# DEVELOPMENT AND TRIAL USE OF ACCEPTANCE SAMPLING PLANS FOR ASPHALT CONSTRUCTION

James L. Jorgenson, North Dakota State University

## ABRIDGMENT

•THE research on variability in asphalt construction in North Dakota brought to light many characteristics of current acceptable construction. They are as follows: (a) Single test results exhibited a large variability causing many of the measurements to be outside the specifications; (b) the current gradation band was only partially effective in controlling aggregate gradation; and (c) payments to the contractor were independent of the quality of his work. The following paragraphs expand on these observations and discuss their implications for improving specifications.

Field measurements are conducted to obtain information, which serves as a basis for making a decision on the acceptability of the construction. For each decision made, there is a probability of its being incorrect; that is, poor material is accepted or good material is rejected. The probability of the decision being incorrect increases with the variability of the measurements on which the decision is made. The primary source of variability is testing error. This variability is reduced by using the average of a number of tests. Therefore, an essential step in increasing the reliability of the decision and, hence, in improving the specifications is to base all decisions on the average of a number of test results.

The gradation limits in the highway department's specifications should be a means of controlling the gradation of the aggregate. Currently, the department does this in only a limited way because of the practice of resampling and because of the attitude that test results just within the limits are as acceptable as those midway between the limits. When the process has a target value just inside the specification band, because of the variability of the process, it is natural to find half of the readings outside the specification limit. The specification limits would be more effective if target values were chosen either at the center of the band or in 2 or 3 standard deviations from the current specification limits. When gradation target values based on the variability of the material are used and enforced, the specification limits will take on real meaning.

A study of the report on variability in asphalt construction reveals a large variation in contractor performance. For example, on one project, 5 percent of the hot bin gradation readings were outside the specification limits; on another project, 17 percent were outside. For asphalt contents, the difference between the design value and the plant consumption value was 0.05 percent for one project and 1.67 percent for another project. In pavement thickness, one contractor produced an average thickness within 0.01 in. of the design value, another 0.46 in. above the design thickness, and another 0.20 in. below the design thickness. Yet, in spite of these variations in performance, all contractors received the same full payment for their work. At least within the latitude of the projects studied, there is little or no incentive for the contractor to do a good job. His pay has been set by the bidding process, so his incentive now is to complete the job for the least cost.

Under the current specifications, the job can often be completed with relative ease. There are specification limits for gradation of aggregate, but they can be stretched considerably through the practice of resampling. Although there are target values for important things such as asphalt content, pavement density, and pavement thickness, the

---

Sponsored by Committee on Quality Assurance and Acceptance and presented at the 50th Annual Meeting.

specifications do not place limits on these variables. The permissible range in these variables is left up to the engineer. The project engineer has the option of shutting down the contractor if, in his judgment, the work is unacceptable. However, this option is seldom used, primarily because the contractor assures the engineer that he is working to correct the deficiency, and partly because the project engineer is also responsible for getting the project completed.

This discussion points out the real need for construction specifications that require the contractor to bear a greater responsibility for the quality of his construction. This will come about when acceptance criteria are specifically stated and substandard work is either not permitted to be placed or, if placed, paid for under an adjusted price.

During the summer of 1968, data were collected from 5 asphalt construction projects for the purpose of simulating the use of statistically based construction specifications. The lot size was taken as a full day's construction. It varied in size from about 1,200 to 2,500 tons.

At the plant, 5 aggregate samples were taken from dry batches at random times throughout the day. The gradation was determined by the percentage passing 4 sieves: ¾ in., No. 4, No. 30, and No. 200. A mix sample was taken for the purpose of making a Marshall test specimen to determine the maximum density of the mix. The following morning after the mat had cooled, 5 randomly located courses were taken and measured for density, thickness, and asphalt content.

Compliance with statistically based specifications is based on the difference between the test values and the target values. In the current North Dakota specifications, the target values are not clearly defined. Consequently, for the simulation, 3 different target values were used for gradation. They were from the Marshall mix design, from the average gradation as determined from samples taken during crushing of the aggregate, and from the average values of gradation during the simulation. The target value on asphalt content was that recommended from the Marshall mix design. The target value on density was 95 percent of the maximum density for the mix as determined by a daily test on the mix. The target value for pavement thickness was taken as the thickness called for in the specifications.

A number of lot payment schedules were tried; the one recommended is given in Table 1. The left column gives the different levels of payment as a percentage of the contract price. The second column gives in general terms the variation permitted in the sample average. A standard deviation, σ, from previous research in North Dakota and a sample size, n, of five are used to obtain the permissible variation of the average from the target values for the different items given in the remaining columns.

