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16. ABSTRACT
We inoculated 3 sets of 5 artificial vernal pools using materials from natural pools. We obtained inoculum from source pools by three methods (scraping/vacuuming, removing blocks of pool bottom, and removing loosened soil) and transferred it to created pools. From 1993-96, we sampled plants and invertebrates in all pools, which were fenced.

Soil-transfer produced greater diversity and relative cover of native wetland plants than other techniques, but all created pools outperformed natural pools in these criteria. Success of invertebrates in created pools was less than for plants, and highest in the soil-inoculated pools. Inhabitants of the water-column did better than benthic forms.

We analyzed the effect of inoculum-removal on source pools with three treatments: leaving scrape/vacuum plots alone, leaving the excavations from which pulverized soil was taken, and filling the depression from which blocks were taken with clean upland soil. With fencing, all source pools rapidly lost diversity, but loss was less on inoculum-removal plots. The scrape/vacuum and soil-fill techniques led to some invasion of pools by non-native species, but this did not occur in the excavation left after soil had been removed.

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vernal pool, seasonal wetland, mitigation, wetland restoration, wetland creation, wetland plants, vernal pool invertebrates

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CALIFORNIA DEPARTMENT OF TRANSPORTATION

Implementing a Quality Management Program Using Statistical Quality Assurance & Performance Standards: 65Y142

FINAL REPORT

Submitted to:

California Department of Transportation
Office of Service Contracts
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16. Abstract

Development of methodology and performance of an independent evaluation to pseudo quantify the qualitative result of Caltrans' implementation of a "Quality Management System." A system that made the Contractor responsible for process control and process control testing, for quality control (QC) and QC testing and the agency (Caltrans) responsible for quality assurance (QA) and QA testing.

The report presents the methodology, the investigative results, conclusions and recommendations for improvement . Highlights include the methodology, the things that were done that were beneficial to implementing the new system and presentation of the overall opinions of the many people that were interviewed in compiling the report.

17. Key Words

Quality control, Quality assurance, Process control, QC/QA

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Disclaimer

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

1. Introduction

The California Department of Transportation (Caltrans) is implementing more effective means of defining, measuring and achieving quality in construction projects as part of an overall quality management strategy. Caltrans is using statistical quality assurance (SQA) in their construction specifications to achieve the required quality.

Caltrans is beginning with dense graded asphalt concrete (AC) specifications, an approach similar to that of other states who have implemented specifications using SQA. The new asphalt concrete specifications were developed in 1995-1996, and rather than beginning with a few pilot projects, nearly all AC projects listed after April 1996 included the new specifications which met the following criteria:

1. Projects with a minimum of 10,000 tons of asphalt concrete,
2. Asphalt concrete is Type A or Type B,
3. Maximum aggregate gradation is ½" or ¾".

These new specifications attempt to change how the assurance of quality is pursued. Process and quality control is the responsibility of the Contractor. Caltrans has begun to specify that the Contractor control asphalt quality in all its components and placement. The evaluation for acceptance and payment remains the responsibility of Caltrans. The new specifications are augmented by the *Manual for Quality Control and Quality Assurance for Asphalt Concrete* ("orchid manual").

In March 1996, the California Department of Transportation issued a request for proposal for an *independent* evaluation of the effectiveness of its new SQA program. In September 1996, Nichols Consulting Engineers, Chtd. (NCE) was selected to be the Consultant for this project and began work on September 19, 1996. Projects from the1996 and 1997 construction seasons were evaluated. As part of this evaluation, the interrelationships between Contractors, Caltrans, the specifications, and the finished products were reviewed.

The evaluation includes results from a few projects in late 1996 and a more intensive evaluation from the 1997 season.

1.1 Project Objectives

To summarize, the overall project objectives are to:

- Provide an independent evaluation of the effectiveness of Caltrans' and Contractor's implementation of a quality management program using statistical quality assurance and performance standards.

- Provide the expertise to review, analyze and make recommendations relative to Caltrans implementation of the new asphalt concrete specifications.

- Review and analyze the technical, operational and human factors associated with the implementation.

- Provide a synthesis of the inter-relationships among Caltrans, the Contractors, the specifications, the resulting products and the performance of all participants.

1.2 Project Work Plan

The project work plan maps out the step-by-step process by which NCE achieve the project objectives. A series of milestones were identified in the proposal. Milestones 1 through 6E, and Milestone 9 were completed and summarized in Interim Report #1, prepared in April 1997. Interim Report #2 included a summary (as of September 1997) of Milestones 6F through 6V, 7, 8 10 and 11. A brief description of the milestones is included below:

Milestone 1: Kickoff Meeting/Review Information: NCE met with Caltrans to review the technical approach and the work plan. In addition, information on the specifications, quality control plans, and training materials were collected and reviewed. The results of this review are summarized in Chapters 2 and 3 of Interim Report #1.

Milestone 2: Attend Training Program: In October 1996, NCE attended one of the training programs for Resident Engineers (REs) and other personnel involved with implementation of the new Section 39 specifications. Training materials were obtained from Caltrans and a review of the information is included in Chapter 3 of Interim Report #1.

Milestone 3. Develop Draft Instrument: The draft instrument, or draft interview guide, used to collect data was prepared as described in Chapter 4 of Interim Report #1. Three primary elements were addressed in this guide: technical, operational and human factors. Additional data were collected from interviews and meetings, and contract documents (plans, specifications and bids) and observations made on the construction site. Interviewees included the REs, the Contractor and other relevant personnel. The development of the draft instrument is summarized in Chapter 4 of Interim Report #1.

Milestone 4: Review Draft Instrument with Caltrans and Finalize - After the draft instrument was completed, it was finalized with input from Caltrans staff.

Milestone 5: Initial Implementation of Instrument - In this milestone, NCE selected a construction site for the initial implementation of the instrument. This was, in effect, a "trial run". Originally, it was intended that the first site selected would be used to identify and resolve any difficulties in the instrument before full implementation on other sites constructed in 1996. However, due to the late start of this project (September 1996), almost all the 1996 construction projects had already been completed, and the others not yet complete were suspended until Spring 1997 due to wet winter conditions. Therefore, the results from this milestone were used to further refine and modify the instrument for the 1997 paving season instead. The results of this milestone are summarized in Chapter 5 of Interim Report #1

Milestones 6A, 6B, . . . , 6Z: Sample Construction Sites - The objective of this milestone was to select a minimum of five (5) and a maximum of thirty (30) construction sites for evaluation where NCE could be present during the entire paving operation since it is critical that we observe and record any unexpected incidents; for example, equipment breakdowns or delays in material deliveries. For 1996, it was not possible to evaluate the construction project due to a late project start. Therefore, only post-job interviews were performed on five (5) sites. For 1997, seventeen (17) additional projects were selected for evaluation which included pre-job, on-site, and post-job interviews and data analysis. The final instrument developed from Milestones 4 and 5 was used to collect information from these sites.

Results for the 1996 post-job evaluation are described in more detail in Chapters 6, 7 and 8 of Interim Report #1. The results of the 1997 pre-job interviews and a partial analysis of data from the 1997 projects (those completed at the time the report was produced) is included in Chapters 3 and 4 of Interim Report #2. This information in the preliminary data analysis has been further augmented with additional data and the results from the on-site and post-job interviews has been evaluated in this final report.

Milestone 7: Midseason Review of Instrument - It was intended that midway through the 1996 construction season, NCE would select another construction site for a midseason review of the instrument. However, since the 1996 construction season was essentially over when this project was initiated, this milestone was applied to the 1997 season. This milestone culminated in an internal feedback/training meeting held in June 1997 with the NCE/Diaz Yourman team to share experiences to date, review difficulties and successes, and provide feedback for improvements to the interview and data collection efforts for the remainder of the 1997 season. The meeting agenda and meeting notes are included in Appendix I of Interim Report #2..

Milestone 8. Meeting with Caltrans and Contractors to Review 1996 Projects - In this milestone, NCE met with Caltrans REs and Contractors to discuss and review the 1996 projects. The objective of this meeting was to review the experiences from both the REs and Contractors that were involved in the 1996 projects. Items for discussion included successes and difficulties with the specifications, the Quality Control Plan, and any other construction related items. This meeting was held in Sonoma during March 1997 and the results are included in Appendix J of Interim Report #2.

Milestone 9: Interim Report #1 - The results of work performed as of January 1997 are summarized and included in Interim Report #1, prepared in April 1997.

Milestone 10: Review of 1997 Activities Prior to Construction Season - Based on the results of the meeting with Caltrans and Contractors (Milestone 8), a review of the instrument by NCE team members was conducted to make any required changes. This milestone allowed NCE to "build on the experience of the 1996 season" and to correct any mistakes prior to the beginning of the 1997 season.

Milestone 11: Interim Report #2 - Interim Report #2 summarizes work performed as of September 1997 and includes a preliminary analysis of information collected and developed from the 1997 construction season.

Milestone 12: Final Report - This report, the Final Report, summarizes information from both interim reports and includes additional data analysis performed as of June 1998. The results from the on-site and post-job interviews have been evaluated in this final report.

1.3 Report Objectives and Organization

The intent of this report is to synthesize the results of Interim Report #1 and #2, revise preliminary findings from the analysis of physical property data using information from additional projects, and summarize the results of the interviews (pre-job, on-site, and post-job). The emphasis of this report has been to describe activities during 1997 construction season.

Specifically, the following items are included in this report:

- A summary description of projects reviewed in the evaluation,
- An analysis of physical property data measured from quality control data samples, including an analysis of pay factors and bid prices,
- An analysis of interviews conducted with various participants, including Caltrans, paving contractors, and industry,
- A review of the need for training and discusses example plans for training personnel involved with QC/QA processes,
- An overview of the implementation of the QC/QA specification and changes that have been made since first implemented, and
- A brief comparison of certain elements within the Caltrans specification with specifications from other states and agencies.

Finally, the report is organized as follows:

Chapter 1	Provides background information and project objectives
Chapter 2	Presents a summary of conclusions and recommendations
Chapter 3	Provides a summary description of the 1996 and 1997 construction projects included in the evaluation
Chapter 4	Describes the analyses performed and the results obtained for physical property and pay factor data
Chapter 5	Summarizes the analyses of interviews of various participants through the implementation, from pre-job through on-site and post-job
Chapter 6	Presents the need for training and discusses example plans for future implementation of QC/QA
Chapter 7	Summarizes the evolution of the QC/QA specification from its inception through early 1998
Chapter 8	Presents a brief comparison between the Caltrans QC/QA specification and the practices of other states and agencies on a few selected elements.

2. Findings and Recommendations

A summary of findings from the various analyses is included in this chapter. Conclusions and recommendations in this section are based on observations and activities performed on selected projects from the 1996 and 1997 construction season. Unfortunately, due to the late start date of the contract and the wet winter, no projects could be monitored in 1996. However, post construction information was collected for five 1996 projects and a partial data analysis was conducted in order to obtain early results. For 1997, a total of 17 construction projects were monitored. Construction on all but two of these projects was completed as of the date of this report (June 1998). Data collection activities on the incomplete projects was terminated in April 1998.

In Interim Report #2, an interim summary was prepared in Chapter 6 which summarized preliminary findings and identified several items for Caltrans' consideration. At the time the interim report was written (September 1997), only half of the projects had been completed where final data and post-job interviews were available. *Therefore, findings from the Interim Reports were preliminary and were subject to change as a more complete set of data from all projects became available.* With the additional data and interview results now available, findings and recommendations presented in this report are more conclusive.

2.1 Overall Findings

Analysis of interviews and physical property data revealed several positive findings:

- *Biddability*: The QC/QA specifications were considered biddable by the majority of those interviewed. Only 30 percent of the contractors who decided not to bid cited QC/QA as the reason.

- *Goals*: There is a consistency in goals across interviews for both Caltrans and the Contractors. The majority of interview respondents felt that the incentives provided by the pay factors encouraged a better product.

- *Workability of Specification*: Most respondents believe the specification can work.

- *Increased Quality*: Most interview respondents thought the QC/QA specification would result in improved quality. Processes used in other industries demonstrate that improved quality can lead to improved productivity with time. It would be reasonable to expect this to occur with the QC/QA asphalt concrete specification as well. A review of quality control data revealed lower standard deviations for pay factor elements than national averages.

2.2 Training

There is a strong need for in-depth training for both Caltrans and contractor personnel at all levels. This need was clearly shown in Chapter 5 and is so important that a separate chapter (Chapter 6) was written to discuss training. Yearly training sessions for District personnel were provided by Caltrans Headquarters and informational meetings were provided to industry. However, an analysis of training interviews from participants in Districts 4 and 7 revealed that the training sessions were relevant but were not always attended by the appropriate audience and training needed to include more detail. Specifically, more examples or scenarios need to be provided, and experiences need to be shared. Both Caltrans and Contractor personnel agreed on the need for training. Since the QC/QA specification was phased in all at once, there is an immediate need for training. It is recommended that the following issues be evaluated and implemented with regard to training.

- *Who to Train:* It is recommended that all levels of personnel (Management, Engineers, Technicians) receive some form of training regarding the QC/QA specification. This training should include participants from both Caltrans and contractors. Many interviewees commented that it would be beneficial to complete some joint training at the beginning of each construction project to provide a common understanding of how QC/QA will be implemented.

- *Types of Training Needed:* The information included in the training needs to be tailored to the personnel receiving it. Different levels of personnel need to be trained in different concepts. There is a need for a common language to be used in the training if Caltrans and contractors are to attend the same training session. A significant number of personnel at the engineering and technician level indicated a need for specific examples (eg. test-strip procedures, pay factor calculations, etc.) incorporated in the class.

- *Administration of Training:* It is recommended that Caltrans consider training/certification to be administered by an independent third party, such as an industry group, consultant, or educational institution. This would allow Caltrans to take advantage of suitable external resources. It is important that Caltrans "sponsor" or "certify" the training so that there is incentive for both Caltrans and contractors to send appropriate personnel to training.

