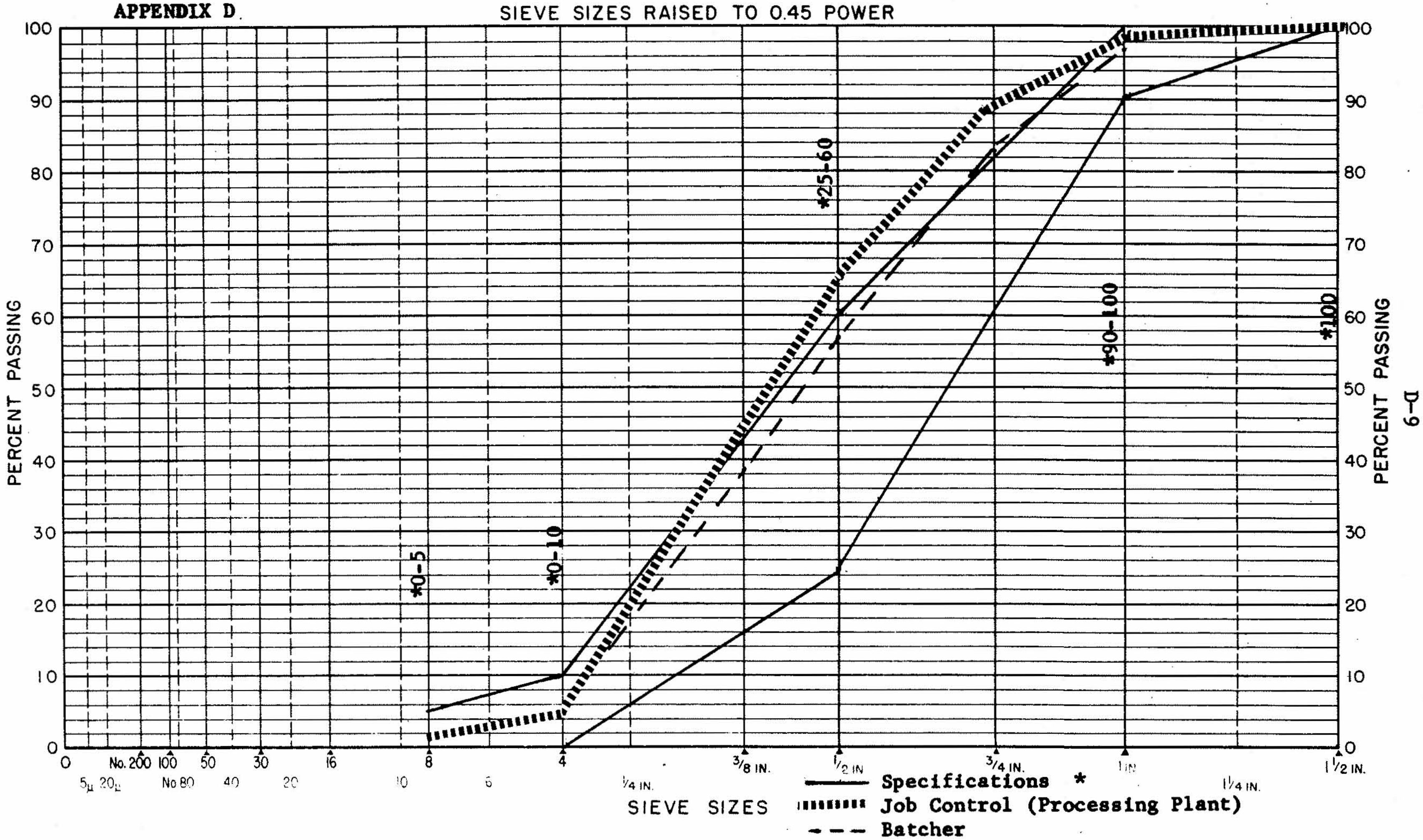
# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER

APPENDIX D.




▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #9 - #57 Gravel Aggregate**

Sheet No.