When the payment schedule was applied to the data collected from the 5 construction projects, the resulting components of lot payments were calculated and are given in Table 2. The lot payment is the average of the thickness, density, and mix contents payments. The mix content payment is the average of the asphalt and 4 gradation payments. For most lots, the premium payments were for gradation and the lower payments were a large variation in asphalt content. It is interesting to note the lot or daily variation in contract payments. This is shown in Figure 1. For projects 1 and 4, the

TABLE 1

LOT PAYMENT SCHEDULE FOR AVERAGE OF 5 TESTS

| Percent Payment | Variation of Average From Target Values | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | General | Gradation[a] (percent passing) | | | | Asphalt Content (percent) | Thickness (in.) | Density (percent) |
| | | ¾ In. | No. 4 | No. 30 | No. 200 | | | |
| 103 | $\leq \sigma/\sqrt{n}$ | 0.45 | 2.24 | 2.24 | 0.90 | 0.25 | 0.134 | 96.3 |
| 100 | $\leq 2(\sigma/\sqrt{n})$ | 0.90 | 4.48 | 4.48 | 1.80 | 0.50 | 0.268 | 95.0 |
| 97 | $\leq 3(\sigma/\sqrt{n})$ | 1.35 | 6.72 | 6.72 | 2.70 | 0.75 | 0.402 | 93.7 |
| 90 | $\leq 4(\sigma/\sqrt{n})$ | 1.80 | 8.96 | 8.96 | 3.60 | 1.00 | 0.536 | 92.4 |
| 80 | $\leq 4(\sigma/\sqrt{n})$ | 1.80 | 8.96 | 8.96 | 3.60 | 1.00 | 0.536 | 92.4 |

TABLE 2
COMPONENTS OF LOT PAYMENTS

| Project | Date | Gradation[a] (percent passing) ¾ In. | No. 4 | No. 30 | No. 200 | Asphalt | Average for Mix Contents (percent) | Density (percent) | Thickness (percent) | Lot Payment (percent) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7-11 | 103 | 103 | 103 | 97 | 90 | 99.2 | 97.0 | 96.4 | 97.53 |
| | 7-12 | 103 | 103 | 103 | 97 | 80 | 97.2 | 100.0 | 97.2 | 98.13 |
| | 7-15 | 103 | 103 | 100 | 90 | 97 | 98.6 | 100.0 | 93.2 | 97.26 |
| | 7-16 | 103 | 103 | 100 | 90 | 97 | 98.6 | 100.0 | 97.0 | 98.53 |
| | 7-18 | 103 | 103 | 103 | 80 | 90 | 95.8 | 100.0 | 100.0 | 98.60 |
| | 7-19 | 103 | 100 | 103 | 97 | 80 | 96.6 | 103.0 | 100.0 | 99.88 |
| | 7-22 | 103 | 100 | 100 | 80 | 80 | 92.6 | 90.0 | 95.0 | 95.88 |
| | 7-23 | 103 | 103 | 100 | 90 | 90 | 97.2 | 97.0 | 78.0 | 90.73 |
| | 7-24 | 103 | 103 | 100 | 90 | 97 | 98.6 | 97.0 | 103.0 | 99.53 |
| | 7-25 | 103 | 100 | 103 | 90 | 97 | 98.6 | 80.0 | 100.0 | 92.88 |
| | Avg | | | | | | | | | 96.89 |
| 2 | 7-1 | 103 | 103 | 103 | 103 | 100 | 102.4 | 97.0 | 103.0 | 100.80 |
| | 6-20 | 103 | 100 | 103 | 103 | 97 | 101.2 | 103.0 | 103.0 | 102.40 |
| | 6-21 | 103 | 100 | 100 | 100 | 97 | 100.0 | 103.0 | 100.0 | 101.00 |
| | 6-27 | 103 | 103 | 100 | 103 | 100 | 101.8 | 100.0 | 100.0 | 100.60 |
| | 6-28 | 103 | 103 | 100 | 103 | 100 | 101.8 | 100.0 | 103.0 | 101.60 |
| | Avg | | | | | | | | | 101.28 |
| 3 | 6-25 | 103 | 103 | 100 | 100 | 100 | 101.2 | 103.0 | 100.0 | 101.40 |
| | 6-26 | 103 | 103 | 100 | 100 | 97 | 100.6 | 103.0 | 100.0 | 101.20 |
| | 6-27 | 103 | 100 | 103 | 100 | 80 | 97.2 | 103.0 | 100.0 | 100.66 |
| | 6-28 | 103 | 100 | 103 | 103 | 97 | 101.2 | 103.0 | 100.0 | 101.40 |
| | 6-29 | 103 | 100 | 100 | 100 | 103 | 101.2 | 97.0 | 98.3 | 98.83 |
| | Avg | | | | | | | | | 100.69 |
| 4 | 8-02 | 103 | 103 | 100 | 100 | 103 | 101.8 | 103.0 | 88.5 | 97.76 |
| | 8-05 | 103 | 103 | 100 | 103 | 97 | 101.2 | 97.0 | 87.0 | 95.06 |
| | 8-06 | 103 | 103 | 100 | 103 | 90 | 99.8 | 100.0 | 100.0 | 99.93 |
| | 8-07 | 103 | 103 | 103 | 97 | 90 | 99.2 | 103.0 | 99.5 | 100.56 |
| | 8-08 | 103 | 103 | 100 | 97 | 97 | 100.0 | 100.0 | 92.5 | 97.50 |
| | 8-09 | 103 | 103 | 100 | 103 | 103 | 102.4 | 100.0 | 100.0 | 100.80 |
| | 8-10 | 103 | 103 | 97 | 103 | 97 | 100.6 | 100.0 | 100.0 | 100.20 |
| | 8-12 | 103 | 103 | 97 | 103 | 97 | 100.6 | 103.0 | 98.0 | 100.53 |
| | 8-13 | 103 | 103 | 100 | 103 | 100 | 101.8 | 103.0 | 88.5 | 97.76 |
| | Avg | | | | | | | | | 98.90 |
| 5 | 7-29 | 103 | 90 | 97 | 103 | 103 | 99.2 | 80.0 | 100.0 | 93.06 |
| | 7-30 | 103 | 90 | 97 | 103 | 90 | 96.6 | 97.0 | 103.0 | 98.86 |
| | 7-31 | 103 | 90 | 97 | 100 | 100 | 98.0 | 100.0 | 100.0 | 99.33 |
| | 8-1 | 103 | 97 | 97 | 100 | 100 | 99.4 | 100.0 | 100.0 | 99.80 |
| | Avg | | | | | | | | | 97.76 |