- *Maintenance of Training and Certification Programs:* It is recommended that there be an ongoing assessment of the training performance and the benefits being providing to the attendees. In the cases of testers and inspectors, re-certification should be required. Continuous and ongoing training, coupled with certification requirements, will ensure that the proper construction practices will be followed from year to year.

2.3 Testing

2.3.1 Test Methods

- *Certification of Testers/Inspectors*: All testers and inspectors should have adequate experience and training for their role and should be certified. Certification is necessary to ensure that all testers and inspectors are qualified. The certification would provide participants with knowledge of the relevant test methods and would certify their qualifications to work on QC/QA projects.

- *Test Methods*: Test methods must be well documented and consistent between Caltrans and contractors, otherwise variations in interpretation of testing procedures will lead to differences in test results. Both contractor and Caltrans personnel suggested that a third party lab might be the best approach to insuring valid results and consistent test procedures.

- *Overcompaction*: A few of the interviewees as well as the NCE team believe that upper specification limits are needed on density to reduce the risk of overcompaction. One method would be to incorporate air voids into the pay factor with an upper limit on density based on the actual air voids of the mix.

2.3.2 Quality Control

- *Random Sampling*: While interview responses from both Caltrans and contractors indicated that they understood the importance of random sampling, the sampling locations on many projects were published in the QC plan. Therefore, the locations were known well in advance of actual production. It is recommended that Caltrans furnish sampling locations to the contractor on a daily basis, either on the morning of the day's production, or the night before.

- *QC Charts*: Most contractors are not using the QC charts and are doing them only to meet the specification requirement. Only a few understand the value of the charts. This situation could be improved if contractors participate in training.

2.3.3 Quality Assurance

- *Sampling*: Split sample testing should continue to be conducted during placement of the test strip. This would permit a sampling rate higher than ten percent during the first few sublots to increase the degrees of freedom for verification. This would also permit measuring the variance in the test method ($s^2_{test\ method}$), which can be compared with precision statements for the test methods. Several other states use split samples for quality assurance testing.

- *Turn Around Time*: In order to realize whether quality is being achieved in a high production environment, it is essential that test results for both quality control and quality assurance are available so that effective decisions can be made. This issue is further discussed under Section 2.6.

- *Use of t-test*: The t-test is insensitive at low degrees of freedom which is the case with limited tests. Using re-sampling methods, it is shown in Chapter 4 that in three of ten cases, the t-test would "not verify" when conventional analysis of variance would "verify". Replacement of t-test with a more robust statistic for verification is recommended.

2.4 Pay Factors

An analysis of quality control data and application of pay factors is presented in Chapter 4. Interview results regarding pay factors are presented in Chapter 5. A summary of the more pertinent findings follows:

2.4.1 *Administration Issues*

- *Compensation Adjustment*: Currently, there is not a consistent procedure for compensation when the pay factor exceeds 1.0. The methods and procedures for payment of pay factor bonuses should be revised so that the quantities placed and the quantities paid for are accountable. This is discussed further under the "Administration of Specification" in Section 2.6.

- *Hardware and Software*: Adequate hardware and the correct version of the AC-Pay software is required to run the pay factor calculations. This is also further discussed under the "Administration of Specification" in Section 2.6.

2.4.2 *Pay Factor Limits*

- *Weighting Factors*: Overall, interview respondents were happy with the weighting factors used to calculate pay factors. Resident Engineers, Quality Control Managers and Project Managers all felt that compaction was weighted too heavily. A few felt that air voids needed to be included to avoid a situation with low air voids and potential rutting or bleeding. The NCE team also recommends that air voids be established in the pay factor. There were suggestions to increase the weighting for gradation or add other items. A few RE's felt that sand equivalent, and stability should be added. Some RE's suggested including smoothness in the pay factor.

- *Bid Prices*: Implementation of QC/QA to asphalt concrete has increased the bid prices. Based on an analysis of bid data from Chapter 4, low bids for QC/QA projects are approximately 5 percent higher than for conventional materials. Interview results from bidders indicated that most bidders increased the cost of the asphalt concrete to include the cost of performing the QC/QA. According to the bidders, the impact was from $1 to $5 per ton of asphalt concrete.

- *Average Pay Factor*: Most contractors were happy with the pay factors, however, most received a bonus. If they had not received bonuses, they might have been more critical of the pay factors. The average PF for the seventeen 1997 projects was 1.02 and the range was from 0.89 to 1.05. If these 17 projects are representative of all projects, then, on average, Caltrans is paying bonuses. Ideally, the pay factors should be set so that average pay factor for all jobs is approximately 1.0, or if the average pay factor is greater than 1.0, then the finished asphalt concrete should be of superior quality. In addition, it should be exponentially more difficult for the contractor to achieve each 1 percent increase in bonus, so that bonuses of 1.05 are the exception, rather than the rule. In other words, most projects should have pay factors around 1.0 with less projects at 1.01 and even less with 1.02, etc. This is especially important considering that bids for QC/QA projects are approximately 5 percent higher than for conventional materials. Both situations suggest that the State is incurring increased costs to implement quality management into asphalt pavement production.

- *Pay Factor Limits*: Ratios for capability analyses can be used to determine if a process can consistently produce materials within existing specification limits. These ratios were calculated for each element of each project and are summarized in Appendix C under the row heading "Capability". One set of limits established by the Japanese requires a minimum of 1.33 to accept a process. Based on data available, it appears that most presently used process controls are not sufficient to meet specification limits.

2.4.3 *Multiple Plants*

Currently, material from more than one plant is permitted to be delivered to the jobsite as is common practice in the San Francisco Bay Area and Southern California. However, there is no procedure for identifying materials from the different plants when they are placed on-grade. Unfortunately, only one of the seventeen projects studied involved multiple plants so data analysis was limited. Recommended procedures for multiple plant situations were presented in Chapter 8 of Interim Report #1. It is recommended that special procedures for multiple plants be considered, which could include some of the following elements:

- Materials from the different plants should not be intermingled at the point of delivery on grade. This will require some type of visual identification of trucks from the different plants.
- Random sampling plans will need to be adjusted to insure that density tests are not taken in transition zones, where materials from both plants are intermixed..
- The test strip at project start-up can be used to determine if the same roller pattern is applicable to each of the materials. Perhaps the test strip can also be used to determine the length of transition zones.
- The specifications should be modified to require separate control charts for each plant.
- The pay factors, particularly for relative density, need to be calculated separately for each plant. The pay factor program should be enhanced to handle this situation.

2.4.4 *Changes in Lot and Lot Size*

- *Use of Single Lot for Entire Project*: Concern over the use of a single lot was expressed in Interim Report #1. A single lot may cause problems if there are significant delays to paving activities or if the project goes into suspension during the winter since the properties of the asphalt concrete components naturally vary over time. In these cases, if a single lot is used over the entire project, a Contractor could be overpaid for substandard material or underpaid for superior materia, as was shown in Chapter 8 of Interim Report #1. Several other statistically based specifications use the lot to represent the production of about one day's production.
- *Multiple Populations within a Single Lot*: Statistical analyses of physical property data in Chapter 5 suggest that the use of a lot size spanning the entire project can introduce multiple populations within a single lot. It can be observed in Appendix C that 12 of the 20 lots suggest differences in one or more elements, i.e., multiple populations could exist within a lot or project. This is not surprising considering the day to day variations that can occur in material properties and plant calibration. Interruptions to paving schedules would also naturally exacerbate the problem. A lot is intended to be composed of data from a single population and the statistical analysis for pay factor is based on this. If multiple populations exist due to natural variations of material properties over time, the lot size should be reduced to account for this variation and multiple lots should be used.

- *When is a Change in Lot Necessary?*: The specification does not clearly describe how much the target values can be changed before a change in lots is necessary. This has caused confusion in the interpretation since there have been cases of the contractor deliberately producing material at a slight offset from the target value so that a new mix design and test strip don't have to be run. On other projects (two of the seventeen studied), very minor changes in asphalt content have resulted in new test strips and additional lots. These situations point out that it is critical that some definition should be made as to what constitutes a change in job mix formula and what is necessary to establish adoption of new lots. Perhaps a limit can be placed on how much the target values can be changed before establishing a new test strip and lot are necessary.

2.5 Contractor's Organizational Structure

The impacts of the contractor's structure was evaluated through a combination of interviews and observations for the 1997 projects. This information is summarized below:

- *Size of Job*: There appears to be no relationship between the contractor's organizational structure and the size of a paving job (as measured by tonnage). Regardless of the size of the job, many different QC organizational frameworks have been used. In Chapter 3, it can be seen that at least five of the six distinct organizational structures are present in each tonnage range.

- *Vertical vs. Horizontal*: The number of contracts with vertically structured organizations (where the QC manager is an employee of the paving contractor) outweighed the number of horizontally structured organizations (where the QC manager is a subcontractor) by a two-to-one margin. There does not appear to be an influence on pay factor as there is no difference in the average pay factors between the two types of organizations.

- *Quality Control vs. Production*: Contractors realized that they have a responsibility to produce a quality product while maximizing production. However, many have not been formally trained in the principles of statistical quality control and assurance. Many do not understand the value of the control charts and use them only to comply with the specification requirement. In addition, a few contractors said that quality control was not their responsibility because they had subcontracted it. Training of contractors in quality control practices is needed as described in the next section.

2.6 Administration of Specification

- *Compensation Adjustment*: On some projects, when the pay factor is above 100 percent, the contractor was paid a bonus which was not specifically taken into account in the funding for the project. There needs to be an accountable system to adjust the AC price, not the AC quantity as has been reported. A formal procedure for making adjustments to asphalt concrete payment (both positive and negative) based on application of pay factors should be developed by Headquarters and distributed.

- In addition, some consideration must be given to adding an automatic 5 percent contingency to the asphalt cost up front in the contract, or possibly at the project design stage. It is our understanding that this issue has been addressed and a 4 percent contingency is now built into the budget for the possibility of a pay factor bonus.

- *Communication*: Internal communication was good amongst both Caltrans and contractors; however, interview respondents thought external communications could be improved by scheduling daily or weekly project meetings, or by providing State staff with cell phones/pagers.

2.6.1 Clarification of Specification

A detailed review of the specification was made in Interim Report #1 and there were several areas that were determined to be vague or confusing. Caltrans, through the aid of a task group, has been working to change specification wording and clarify portions which are vague or confusing. As the specification is revised, it is recommended that the suggestions below be incorporated:

- Definition of key terms should be added to the beginning of the specification (see Chapter 2 of Interim Report #1).

- In order to reduce confusion between specification or <u>product</u> control and <u>process</u> control, it is suggested that specification wording that refers to "control charts" be changed when specification limit charts are intended. It would be prudent to consider rewording "linear control charts" to something on the order of "specification charts" or "run charts" etc. (see Chapter 4, Page 9).

2.6.2 Resources

- *Follow-up Support*: It is vital to the success of the implementation of QC/QA that there is adequate support for decisions at the Headquarters and District level. Most of the decisions regarding clarification and interpretation of the specification have been funneled through Terrie Bressette. Unfortunately, the expectation for one person to "do it all" can create a bottleneck when rapid decisions must be made.

- *Quality Assurance Testing*: According to the interviews, most of the disputes that led to delays were related to verification of the test strip, particularly with regard to getting timely results back from Caltrans labs. This issue had the second highest number of responses when interviewees were asked, "What did Caltrans do to make implementation difficult?" It is recommended that Caltrans commit to providing verification results by a certain date, as has been done for the quality control results submitted by the Contractor.

- *Hardware and Software*: The Department's pay system does not allow a simple method for payment of bonuses and penalties. Interview results revealed that some of the RE's personnel were not equipped with adequate hardware to run the pay factor calculation program. In addition, both Caltrans and contractor personnel voiced that they were not always up to date with the latest version of the AC-Pay software. It is our understanding that both of these issues are being addressed as the Department has acquired many new PC computers and the AC-Pay software is now available on the Internet.

3. Construction Projects Evaluated

This chapter includes the following information:

- Summary description of the 1996 and 1997 construction projects included in the evaluation,
- Description of the pilot implementation project used for the evaluation's "trial run",
- Tonnage ranges for cach of the 1997 projccts,
- General description of Contractor's structure for each of the 1997 projects

3.1 1996 Projects

It was originally proposed that construction projects within the 1996 paving season would be selected for analysis. The plan was for NCE to be present on-site during the entire paving operation to observe construction, and to interview construction personnel. Unfortunately, by the time the contract was executed (September 1996), the paving season for much of the state was coming to a close. With the late start and unusually high rains beginning in November 1996, all new and existing projects were suspended until Spring 1997. The weather played havoc on the paving schedule; on one project, for example, the test strip was postponed numerous times from November 1996 to February 1997.

Therefore, it became apparent that NCE could not monitor any 1996 projects from beginning to end as originally planned; however, five projects which utilized the QC/QA specifications had been completed by November 1996. Therefore, in an attempt to obtain preliminary findings, post-job interviews on *only* those five projects were performed. All available construction documents were collected for analyses, considering the short time frame.

Post-job interviews were conducted the week before Christmas, which made it challenging due to the vacation schedules of construction personnel. A priority was placed on conducting face-to-face interviews with the Caltrans Resident Engineer, the Contractor's Project Manager and the Quality Control Manager. Other construction personnel, such as testers and inspectors, were interviewed over the phone if time constraints did not allow scheduling face-to-face interviews. Additional interviews were conducted with trainers, attendees of training sessions, and the task group who developed the specifications.

3.1.1 Summary of 1996 Projects

Out of the five projects, four were rural jobs. The fifth was not within city limits, but was not classified as rural. The projects ranged in size from less than 20,000 tons to more than 80,000 tons and were distributed throughout Northern, Central, and Southern California. The projects were scattered across 3 Caltrans districts.