Date

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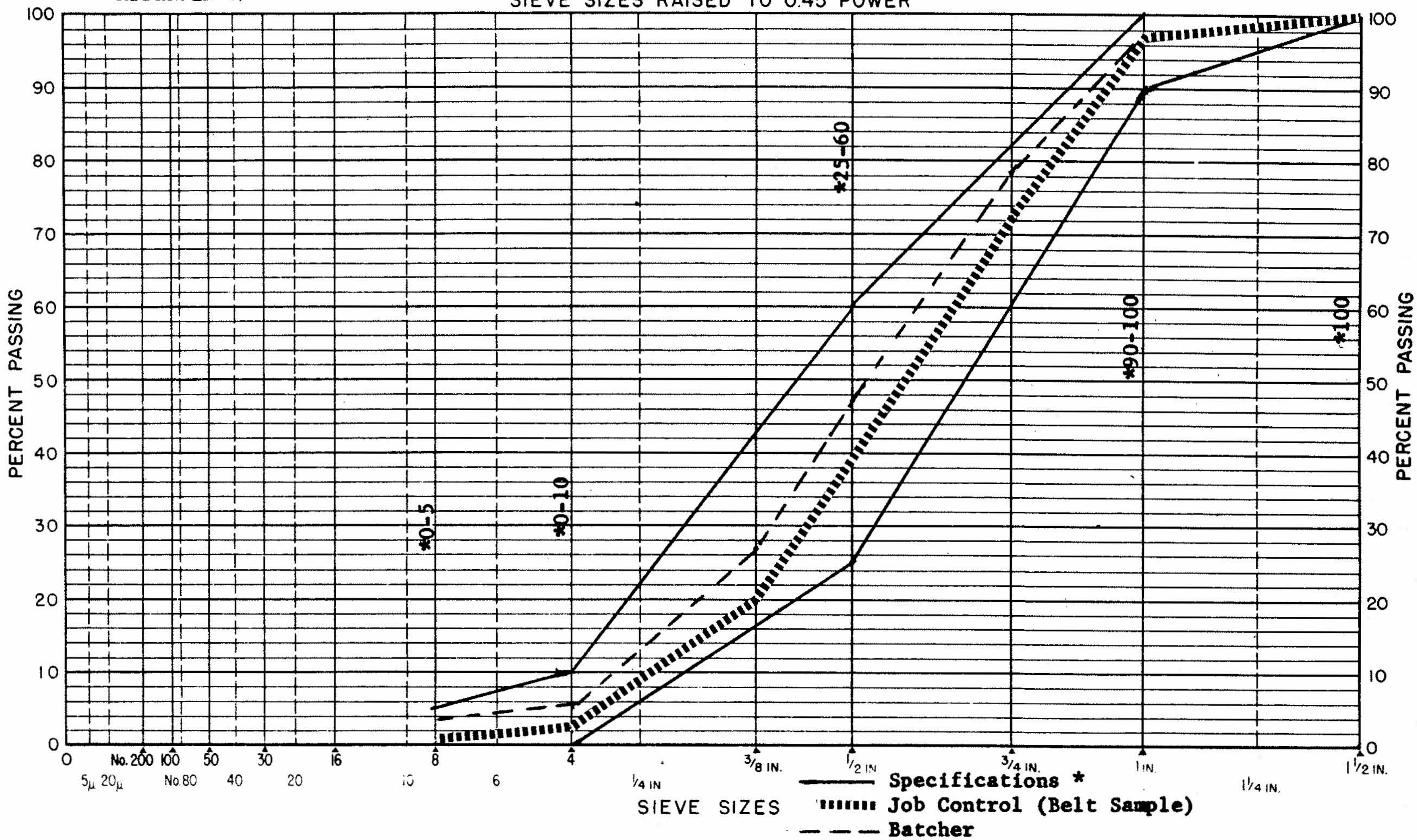
BUREAU OF PUBLIC ROADS

**APPENDIX D**

# GRADATION CHART
SIEVE SIZES RAISED TO 0.45 POWER




▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

**Study #10 - #57 Gravel Aggregate**

Sheet No.