[a]Target value is Marshall mix design.

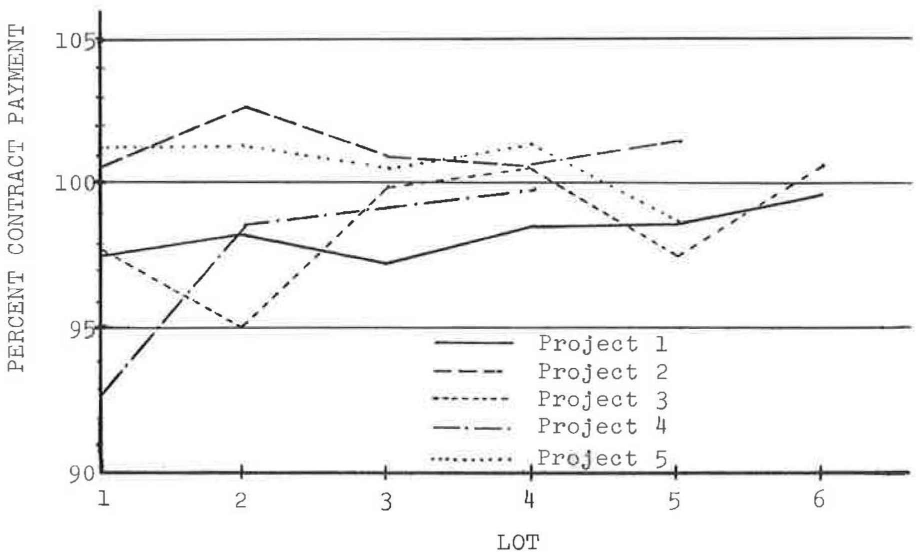


Figure 1. Simulated daily payments.

daily payments are all below 100 percent; however, for projects 2, 3, and 5, the payments fluctuate around 100 percent.

In summary, simulation of statistically based construction specifications on 5 asphalt construction projects in North Dakota shows that normal plant operations based on realistic target values will result in payments at or near 100 percent of contract price. Further advantages in the statistically based construction specifications were listed in the early part of this report. The following recommendations are made: (a) target values for all significant variables must be specified in the plans and specifications; (b) acceptance limits with appropriate price adjustments must be specified in the plans and specifications; and (c) it is necessary to rewrite current specifications to take out many of the restrictive control rules, thus allowing the contractor a freer hand in conducting his work.