Four projects were overlays and the fifth was a reconstruction project. Three out of five projects had one or a combination of the following:

- multiple prime contractors (joint ventures)
- multiple hot mix plants
- multiple aggregate sources
- multiple mix designs

Each project had its own unique organizational structure. One project was controlled by the prime contractor, but there were separate subcontractors for QC testing, hot-mix supply, and hauling. On another project, a single contractor performed its own QC testing in addition to paving. The vice-president was also the QC Manager and head of traffic control. On still another project, there were two prime contractors. The QC Manager was an employee of one prime, yet he had control over the entire project.

Findings from the evaluation of the 1996 projects are summarized in Interim Report #1. Since these findings are based on post-job information only, no confirmation of the interview results could be made from direct observations or on-site interviews. Therefore, without this check on the validity of the findings, the results from the 1996 projects were only considered for preliminary use and have not been used in this report.

3.1.2 Pilot Implementation

Prior to collecting information for the 1997 projects, a pilot implementation was conducted to do a "trial run" of the interview procedures, interview questions, and direct observation procedures. The pilot implementation site was selected from QC/QA candidate projects currently underway or scheduled for completion in late 1996/early 1997. Criteria considered in the selection of a pilot site included:

- Project location - wanted convenience to the NCE project staff to reduce travel costs.
- Project size - wanted small enough size so that pre-job, on-site, and post-job conditions could be observed before visiting other projects.
- Project type - wanted a project where asphalt concrete paving was the primary work, as opposed to a project where paving is incidental to other work, such as an overpass or a sound-wall project.

A suitable site was selected in rural central California. The project was a straightforward overlay job on a multi-lane highway with a total asphalt concrete tonnage less than 30,000 tons. The mild climate and the low tonnage were considered ideal because of the necessity to conduct the implementation before the rainy season and to obtain the results quickly. All of the asphalt placed was supplied from one plant using one aggregate source and mix design. The prime contractor also was the paving contractor and hot mix supplier. The QC manager and the QC tests were done by a subcontracted laboratory. Results from the QC tests were reported to the prime contractor who in-turn forwarded them to Caltrans as required by the specifications.

Information collected during the pilot implementation was analyzed with the other 1996 projects and was reported in Interim Report #1. The experience was used to make minor adjustments to interview questions, procedures, and forms. The pilot implementation was also used to aid in "calibrating" NCE's field engineers so that data were collected in a consistent manner.

3.2 1997 Projects

Seventeen construction projects using the new asphalt concrete QC/QA specification were selected for monitoring during the 1997 construction season. The selection of these projects was based upon achieving several primary objectives. One objective of the selection process was to choose construction projects from all across the state. The goal was to have a wide range of projects and a broad coverage of geography. To accomplish this, NCE attempted to choose at least one project from each district. Ultimately, 10 of the 12 districts were represented. Districts 3 and 12 did not contain a project for evaluation. District 3 contained QC/QA projects that were evaluated during the 1996 construction season. QC/QA projects in District 12 were multi-phase projects that were not expected to be completed within the 1997 construction season. The locations of the chosen projects are illustrated in Figure 3.1.

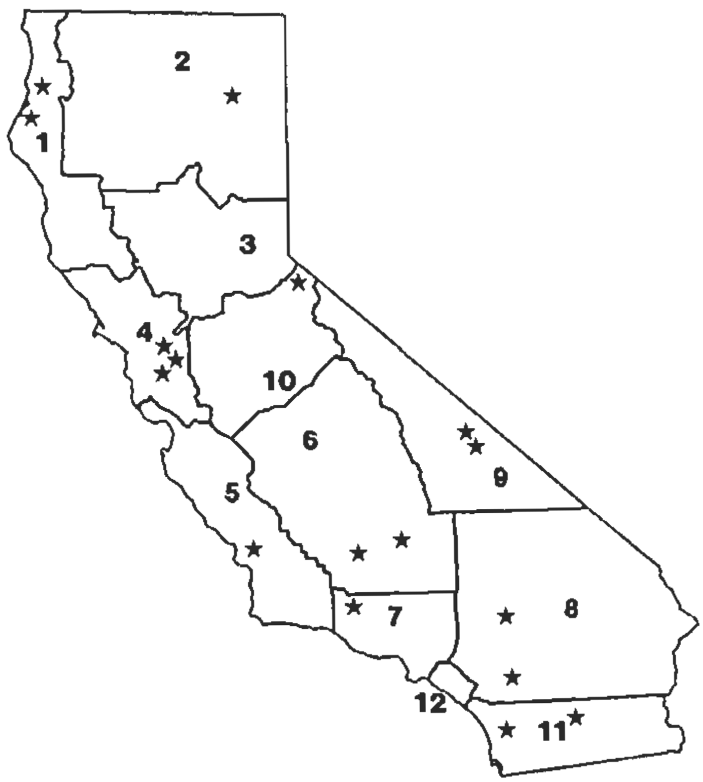

Figure 3.1 Location of Projects.

Another objective was to select projects encompassing a wide range in tonnage. Of the seventeen projects, the minimum amount of asphalt concrete placed was 16,800 tons, whereas the maximum amount of tonnage exceeded 100,000 tons. Other objectives were to include both major interstates and state routes, rural and urban areas, and mainline paving as well as multi-phase interchange paving. Finally, projects had to be selected with paving schedules ending in late 1997 to allow sufficient time to collect all relevant data before the submission dates for Interim Report #2 and the final report.

3.2.1 Distribution of Projects

In addition to tonnage, another objective in project selection was to include projects in both urban and rural locations, projects with continuous and intermittent paving, and projects with a broad distribution of organizational structures. The distribution for the 1997 projects is contained in Table 3.1. The amount of asphalt concrete placed was divided into two categories: 10,000 to 35,000 tons and more than 35,000 tons. The breaking point of 35,000 tons was chosen as it is a rounded approximation of the median tonnagc value of 38,300 for all asphalt concrete projects greater than 10,000 tons constructed in 1997 (55 total) using the QC/QA specification. Projects with a total tonnage less than 10,000 were not required to use the QC/QA specification. The location of the project was classified as urban or rural. Paving that was classified as continuous indicated that the pavement was placed without any instances where the contractor pulled off to perform other activities. Projects classified as "intermittent" indicated that the contractor pulled off the project to work on other projects or there was a substantial delay during the paving process. Finally, the contractor's organizational structure was categorized into six groups, A through F. The contractor's organizational structure is a flowchart indicating the relationships between the prime contractor, paving operations, supplier, QC manager, and QC testing. These structures are further described in sections 3.2.2 to 3.2.7 and are illustrated in Figures 3.2 - 3.7

Table 3.1 Distribution of 1997 Projects

Tonnage	Number of Projects and Characteristics	Organizational Structures Represented	
10,000 - 35,000	**9 Total** **Location** - 2 urban, 7 rural **Paving** - 7 continuous, 2 intermittent **QC Org. Structure** - 3 horizontal, 6 vertical*	A B C D E F	2 Projects 1 Project 1 Projects 1 Project 3 Projects 1 Project
> 35,000	**8 Total** **Location** - 2 urban, 6 rural **Paving** - 4 continuous, 4 intermittent **QC Org. Structure** - 3 horizontal, 5 vertical*	A B C D E F	2 Projects 1 Project 2 Project 2 Projects 1 Project No projects

* Horizontal QC Organizational Structure - QC Manager is a subcontractor to paving contractor or prime contractor
Vertical QC Organizational Structure - QC Manager is an employee of the paving contractor

Based on the table above, the 1997 projects appear to be well distributed and representative of the majority of paving contracts for 1997.

It is interesting to note that there appears to be no relationship between the contractor's organizational structure and the size of a paving job (as measured by tonnage). Regardless of the size of the job, many different QC organizational frameworks have been used. Each tonnage category is represented by at least five of the six distinct organizational structures. Organizational structures can be generally classified into two different types - horizontal and vertical. In the horizontal structure, the QC manager is a subcontractor to the paving contractor or the prime contractor. In the vertical structure, the QC manager is an employee of the paving contractor. The number of contracts with vertically structured organizations outweighed the number of horizontally structured organizations by a two-to-one margin.

3.2.2 Project Descriptive Information

The seventeen projects evaluated in 1997 were assigned unique project codes, 1 through 17. Descriptive information for the projects is presented in Table 3.2. This descriptive information was summarized to aid in noting trends in interview results as well as pay factor data.

Table 3.2 Project Descriptive Information for 1997 Projects

Code	Tonnage Range	Rural/Urban	Intermittent/ Continuous	Organizational Structure	Horizontal/Vertical
1	10,000 to 35,000	U	Continuous	A	V
2	> 35,000	R	Delay	D	V
3	10,000 to 35,000	R	Delay	D	V
4	> 35,000	R	Continuous	A	V
5	> 35,000	U	Delay	C	H
6	> 35,000	R	Continuous	D	V
7	> 35,000	R	Continuous	E	V
8	10,000 to 35,000	R	Continuous	B	H
9	10,000 to 35,000	U	Delay	F	H
10	10,000 to 35,000	R	Continuous	E	V
11	10,000 to 35,000	R	Continuous	E	V
12	> 35,000	U	Delay	C	H
13	10,000 to 35,000	R	Continuous	E	V
14	10,000 to 35,000	R	Continuous	C	H
15	> 35,000	R	Delay	B	H
16	10,000 to 35,000	R	Continuous	A	V
17	> 35,000	R	Continuous	A	V

3.2.3 Organizational Structure A

The seventeen projects were classified into six different organizational categories, illustrated in Figures 3.2 - 3.7. Figure 3.2 shows the Type A organizational structure. In this structure, the prime contractor performs all paving and quality control duties. The prime contractor produces the material, constructs the pavement, and all quality control management and testing is performed by employees from within the prime contractor's organization.

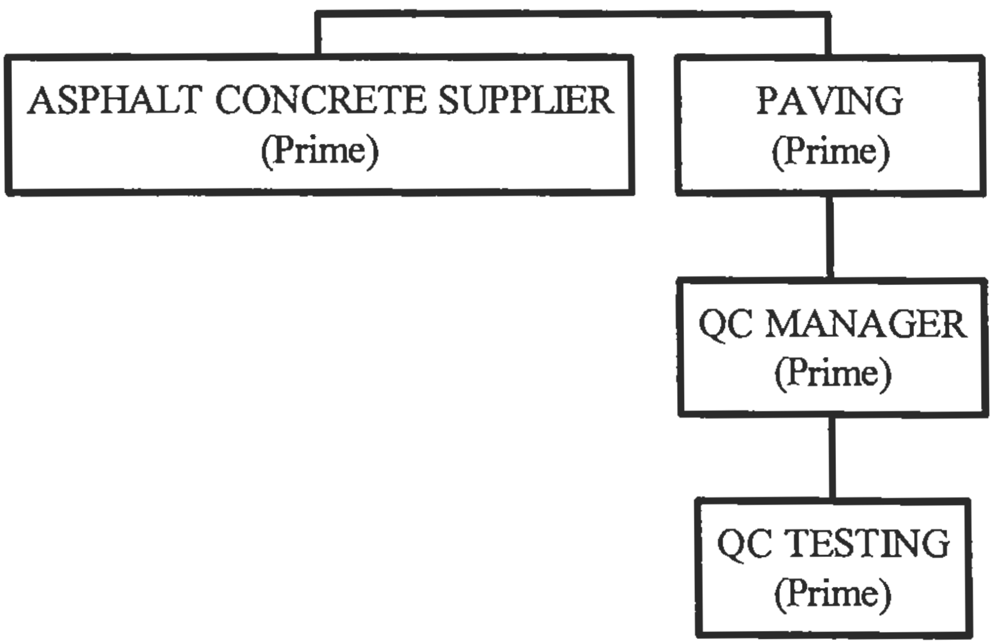

Figure 3.2 Organizational Structure A

3.2.4 Organizational Structure B

Figure 3.3 illustrates a Type B organizational structure. With this type of structure, the prime contractor supplies all material and performs all paving operations, but the QC manager and the quality control testing is administered by a subcontractor. Under this structure, the prime contractor is responsible for production and the subcontractor is responsible for monitoring quality. The QC manager then reports and submits all quality control data to the prime contractor.

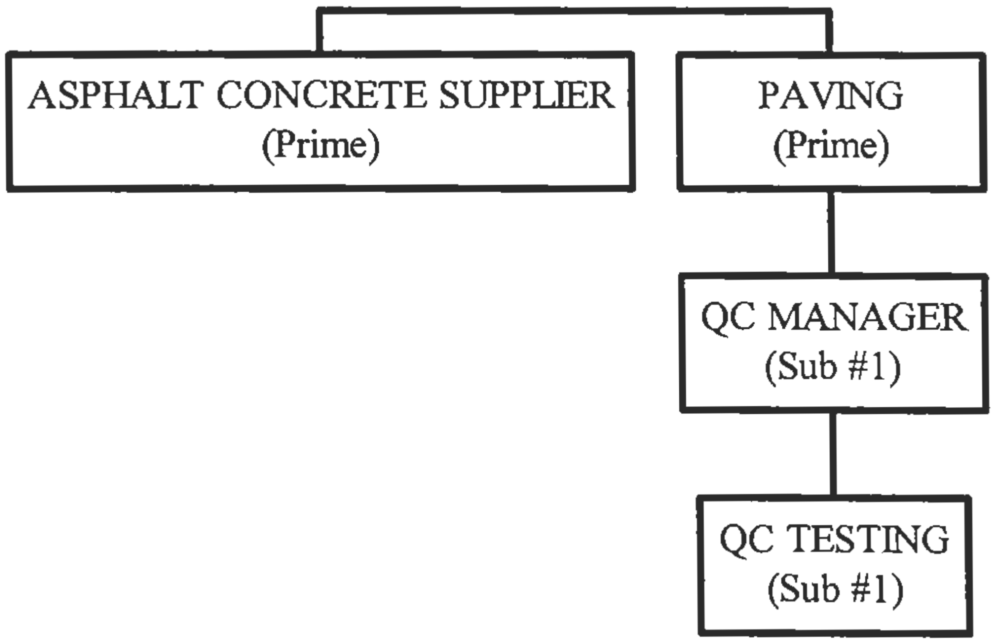

Figure 3.3 Organizational Structure B

3.2.5 Organizational Structure C

Figure 3.4 illustrates the organizational structure for Type C. This structure is identical to a Type B organizational structure with the single exception that the material is now supplied by a separate subcontractor, unlike Type B where the prime contractor supplied their own material. However, paving is still performed by the prime contractor and the QC manager and all QC testing is still administered by a separate subcontractor.