Date

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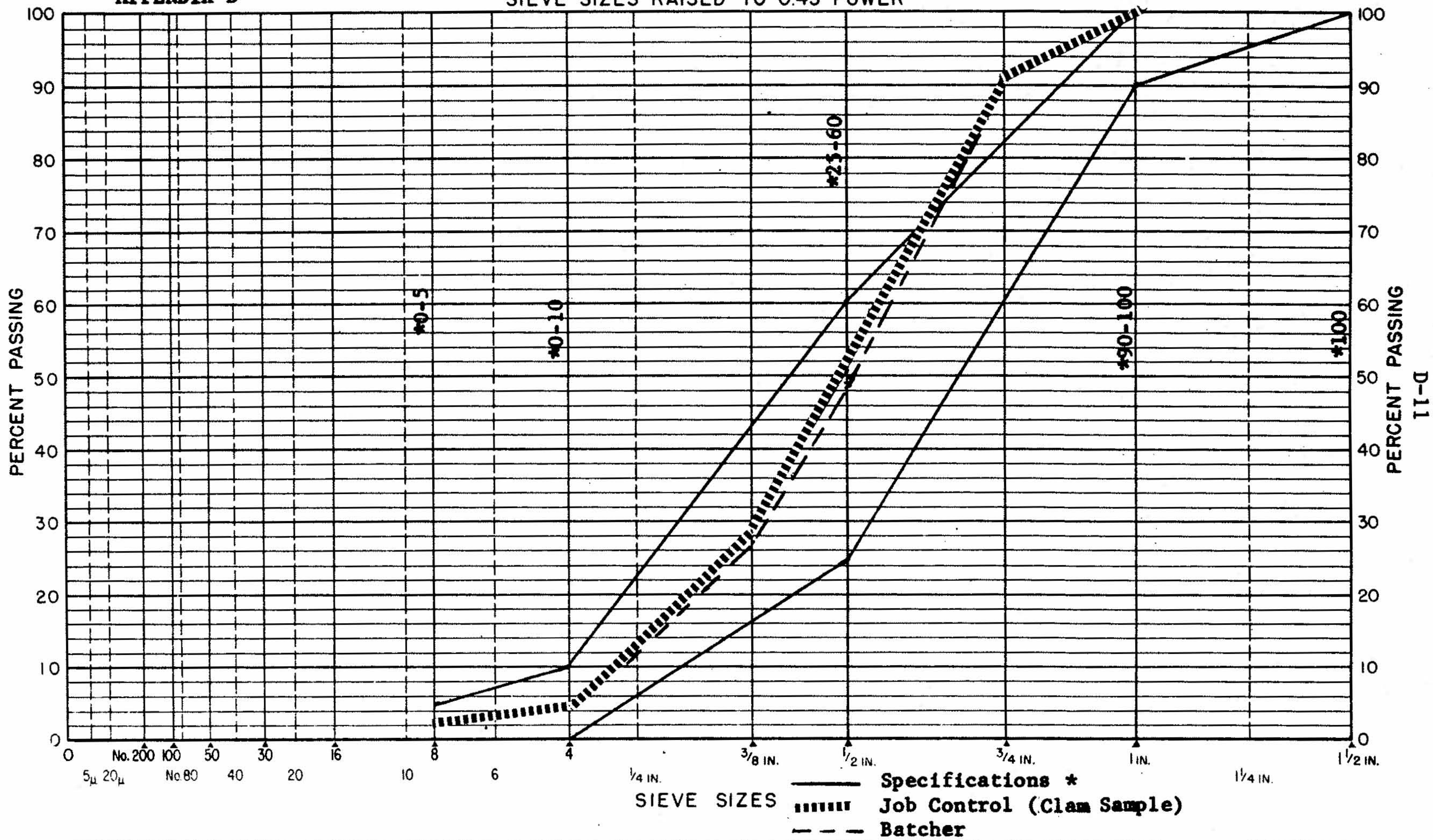
BUREAU OF PUBLIC ROADS

# GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER

**APPENDIX D**




| ▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES | Identification of gradations: **Study #11 - #57 Limestone Aggregate** | Sheet No. / Date |
|---|---|---|

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