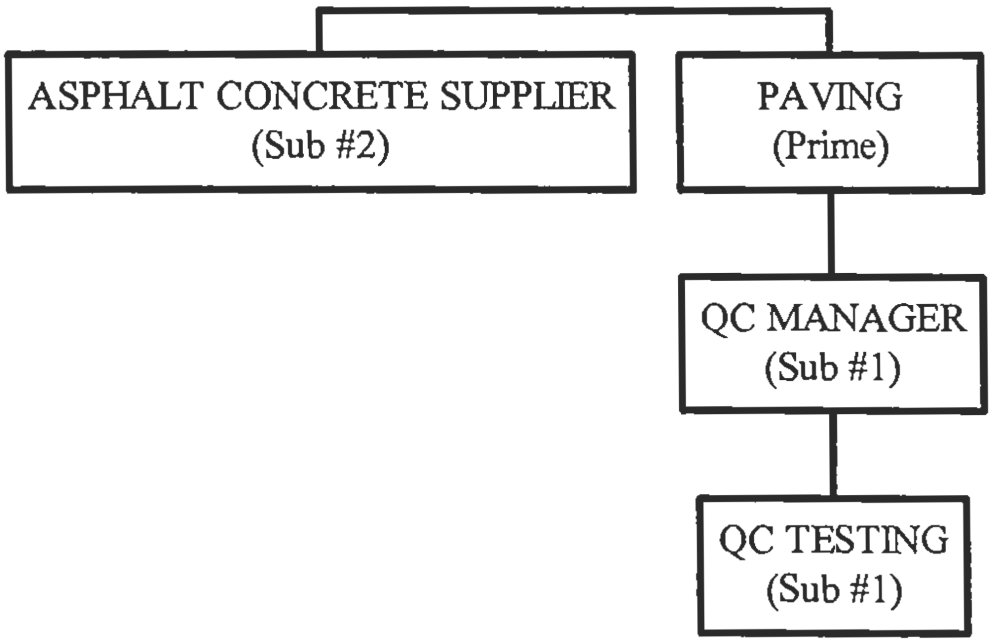

Figure 3.4 Organizational Structure C

3.2.6 Organizational Structure D

Figure 3.5 illustrates the Type D organizational structure. This flowchart is again similar to Type B, but with the exception that for Type D, the QC manager is an employee of the prime contractor. In this case, the prime contractor supplies the material and performs the paving and all QC testing is performed by a subcontractor. The QC manager acts as a liaison between the prime paving operations and the subcontracted QC testing operations.

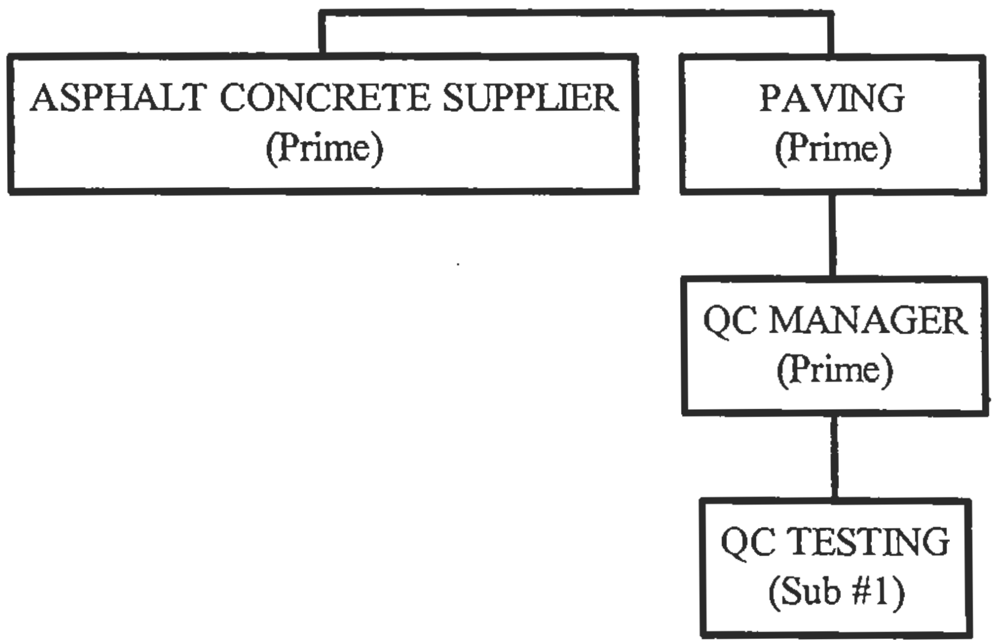

Figure 3.5 Organizational Structure D

3.2.7 Organizational Structure E

In Figure 3.6, a Type E organizational structure is illustrated. In this case, the prime contractor supplies the material, performs the paving operations, and the QC manager is an employee of the prime contractor. However, the responsibilities of quality control testing are shared by the prime contractor and a subcontractor, according to QC test type. In many cases, quality control tests for density are performed by the subcontractor with gradations and oil content determinations being performed by the prime contractor. All quality control data and test results, from both the prime's quality control staff and the subcontractor's quality control staff, are reported to the prime contractor's QC manager.

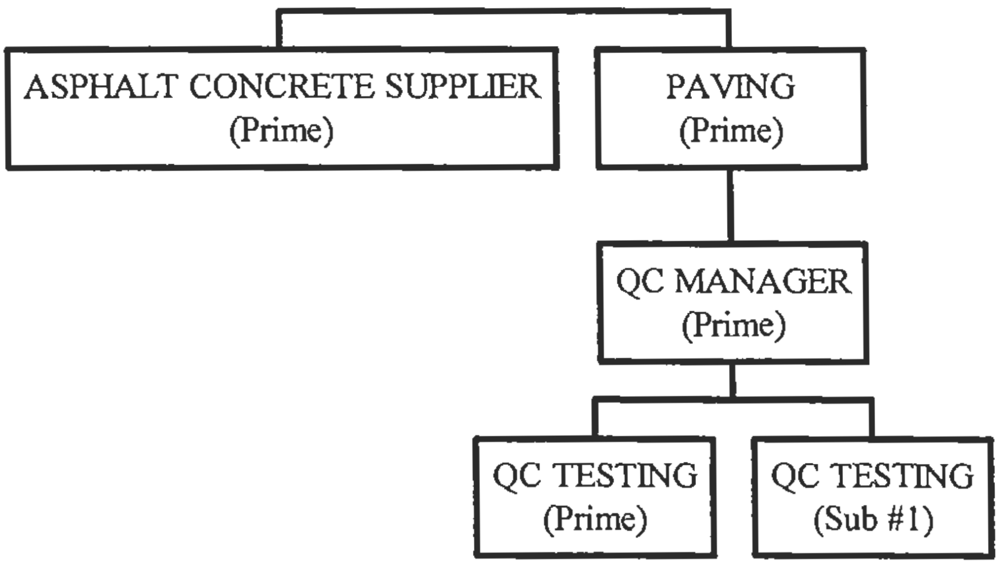

Figure 3.6 Organizational Structure E

3.2.8 Organizational Structure F

The final organizational structure, classified as Type F, is a unique situation in which the prime contractor is a general contractor who subcontracts all paving operations. The asphalt concrete is supplied by one subcontractor. The paving operation is performed by another subcontractor. A third separate subcontractor consists of the QC manager and all quality control testing. Figure 3.7 illustrates the flowchart for this organizational structure.

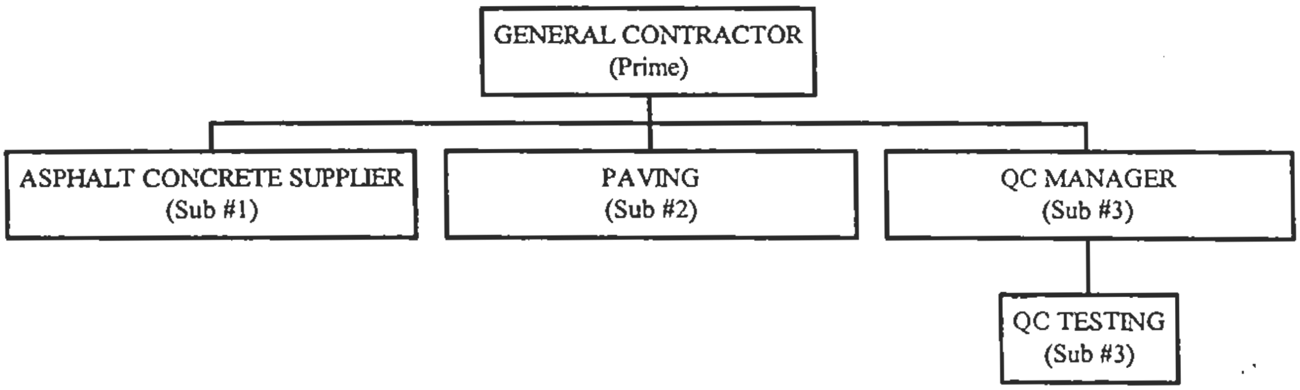

Figure 3.7 Organizational Structure F

4. Analysis of Physical Property Data

This chapter presents an analysis of physical property data from quality control samples, including:

- Statistical analyses including mean, standard deviation, and coefficient of variation,
- An analysis of statistical process control and data distributions for QC data,
- A statistical review of the data distributions for normality and multiple populations,
- An analysis of bid prices for QC/QA and conventional asphalt concrete projects,
- An analysis of pay factors and project tonnage
- Recommendations for creating a database to store QC and performance data,
- An analysis of multiple plant operations,
- Recommendations regarding lot size and verification testing, and
- Overall recommendations with respect to pay factor limits

4.1 Data Collection Status

At the time of Interim Report #2 (September 30, 1997), only 4 of 17 projects (24 percent) had a complete set of pay factor related test results with final pay factors calculated. Preliminary findings were presented, but the report advised that drawing conclusions based on partial data is not appropriate since this data cannot be assumed to be representative of the population of projects.

In order to provide sufficient time for data analysis before the final report deadline, data collection activities were ceased in April, 1998. At that time, 16 out of 17 projects were finished, allowing a more complete data analysis for this final report. Table 4.1 below illustrates the status of data collection for all projects as of April, 1998.

Table 4.1 Project data collection status as of April, 1998.

Project Code	Data Collected				Direct Observations	Document Analysis	Pay Factor
	Contractor		Caltrans				
	Test Strip Results	QC Tests	Test Strip Results	QA Tests			
1	X	X	X	X	X	X	Final
2	X	X	X	X	X	X	Final
3	X	X	X	X	X	X	Final
4	X	X	X	X	Not Performed	X	Final
5	X	X	X	X	X	X	Prelim.
6	X	X	X	X	X	X	Final
7	X	X	X	X	X	X	Final
8	X	X		P	X	X	Final
9	X	X	X	X	X	X	Final
10	X	X	X		X	X	Final
11	X	X	X	X	X	X	Final
12	X	P	X	P	X	Not Performed	Prelim.
13	X	X	X	X	X	X	Final
14	X	X	X	X	X	X	Final
15	X	P	X	Data collection terminated due to delays			Prelim.
16	X	X	X	X	X	X	Final
17	X	X	X	X	X	X	Final

X - Data collection complete. P - Data collection in progress. Empty Box - No data has been collected.

4.2 Data and Summary (Appendices)

This section includes a summary of data for sixteen of the seventeen 1997 projects. Data available as of April 1998 have been included in this analysis. Final pay factors were available for all but three of the projects (project codes 5, 12, and 15).

Data summaries were compiled in Excel® for the sixteen projects identified above. Data and results of some analyses are summarized in six appendices; data within each appendix are arranged by project code wherever possible. A brief review of the contents of the appendices is as follows:

A. **Appendix A** contains raw data on physical properties that was measured as part of the quality control program of the Contractor. The Appendix first shows the data as a tabulation and is followed by data plots (run charts) for each element (where an element is defined as each gradation size [3/4, 3/8 . . . No. 200], asphalt content, and relative density) that is required to calculate pay factors. For one case, data for moisture content is included.

   Run charts show data as measured for each sublot and the plot shows upper and lower specification limits labeled as "USL" and "LSL." These designations are used to prevent confusion with upper and lower control limit conventions ("UCL" and "LCL") used for statistical process control that will be discussed later.

B. **Appendix B** is a typical analysis of data for a single project code (in this case, project code 6). This analysis for project code 6 is included to show how the analysis for each project was conducted. In order to reduce report size, data for the remaining projects are on electronic file and are available on request.

   Statistical analyses were made with the program "JMP®" as provided by the SAS Institute.

   The first section is a data plot copied from Appendix A. This is followed by a statistical analysis for each element that includes descriptive statistics such as mean, standard deviation, count of sublot data points, etc., as found under the heading, "Moments" and a histogram of the data with a normal curve superimposed over the histogram.

   Following descriptive statistics are "Test for Normality" and "Capability Analysis." Both will be described in a following section, but briefly, normality is a measure of the dispersion of data (e.g. gaussian or normal, skewed, etc.) and capability analysis is an indication of the capability of the process as described by the data to be able to produce a product to a specification.

   Based on visual inspection of the data plot for each element, data that appeared to contain runs with different groups based on "averages" or variability was analyzed to determine if these differences do, indeed, exist. Results of analysis of variance (ANOVA) and comparison of means by the Tukey-Kramer comparison of means are included, i.e., page B-6, for the 3/4 fraction. Output includes "comparison circles" that show differences between means when circles do not intersect.

Two sets of statistical process control (SPC) charts are included for reference and to provide information for contractors that may be interested in development of internal process control that has, in other industries, been shown to result in product improvement, increased profits, and, for the case of pavements, improved performance. One set of charts is based on individual measurements (ref. page B-7) and another was based, arbitrarily, on a sample size of 4. The chart for individuals shows indicators of the necessity to adjust the process based on the Western Electric Rules of statistical process control or statistical quality control. The Western Electric rules are included in Appendix F.

C. **Appendix C** summarizes analyses for all projects as described by the typical analysis of Appendix B. The summary includes the following row headings for each element:

1. Count of data points (usually sublots).

2. Maximum, minimum, and range (range = maximum - minimum).

3. Mean, standard deviation, and coefficient of variation. Coefficient of variation (CV) expresses variability by standard deviation as a percentage of the mean and is used for comparisons of data dispersion that varies with the mean and is described by:

$$\mathbf{CV = [standard\ deviation \div mean] \times 100}$$

4. Specification targets and specification limits (USL and LSL)

The row heading "Normal" is a subjective evaluation of normality as described by the Shapiro-Wilks W-test. "In Control" is also a subjective evaluation of process control as described by the statistical process control (SPC) charts analyzed as shown in Appendix B. "Capability" is a summary of capability analyses and will be briefly discussed later.

Finally, a notation is made for projects that appear to contain multiple populations within a lot as determined by inspection of data charts, and confirmed by ANOVA, and means comparisons.

D. **Appendix D** summarizes pay factors and tonnages of the projects studied and shows results of least square fits in an attempt to relate pay factors to standard deviations and coefficients of variation. Note that in order to maintain anonymity projects are identified by letter code or are not identified.

E. **Appendix E** includes plots of variability (standard deviation and coefficients of variation).

F. **Appendix F** shows the Western Electric Rules for statistical process control and shows the eight run situations that require process adjustment to maintain control.

G. **Appendix G** is a comparison between the t-test and analysis of variance for verification.

4.3 Data Analysis

4.3.1 Overall Variability

Appendix C shows all calculated statistics including mean, standard deviation, and coefficient of variation. Table 4.2 shows project means for each element tabulated by project code. Table 4.3 shows standard deviations for each element by project code. Table 4.4 shows coefficients of variation for each element by project code.

Table 4.2 Project Means

Proj. Code	Element							
	3/4	3/8	No. 4	No. 8	No. 30	No. 200	Asphalt Cont.	Rel Den
1 (Lot 1)	97.8	66.6	43.6	35.2	21.8	4.67	4.74	96.09
1 (Lot 2)	97.8	67.5	48.4	34.6	18.5	4.73	5.01	97.14
1(Lot 3)	97.7	70.6	51.5	36.9	19.6	5.05	4.67	97.23
2	96.2	67.4	45.6	35.0	16.6	3.12	4.42	97.73
3	97.6	73.4	47.3	36.1	22.9	3.63	5.94	98.83
4	95.6	72.0	53.6	39.1	20.3	4.10	4.79	98.01
5	99.9	70.8	48.8	36.3	18.6	3.36	5.07	97.93
6	93.6	70.8	50.4	38.5	18.1	4.60	4.80	97.12
7	100.0	79.0	53.5	37.9	18.0	6.11	6.11	97.15
8	98.2	63.9	44.9	33.7	17.8	6.56	5.15	98.32
9	98.8	65.9	48.4	32.5	16.3	3.61	4.62	97.58
10	95.6	70.5	47.4	35.8	18.8	4.44	4.62	
11	97.2	72.1	52.4	39.7	19.0	4.98	5.26	96.91
12	99.9	72.0	49.2	36.0	18.1	3.30	5.04	98.88
13	99.1	70.4	53.0	40.2	20.8	5.38	4.96	97.46
14	94.1	73.0	53.7	38.9	16.6	3.30	6.38	
16 (Lot 1)	94.3	65.8	46.8	35.3	18.8	3.30	5.23	97.85
16 (Lot 2)	94.0	69.6	49.5	36.5	19.5	3.92	4.55	96.67
16 (Lot 3)	95.4	72.5	52.8	39.4	21.6	4.02	4.57	97.38
17	98.0	69.5	53.7	41.5	21.4	4.01	4.67	96.87
Ave	97.1	70.2	49.7	37.0	19.2	4.3	5.0	97.5

The variability for each element, as expressed by standard deviation, was compared with data that has been developed nationally and is reported by Epps, J.A., et al, "Accelerated Field Test of Performance-Related Specifications for Hot-Mix Asphalt Construction, Task G Interim Report (Final Draft)," FHWA Contract DTFH61-94-C-00004). In general, Caltrans data are much less variable than the reference data, as shown in Table 4.3.

Table 4.3 Project Standard Deviations

Proj. Code	Element							
	3/4	3/8	No. 4	No. 8	No. 30	No. 200	Asphalt Cont.	Rel Den
1 (Lot 1)	1.9	2.7	1.7	1.1	0.6	0.89	0.30	1.10
1 (Lot 2)	1.1	2.4	2.7	2.6	2.1	0.47	0.10	0.39
1(Lot 3)	0.8	2.7	3.4	2.1	1.6	0.62	0.14	0.67
2	2.3	3.0	1.4	1.9	2.2	0.52	0.12	0.67
3	0.5	1.2	1.9	1.3	1.1	0.25	0.17	1.11
4	1.0	2.2	2.9	2.3	1.8	0.52	0.26	0.86
5	0.3	1.8	1.3	1.2	0.9	0.32	0.13	0.73
6	1.7	2.1	1.6	1.3	0.8	0.19	0.13	0.45
7	0.0	1.5	1.2	1.2	1.0	0.35	0.17	0.54
8	1.1	2.9	2.9	2.4	1.4	0.74	0.26	0.91
9	0.9	2.6	2.8	3.4	1.9	0.50	0.35	1.35
10	1.0	1.2	1.2	1.2	1.0	0.50	0.10	
11	0.4	1.0	2.0	1.8	1.5	0.81	0.19	0.42
12	0.2	1.3	1.2	1.3	1.5	0.38	0.20	0.72
13	0.7	1.4	1.1	1.5	1.1	0.42	0.17	0.45
14	1.4	1.8	2.2	2.9	2.1	0.81	0.33	
16 (Lot 1)	0.5	2.8	1.0	1.4	1.0	0.43	0.38	0.6
16 (Lot 2)	1.1	1.5	1.3	0.8	0.5	0.61	0.26	0.58
16 (Lot 3)	1.1	2.0	1.8	2.1	1.3	0.29	0.16	0.6
17	1.1	2.9	2.9	2.2	1.7	0.68	0.17	0.51
Ave	1.0	2.1	1.9	1.8	1.4	0.5	0.2	0.7
FHWA	1.43	2.49	3.51	2.81	1.74	0.94	0.24	1.69*

* Based on percent maximum theoretical density.

Table 4.4 Project Coefficients of Variation

Proj. Code	Element 3/4	3/8	No. 4	No. 8	No. 30	No. 200	Asphalt Cont.	Rel Den
1 (Lot 1)	1.9	4.0	4.0	3.2	2.6	19.02	6.39	1.15
1 (Lot 2)	1.1	3.5	5.5	7.4	11.5	9.88	2.07	0.40
1(Lot 3)	0.8	3.9	6.6	5.7	8.0	12.30	3.02	0.68
2	2.4	4.4	3.2	5.3	13.1	16.81	2.79	0.69
3	0.5	1.6	4.1	3.7	4.9	6.95	2.83	1.13
4	1.1	3.1	5.4	5.9	8.9	12.65	5.33	0.87
5	0.3	2.5	2.7	3.2	4.9	9.48	2.46	0.74
6	1.8	2.9	3.2	3.3	4.2	4.04	2.76	0.46
7	0.0	1.9	2.2	3.1	5.5	5.66	2.70	0.56
8	1.1	4.5	6.4	7.0	7.7	11.29	5.07	0.92
9	0.9	4.0	5.7	10.5	11.4	13.77	7.48	1.38
10	1.1	1.8	2.5	3.4	5.5	11.31	2.16	
11	0.4	1.5	3.8	4.5	8.1	16.31	3.59	0.43
12	0.2	1.8	2.4	3.5	8.2	11.54	3.95	0.73
13	0.7	2.0	2.1	3.8	5.1	7.76	3.42	0.47
14	1.5	2.5	4.2	7.5	12.5	24.60	5.23	
16 (Lot 1)	0.5	4.2	2.1	3.9	5.2	13.00	7.32	0.61
16 (Lot 2)	1.2	2.2	2.6	2.2	2.7	15.68	5.77	0.60
16 (Lot 3)	1.1	2.7	3.4	5.4	6.1	7.28	3.40	0.62
17	1.2	4.1	5.4	5.4	8.0	17.07	3.56	0.52
Ave	1.0	3.0	3.9	4.9	7.2	12.3	4.1	0.7

Plots of standard deviation and coefficient of variation for each project are in Appendix E.

4.3.2 Process Control

It is doubtful that conventional statistical process control (SPC) was used by Contractors for any of the projects analyzed thus far and a full discussion of process versus product control is beyond the scope of this project. However, it does appear to be worthwhile to consider some of the ramifications from applying these principles to Caltrans hot mix projects.

Two references that may be of use are :

1. "Pyzdek's Guide to SPC, Volume 1 - Fundamentals, 1990 and Volume 2- Applications and Special Topics, 1992," Thomas Pyzdek, ASQC Quality Press and Quality Publishing; and

2. "Statistical Process Control - Second Edition," L.A. Doty, Industrial Press, 1996

For preliminary analysis, a normal curve is superimposed over the histogram for the data and the Shapiro-Wilks-W test is performed. Note that if the "p-value" for the test is less than, say, 0.05, the data are not considered to be normally distributed. Results of this test are noted in the summary (Appendix C) for information. A typical distribution plot of asphalt content for project code 6 is shown on Figure 4.1. Several distribution attributes can be investigated including identification of multimodal curves, indicating the possibility of multiple populations within the lot, and identifying non-normality, which can limit application of certain statistical process methods.

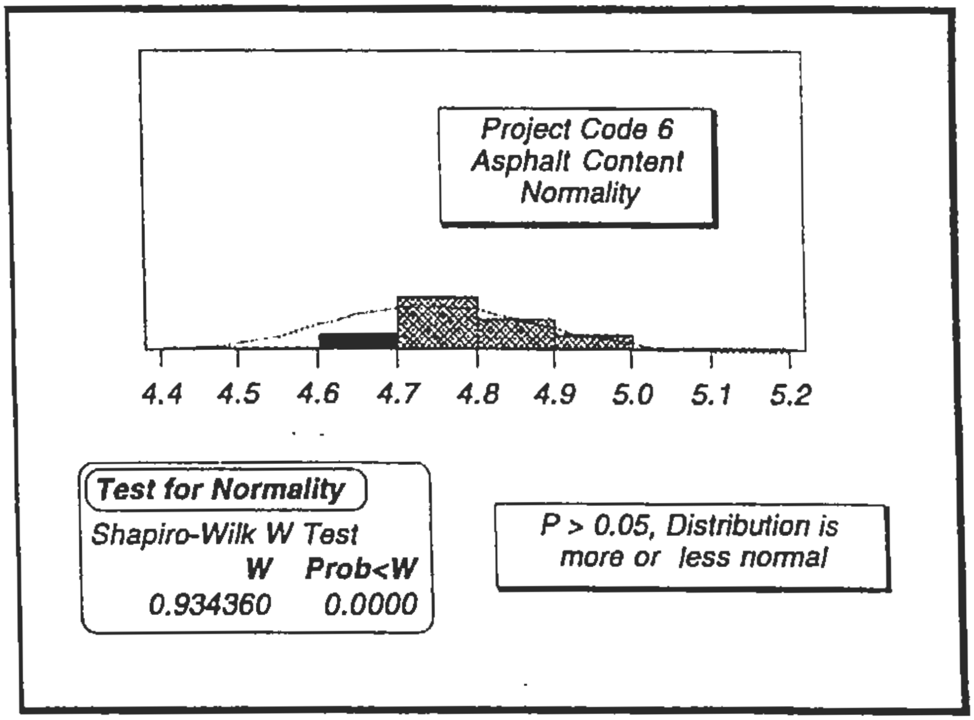

Figure 4.1 Distribution and Test for Asphalt Content Normality - Project Code 6

For each element of each data set, a conventional statistical control chart was developed. These charts are widely used in industrial quality control programs and show when adjustments are necessary to maintain process control.

Statistical process control charts (often referred to, in the quality control community, as "control charts"), consist of a time chart with upper and lower control limits (UCL and LCL) placed at plus and minus three standard deviations. Three standard deviations (or 3 sigma) represents approximately 99.7 percent of normally distributed data. Points that fall outside the limits indicate that some aspect of the process is "out of control."

About 27 types of charts are commonly used for continuous variables and attributes, i.e., percent defective, etc. and rules have been established to determine data trends that require some action or adjustment to the process while recognizing that it may be important not to act if a single measurement falls outside control limits. One set of these rules is referred to as the "Western Electric Rules," reproduced in Appendix F. As an example (without examination of the effects of non-normality), Figures 4.2 and 4.3 show two possible control charts for asphalt content for project code 6. The numbers next to some of the data points indicate the applicable Western Electric Rule.

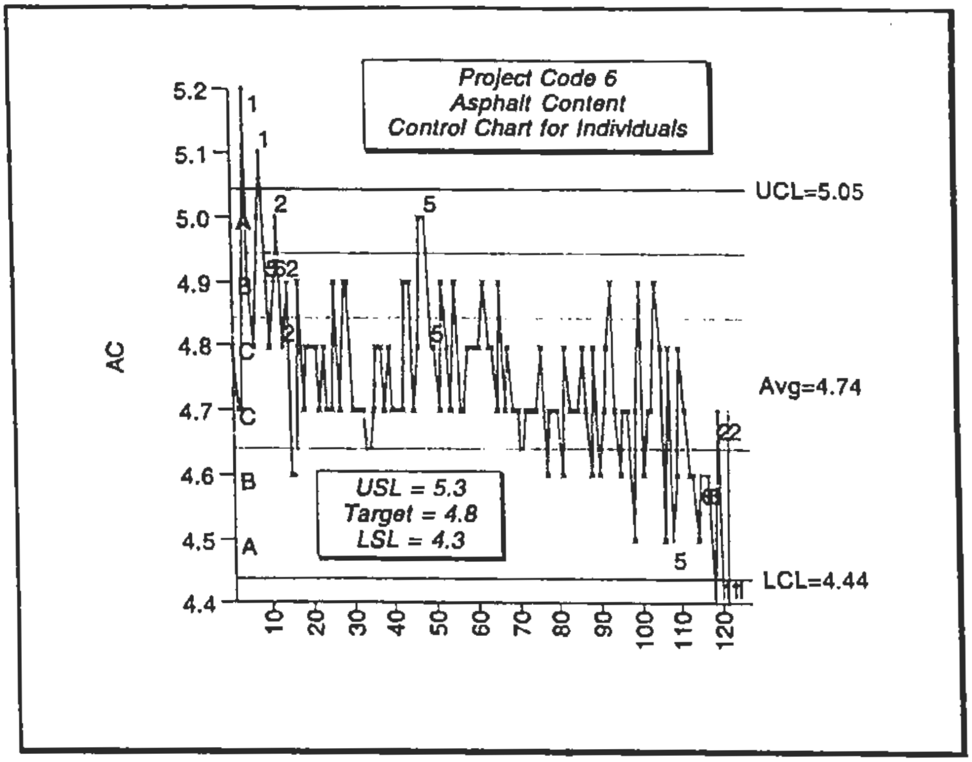

Figure 4.2 Example Control Chart for Individuals - Project Code 6

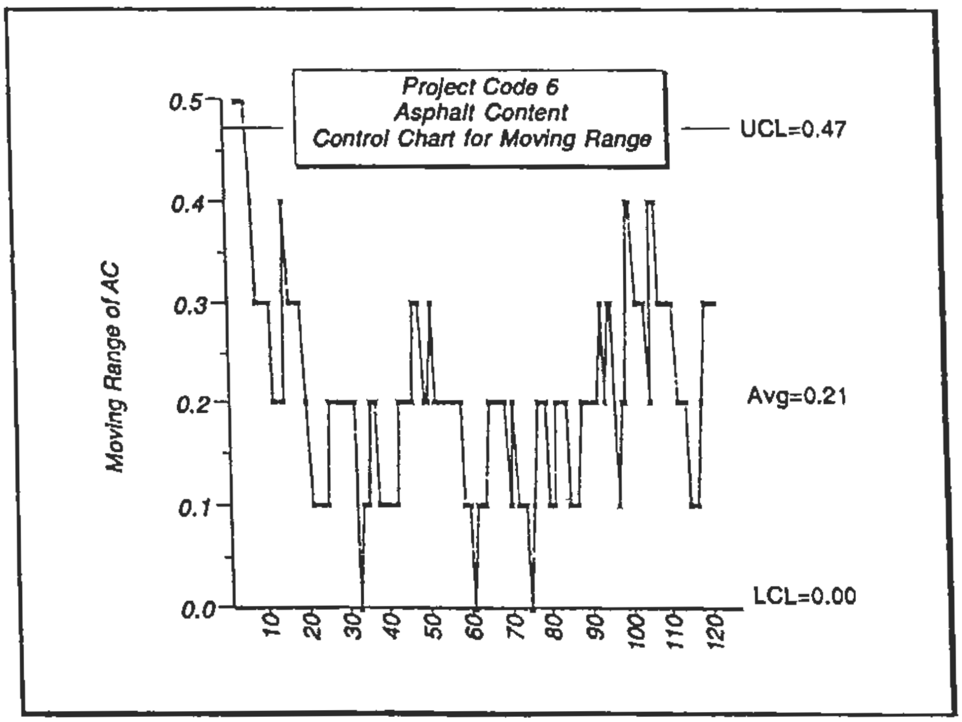

Figure 4.3 Example Control Chart for Range - Project Code 6

Figure 4.2 shows violations of the Western Electric Rules for process control although none of the data points are outside the specification limits. Appendix C summarizes violations of Western Electric Rules for all charts, shown to the right of the row heading, "In Control."

It is possible to use specification limits as control limits if it is understood that specification limits must represent plus and minus three standard deviations and that their use controls product quality and not the process.

In order to reduce confusion between specification or product control and process control, it is suggested that consideration be given to changing wording in the specification that refers to "control charts" or "limits" when specification limits are intended. It would be prudent to consider rewording "linear control charts" to something like "specification charts or "run charts" for example.

Finally, ratios for capability analyses were calculated for each element of each project. These ratios can be used to determine if a process can consistently produce materials within existing specification limits. One set of limits established by the Japanese requires a minimum of 1.33 to accept a process. Appendix B presents five capability ratios that were calculated for each element of each project code. A review of each of these is summarized in Appendix C in the row heading, "Capability." While non-normality and the possibility of multiple populations within a lot may reduce the effectiveness of capability ratios to analyze process or product control, the high number of non-compliance (ratios below 1.33) suggests that a review of specification limits, pay factors, and weighting of pay factors should be considered.

Based on data available, it is clear that most of the current process controls are not sufficient to meet specification limits. One of the reasons to question conventional quality control methodology, as used in the present specification, is the preponderance of pay factors greater than 1.00. These high pay factors suggest a problem with assignment of pay factors, the method of weighting pay factors for each element, or in selection of properties for pay factors.

4.3.3 Multiple Populations Within a Lot

A final note in the summary table of Appendix C reports observations about multiple populations in the lot. These observations are important for later consideration of single versus multiple lots for pay factors.

Consider the data plot for asphalt content of project code 6 (Appendix B, p. B-23) or as shown on Figure 4.4.

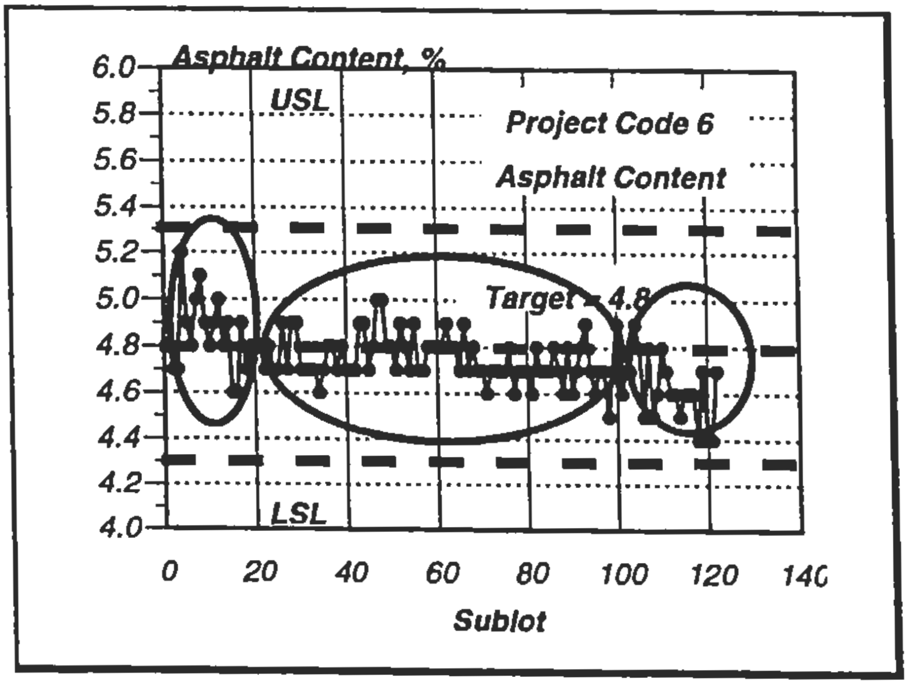

Figure 4.4 Asphalt Content Data - Project Code 6

A visual inspection of Figure 4.4 suggests a different mean (and perhaps variability) for Group A (sublots 1-20) versus Group B (sublots 21-100) versus Group C (sublots 101-122). This can be tested with conventional analysis of variance (ANOVA) methods. For this case, JMP® provides an ANOVA and a comparison of means with the Tukey-Kramer test. ANOVA results are shown in Table 4.5 and the Tukey-Kramer Comparison is shown in Table 4.6 with a graphical analysis on Figure 4.5. Note that both analysis methods indicate statistically significant differences in the means for Groups A, B, and C.

Table 4.5 Analysis of Variance, Group Means - Project Code 6, Asphalt Content

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	0.5302243	0.265112	19.8650
Error	119	1.5881364	0.013346	Prob>F
C Total	121	2.1183607		0.0000

Table 4.6 Tukey-Kramer Means Comparison - Project Code 6, Asphalt Content

Means for Oneway Anova

Level	Number	Mean	Std Error
A	20	4.84500	0.02583
B	80	4.75000	0.01292
C	22	4.62273	0.02463

Std Error uses a pooled estimate of error variance

Comparisons for all pairs using Tukey-Kramer HSD

q*
2.37343

Abs(Dif)-LSD	A	B	C
A	-0.08671	0.026453	0.137561
B	0.026453	-0.04335	0.061266
C	0.137561	0.061266	-0.08267

Positive values show pairs of means that are significantly different.

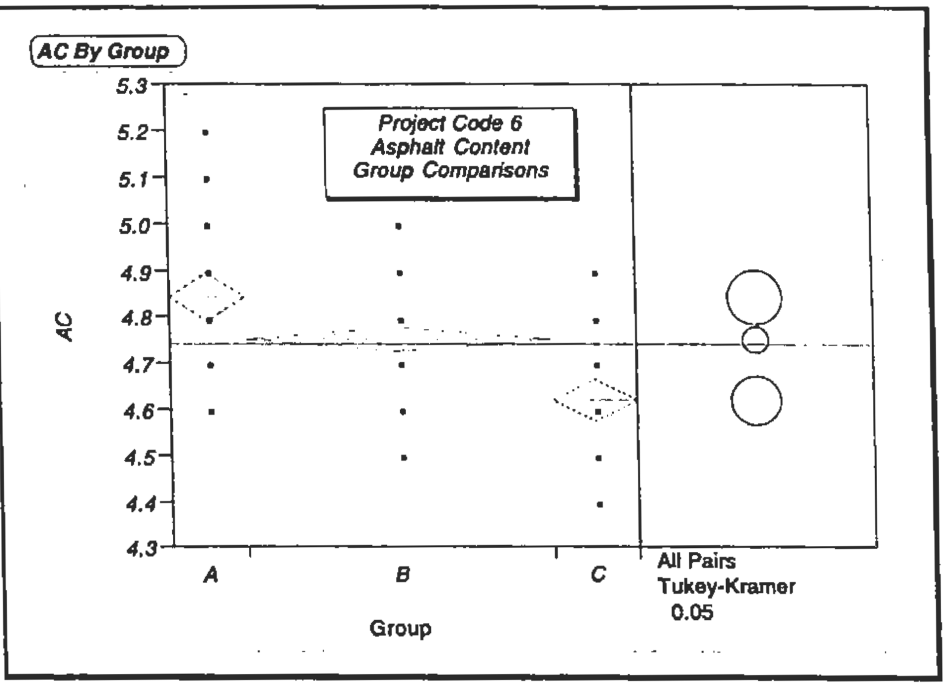

Figure 4.5 Graphical Analysis of Differences Between Groups - Project Code 6, Asphalt Content

Note in Figure 4.5 that diamonds represent mean (center of diamond) and two standard deviations (tips of diamond) for each group and that Tukey-Kramer shows a difference when the "comparison circles" do not intersect.

One point to consider is that while conventional analysis techniques show statistical significance, some judgment is necessary to determine if a practical significance exists. For example, in this case, the mean for Group A is 4.84 versus a mean of 4.75 for Group B and 4.62 for Group C. From a materials (asphalt content) point of view, this is probably a statistically significant difference. However, for aggregate gradations and other attributes, statistical significance exists with little or no practical implications.

It can be observed in Appendix C that 12 of the 20 lots suggest differences in one or more elements, i.e., multiple populations could exist within a lot or project. Additional discussion will follow when the issue of single versus multiple sublots is considered.

4.4 Bid Prices

Asphalt concrete bid price data and engineer's estimates were provided by Caltrans for 1997 QC/QA projects and 1996 non-QC/QA projects. Based on information provided in September 1997, bid prices for QC/QA projects non-QC/QA projects and for the seventeen 1997 projects evaluated by NCE are provided in Table 4.7.

Table 4.7 Asphalt Concrete Bid Prices for QC/QA and Non-QC/QA Projects

	QC/QA	*Non-QC/QA*	*1997 QC/QA Projects Evaluated by NCE*
Number of Projects	*55*	*72*	*17 (included in 55)*
Tonnage (1,000's tons)	*2,773*	*3,318*	*696*
Wt. Ave. Engr. Est.	*$33.09*	*$31.77*	*$34.48*
Wt. Ave. Low Bid	*$30.88*	*$29.36*	*$34.35*

Note: Weighted Average Engr Est = (Total Est. ÷ Total Quantities)
Weighted Average Low Bid = (Total Bids ÷ Total Quantities)

Low bid prices for 127 QC/QA and non-QC/QA projects revealed that bids for QC/QA projects are about 5 percent higher than for conventional projects. For an average project size of approximately 48,000 tons, the average price for QC/QA projects would be $1,482,000 whereas the average conventional project would be priced at $1,409,000. This results in an average premium first cost of $ 73,000 for QC/QA projects.

This premium presumably reflects increased costs to the bidder for testing personnel and laboratories and should be offset by reducing these costs for Caltrans and by improved performance.

For the seventeen projects evaluated in 1997, low bids are approximately 11 percent higher than low bids for all QC/QA projects reported by Caltrans. Because the seventeen 1997 projects represent only about 13 percent of the total projects, this will be considered an anomaly until additional data are available for analysis. Bid prices that were available and Engineer's estimates for the 1997 construction projects are shown on Figure 4.6. The bid prices are shown for each project in decreasing order.

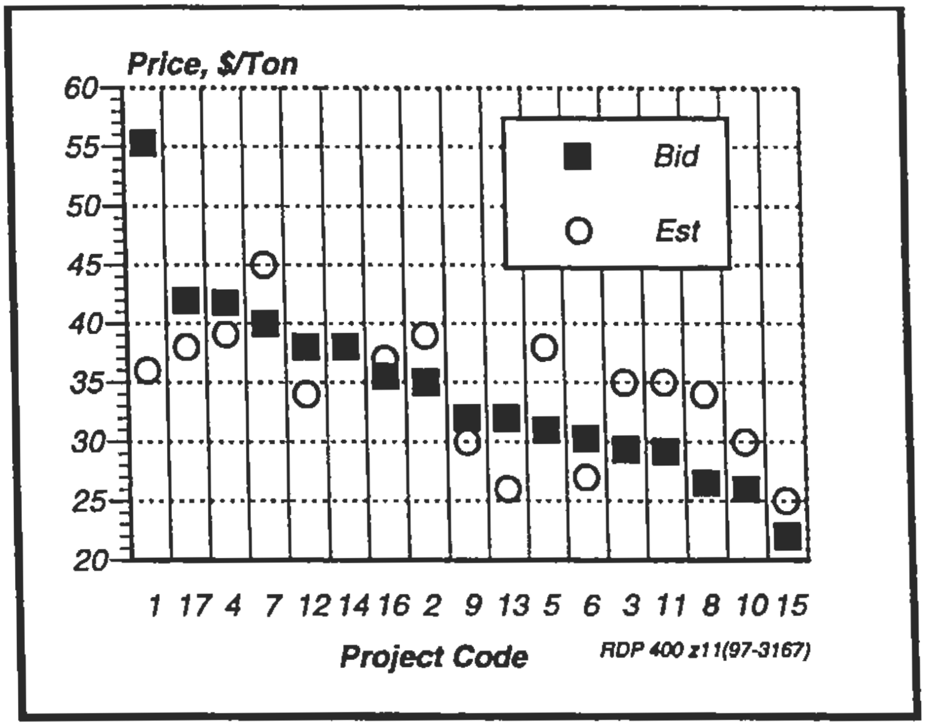

Figure 4.6 Bid Prices and Engineers Estimates for 1997 Projects

4.5 Project Tonnage and Pay Factors

Overall pay factors, tonnage ranges and contractor structures for each of the 1997 projects are reported in Table 4.8. Note that the contractor's organization does not appear to have an influence on pay factor as shown at the bottom of the table.

Table 4.8 Project Information and Pay Factors

Code	Tonnage Range	Contractor Organization	Pay Factor
1	10,000 to 35,000	Vertical	0.8901 (Lot 1) 1.0472 (Lot 2) 1.0288 (Lot 3)
2	> 35,000	Vertical	1.0457
3	10,000 to 35,000	Vertical	1.0452
4	> 35,000	Vertical	1.0342
5	> 35,000	Horizontal	1.0495
6	> 35,000	Vertical	1.0459
7	> 35,000	Vertical	1.0430
8	10,000 to 35,000	Horizontal	1.0340
9	10,000 to 35,000	Horizontal	0.9697
10	10,000 to 35,000	Vertical	1.0500
11	10,000 to 35,000	Vertical	1.0207
12	> 35,000	Horizontal	1.0465
13	10,000 to 35,000	Vertical	1.0470
14	10,000 to 35,000	Horizontal	0.9989
16	10,000 to 35,000	Vertical	0.9837 (Lot 1) 1.0115 (Lot 2) 1.0455 (Lot 3)
17	> 35,000	Vertical	1.0320
	Horizontal Structure	Vertical Structure	Overall
Average Pay Factor	1.02	1.019	1.0235
Std. Dev. Pay Factor	0.034	0.051	0.03890

An analysis of the relationship between pay factors and project tonnage is presented in Appendix D. A plot of pay factors versus project tonnage is shown on Figures 4.7.

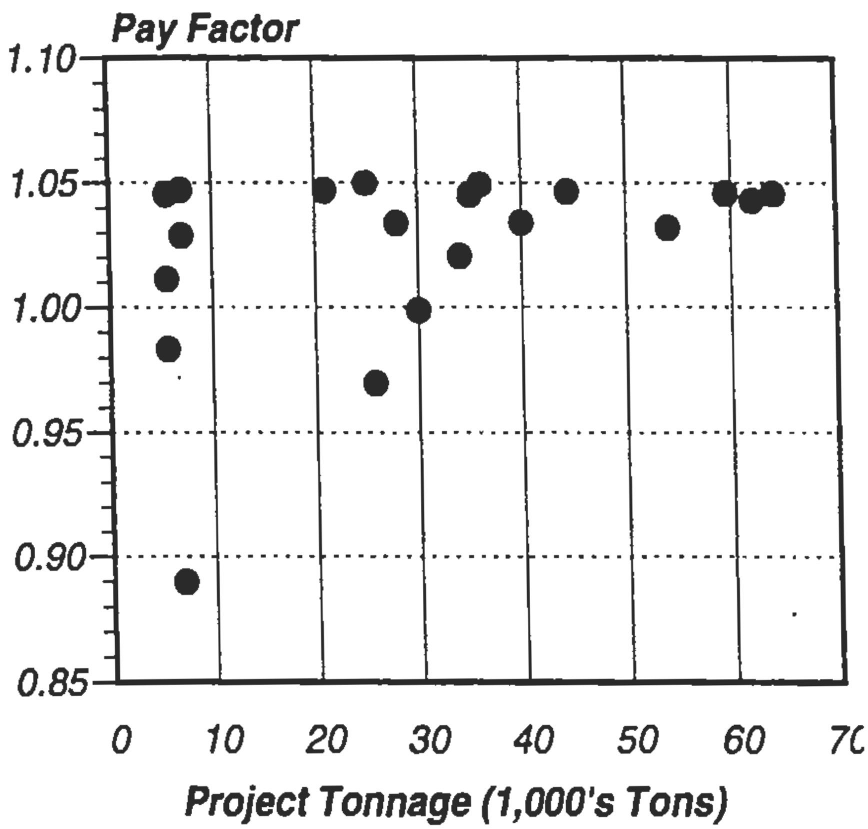

Figure 4.7 Pay Factor vs. Project Tonnages

4.5.1 Relationships of Tonnage and Variability to Pay Factors

Although data are somewhat limited, Appendix D shows several possible relationships between specification elements and pay factor based on least square fits.

Results from a limited analysis of pay factor versus tonnage is presented in the first portion of Table D2 in Appendix D and it appears that no relationship exists between project tonnage and pay factor.

As was stated in section 4.3.1, coefficients of variation were used to determine the effect of variability on pay factors. There does appear to be the suggestion, at least, of a relationship between overall coefficient of variation or standard deviations of No. 200, asphalt content, and relative density when all interactions are considered (see Table D2, Appendix D). Based on limited data it would appear that the intent of specification pay factors is effective. But the data also suggest that pay factors should receive additional study in view of the fact that only three of the twenty lots had overall pay factors lower than 1.00.

4.5.2 Sensitivity to Variation, Case 1

Some questions have been raised regarding the sensitivity and appropriateness of the pay factors. One of the questions is, "If compaction steadily increases from 96 to 98 percent, is the contractor penalized for doing a better job on compaction?"

First, the specification is written around a minimum of 96 percent with no limitation on maximum density (one-tailed test), and there is a perception that increased relative density above 96 percent is desirable. However, compaction at construction to air voids less than three or four percent, for some mixes, may be detrimental to performance (early bleeding and rutting).

Even if over-compaction is not an issue, the contractor would not be penalized if all other factors (variability) remained unchanged.

However, the question deserves additional attention because the specification does not clearly indicate how to apply statistics to relative density to determine quality limits. Perhaps it has been assumed that a maximum relative density of 100 percent is the upper limit, which is not correct since field densities can be higher than laboratory test maximum density (LTMD).

4.5.3 Sensitivity to Variation, Case 2

Another question which has been raised is, "The Contractor is tight on variability, but is at the lower specification limit. Does the contractor deserve a bonus?"

The only way to address this issue is to conduct a "what-if" study (preferably with Resample Methods) and determine how specification pay factors are affected by the matrix situations as shown on Figure 4.8.

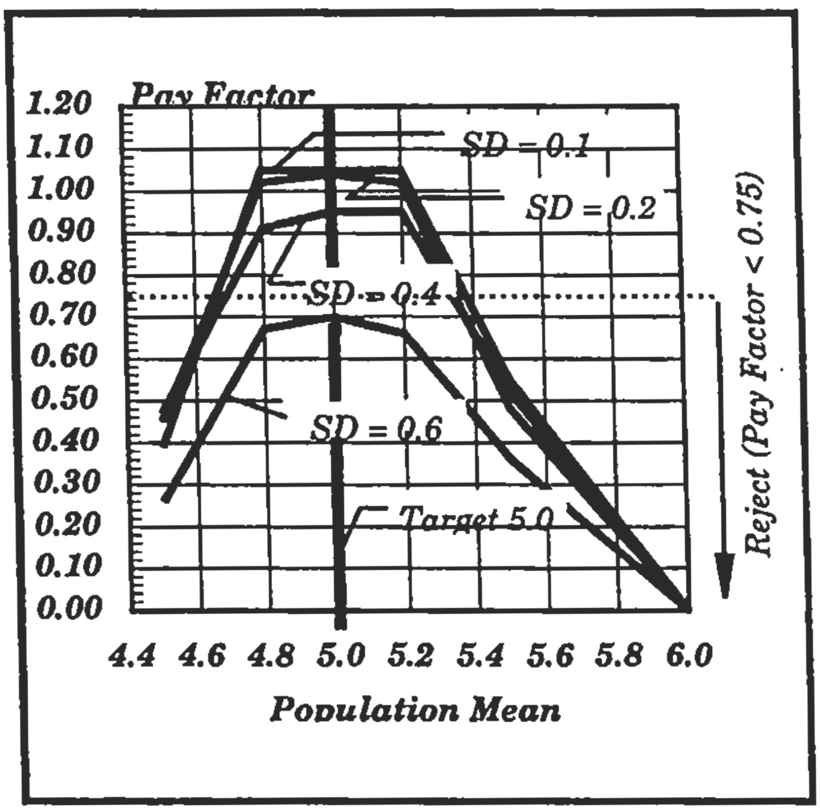

Figure 4.8 Example - Effect of Mean and Variability on Pay Factors for Asphalt Content

This figure was shown in the proposal for this project and used a limited amount of data to address the question. Note that for a given standard deviation (say 0.1), as asphalt content moves away from the target, pay factor decreases. Now that real data has been generated to determine realistic variability, the study should be conducted with a large number of samples from Resample Methods. This is an exercise worth conducting to evaluate all pay factors but is considerably beyond the scope of this implementation project.

4.6 Database

As was noted in Interim Report #1, an appropriate database is necessary if Caltrans wishes to further use the data to verify or study the effect of variability on pay factors and to determine relationships between pay factors and other elements such as bid price, tonnage, and, of course, performance. A conventional flat file or relational database such as Claris FileMaker Pro® is suggested to replace the present Excel® spreadsheet since searching a spreadsheet is limited to visual scanning which is ineffective, at best, for a system as large as is anticipated for this project.

Data elements or fields should include all data on actual measurements as well as bid prices and performance data. It is also suggested that performance evaluation data include projects constructed under QC/QA specifications as well as conventional specifications in order to address cost-benefits of the specification.

The database should be maintained by Caltrans, but use of an outside contractor should be considered to update the system.

Contractors should be required to include electronic data as well as hard copy. One should be careful with this requirement and severely limit the data, following Caltrans outline and format, to prevent receiving such large amounts of data that it prohibits easy access and analysis.

4.7 Relating Pay Factors to Long-Term Performance

Currently, the Caltrans QC/QA specification has assigned the parameters of aggregate gradation, asphalt cement content, and relative compaction as the items from which a composite pay factor is determined. Each of these parameters was assigned an arbitrary weighting to signify its contribution to the composite pay factor. However, it is considered important to relate the weighting factors to the long-term performance of the asphalt concrete pavement so that a contractor is penalized or reimbursed for the quality of the pavement constructed as it relates to long term performance. A framework for developing these relationships has been presented in the following references:

1. "Pay Factors for Asphalt-Concrete Construction: Effect of Construction Quality on Agency Costs," Technical Memorandum TM-UCB-CAL/APT-97-1, Deacon J. A., et al.

2. "Fatigue Performance of Asphalt Concrete Mixes and its Relationship to Asphalt Concrete Pavement Performance in California," Asphalt Research Program, CAL/APT Program, 1995, Deacon, J. A., et al.

The current data that are collected as a requirement of the QC/QA specification address some of the elements thought to relate to long-term pavement performance, as measured by the failure criteria of fatigue cracking and rutting. Specifically, aggregate gradation and asphalt cement content are known to have a significant effect on both rutting and fatigue life, and relative compaction is also strongly related to fatigue life. However, the measurement of density in the field through relative compaction has been noted as an indirect method of measurement. It has been acknowledged that the variability of relative compaction, as currently measured under the QC/QA specification, is not well known. Air void measures may exhibit less variability with a greater chance that a relationship can be drawn between air voids and pavement performance.

Thickness of the pavement is not currently measured, even though it is considered to have a significant effect on the fatigue resistance of a pavement. Unfortunately, for most rehabilitation projects, such as overlays, the asphalt thickness varies in order to provide a smooth final surface. For new construction, thickness could possibly be measured using one of three strategies: cores, grid survey, or possibly infrared technology. Innovative technologies should be investigated to identify methods suitable for measuring thickness on both overlays and new construction.

In conjunction with the collection of conventional QC data currently required by the specifications, "shadow" studies may be conducted on materials sampled from many projects. The "shadow" studies could include laboratory performance simulations and/or with a Heavy Vehicle Simulator (HVS) to review the pay factor weightings (Reference 1 above). These simulations may be performed on asphalt concrete to quantify the effects of construction quality, specifically air voids, asphalt content, gradation, and pavement thickness, and establish pay factor schedules (Reference 2 above).

Finally, in order to establish relationships between pay factor and long-term performance, field performance measurements (especially fatigue and rutting) on completed QC/QA projects, as well as conventional projects, should be monitored and stored in the database referred to in Section 4.6.

4.8 Multiple Plant Operations

As identified in Interim Report #1, it is a common practice to have more than one plant supply asphalt concrete to an individual project. Different materials from different plants will also have different properties, thus influencing compacted density. This is currently handled in the specifications by using the mixture with the higher maximum density (LTMD or FTMD) as the basis for determining relative compaction, however, this leads to concerns about "over rolling", possibly leading to low in-place air voids or fractured aggregates. Also, if the specific gravities of the two mixes are substantially different, which can happen depending on aggregate sources, a contractor may never be able to meet compaction requirements for the mix with the lower TMD.

Use of multiple plants also requires material sources to be easily identified during sampling in the field. Typically, this precludes the possibility from sampling behind the paver and sampling is often done at the plant instead, which does not account for possibility of segregation during hauling and placement.

Of the seventeen 1997 projects analyzed for this report, only one project used multiple plants, apparently a batch plant at one location and a dryer drum at another. The drum plant used two target asphalt contents, therefore, there were three lots for this project code.

It is clear that differences in material properties due to differences in plant operations will be reflected in pavement characteristics. However, quantification of differences is difficult since gradations and asphalt contents are based on samples obtained at the individual plants thus, effects of variability on the pavement are difficult to determine. Increased variability of relative density may be one measure to determine, qualitatively at least, if plant differences are significant since random density tests would, presumably, include materials from all plants.

Appendix E shows standard deviations and coefficients of variation by project code for each data element and separates data from the multiple plant situation (project codes 1B = batch plant, 1D7 = drum with 4.7 target asphalt content, and 1D9 = drum with 4.9 target asphalt content).

From the figures in Appendix E, it would appear that these plants exhibit greater variability in gradation of the coarse fraction of aggregates and this will probably be reflected in mixtures as placed on grade but is not measurable.

While examination of variability of relative density does not indicate increased variability for the multiple plant situation, additional analysis of variance to compare relative density of the three situations shown on Figure 4.9 suggests that relative densities were different for sublots apparently produced by the batch versus the drum plant at 4.9 percent asphalt content.

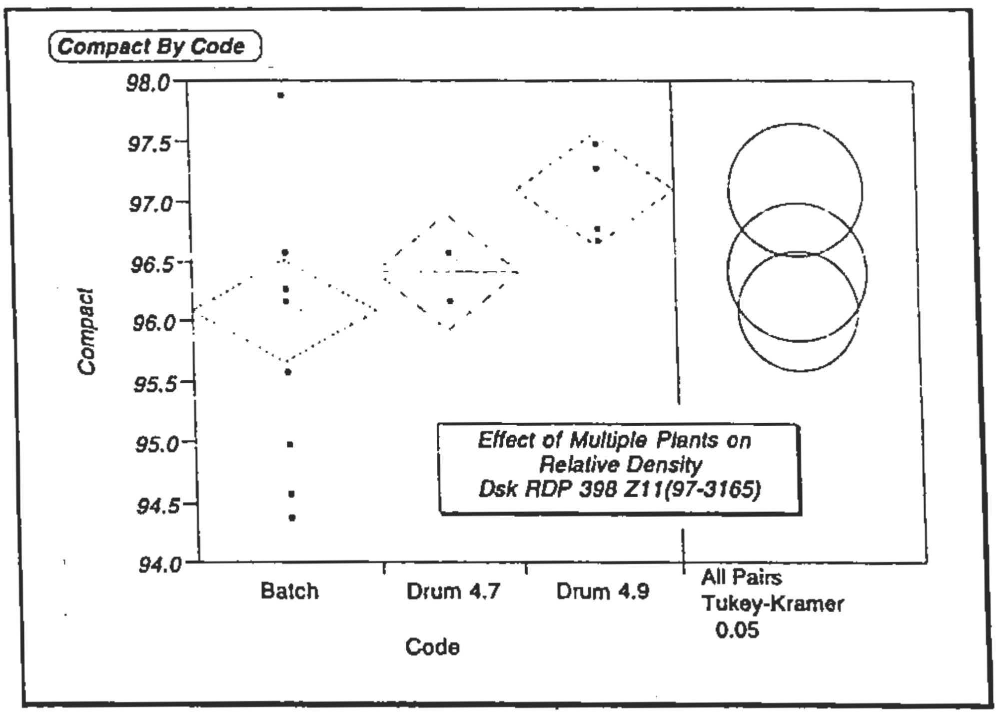

Figure 4.9 Multiple Plant Comparison

A review of dates of production from each of the plants as shown in Table 4.9 indicates that batch and the drum mixer at 4.9 percent asphalt content operated on the same days with approximately the same mix design yet relative densities are significantly different (Figure 4.9).

Data reports are not clear in reporting location of density tests, or which maximum density was used, and if these locations were assigned to each plant. However, these differences, although based on a single sample, suggest that additional study is necessary to determine if procedures to insure density testing from known plant sources should be developed.

Table 4.9 Multiple Plant Operation Dates and Targets

	Batch	Drum - 4.9%	Drum - 4.7%
Operation Dates			
Start	05-April	02-May	13-May
Finish	07-May	13-May	02-June
Targets			
3/4"	100	100	100
3/8"	63	69	69
#4	49	48	48
#8	36	34	34
#30	18	17	17
#200	4	4	4
%AC	4,90	4.90	4.70

4.9 Use of a Single Lot for an Entire Project

Concern over the use of a single lot for the entire project was expressed in Interim Report #1. Several other statistically based specifications use the lot to represent the production of about one day and that this lot is usually subdivided into four sublots. Pay factors are calculated for each lot and payment is made accordingly.

A single lot may cause problems if there are significant delays to paving activities within a project or if the project goes into suspension for the winter. A second problem is that a Contractor could be underpaid for high quality material or overpaid for substandard material. This potential problem was shown in Interim Report #1 using Resample Methods.

Data analyzed thus far indicate that multiple populations exist within a single project. If multiple populations exist due to natural variations of material properties over time, the lot size should be reduced to account for this variation and multiple lots should be used.

Two projects used multiple lots for generation of pay factors and both contained three lots. Results of comparisons between lots for each element used for pay factors is shown in Table 4.10.

Table 4.10 Multiple Lot Projects - Differences in Elements between Lots

Proj	Measure	Difference
	3/4"	NSD*
	3/8"	Lot 1 < 2 and 3
	4	Lot 1 < 2 and 3
1	8	NSD
	30	Lot 1 > 2 and 3
	200	NSD
	%AC	NSD
	Compaction	Lot 1 < 2 and 3
	3/4"	Lot 3 > 1 and 2
	3/8"	Lot 3 > 2 > 1
	4	Lot 3 > 2 > 1
16	8	Lot 3 > 1 and 2
	30	Lot 3 > 1 and 2
	200	Lot 3 > 1 but not 2
	%AC	Lot 1 >> 2 and 3
	Compaction	Lot 1 > 2 but not 3, 3 > 2

*NSD = No Significant Difference

As expected, each project shows some differences between lots, and it appears that relative density, asphalt content, and No. 200 sieve size are responsible for the changes although the specification does not speak to what changes and what extent of changes constitutes a different lot.. This points out that consideration should be made to reconsidering specification definitions of a "lot." Definitions should be established which say what constitutes a change in job mix formula and what is necessary for adoption of new lots.

4.10 Verification Testing

Interim Report #1 expressed the desire for testing split samples to separate out the sampling variance from the testing variance in order to verify the quality control tests. The report also identified that the standard t-test is insensitive to small numbers of samples (low degrees of freedom).

It is beyond the scope of this project to address all questions relative to the effects of multiple populations on verification testing and application of pay factors. But if multiple populations do, indeed, exist within a single lot, and if these populations do affect realistic pay factors (which could be evaluated using Resample Methods), existing verification testing methodology as required by the specification should be examined.

There seems to be some confusion regarding the intent and practicalities of "verification" and associated testing. According to the Code of Federal Regulations, the intent of verification is to validate the quality of material with samples that are taken independently of quality control samples. The need to validate is understood, but some practical issues should be addressed.

In the current QC/QA specification, verification is determined through use of a t-test that compares the mean of the Contractor's quality control data with independent samples obtained by Caltrans. The specification allows Caltrans to sample at a frequency as low as one Caltrans sample to ten Contractor samples.

It is reported that return of verification information from Caltrans has not been immediate. As presented in Interim Report #2, a turn-around time of 2 to 3 weeks was common. For smaller projects (five of the nine projects considered have less than 60 sublots), it is possible that verification results would not be received until after the project is completed. This occurred on at least one of the seventeen projects studied. Unfortunately, if some problem in testing occurs, there is no way to make corrections after the project is complete, which is a disservice to both the Contractor and Caltrans.

Furthermore improper test procedures or calibration problems probably would not be detected until the second verification test. This could mean that two-thirds of the project is complete before this is determined. This points out thc importance of consideration of the requirement for split sample testing with quick test turnaround at least for the early sublots of the project.

A second problem is not with verification testing as such, but with use of the t-test to determine if Contractor testing is acceptable under the concept of partnering and "trust but verify." Because of the relatively small number of samples used for verification (minimum of ten percent of Contractor testing), the risk of incorrectly accepting or rejecting is high. This is illustrated in the following example.

Assume a specification requirement for asphalt content of 5.0 percent plus or minus 0.5 (4.5 to 5.5). Consider 50 asphalt content sublots sampled from a population with mean 5.0 percent and standard deviation 0.20. Contractor sampling and testing could produce an overall mean of 5.0 and standard deviation 0.15 which would have a pay factor of 1.05. As a minimum, Caltrans would obtain five independent samples. For whatever reason, say the verification sample is from a population with mean 5.0 percent and standard deviation 0.4.

If ten sets of samples are compared with the conventional t-test as provided in the specification for verification, seven would verify (and accept the pay factor of 1.05 with data not from the population tested by the Contractor). Three would reject or not verify and, thus, require additional testing, third party testing, etc. This is shown in Table G-1 of Appendix G (page G-2).

If, on the other hand, a conventional analysis of variance were used as shown in Table G-2 and Figure G-1, the conclusion that no significant differences exists would have been made.

4.11 Recommendations

1. Review limits for pay factors.

2. Recommend review of effects of multiple populations within a single lot for pay factor determination and verification. Consider reducing lot size.

3. Recommend replacing the t-test with more robust statistic or methodology for verification.

4. Recommend changing the specification wording to reduce confusion with terms such as upper and lower control limits for specification limits as compared with statistical process control limits.

5. Recommend tracking of materials from multiple plants and set relative density pay factors for each plant.

6. Recommend including specification limits on density to prevent overcompaction.

7. Recommend clarification of the specification with regards to calculations for density pay factors and consider an upper limit based on air voids.

8. Recommend clarification of definition of a lot and what changes in job mix formula constitute addition of another lot to the project.

5. Analyses of Interviews

This chapter summarizes an analysis of interviews of various participants through the implementation, including Caltrans and contractors, from pre-job through on-site and post-job, including:

- A description of the approach used to analyze the interviews,
- An analysis of interviews with training attendees,
- An analysis of interviews with district engineers, resident engineers, and their staff,
- An analysis of interviews with vice presidents, project managers, and quality control managers within construction firms,
- An analysis of interviews with construction firms who bid QC/QA jobs, as well as those who chose not to bid QC/QA jobs.

5.1 Analysis Procedure

At the time of Interim Report #2 (September 30, 1997), some of the projects were incomplete and data collection was still underway. At that time, on-site and post-job interviews were still being finalized. However, all of the interviews associated with training and the bidding processes were completed. In addition, all of the pre-job interviews were complete. Therefore, the analysis of interviews was limited to bidding, training, and pre-job interviews only.

For this final report, all of the interviews, pre-job through post-job have been completed for the seventeen projects of the 1997 season. In addition, direct observation of the implementation process (Caltrans and Contractors) for these projects has also been completed by NCE field engineers. Table 5.1 maps the data sources to the research questions. In this table, an "X" indicates that a particular data source contributes to answering a specific research question.

The research method used in this study requires methods triangulation. Methods triangulation is defined as "checking out the consistency of findings generated by different data collection methods." In other words, to be confident in your findings, you would need to have multiple data sources validate that finding. Findings are strengthened by consistency of findings across types of interviews (pre-job, on-site, post-job, training, and bidding), across interviewee types (Caltrans and contractor), across interviewee levels (Resident Engineer, Construction Engineer, and District Division Chief – Construction on the Caltrans side, and Quality Control Manager, Project Manager, and Vice-President on the contractor side), as well as, across other data sources (document analysis and direct observation).

Results from the various data sources concerning the various research questions have been organized into a number of topic areas including: training, implementation issues, contractor's organization, bidding, and suggestions for improvement. Each of these topic areas is covered in the following sections.

Table 5.1 Data Sources to Address Research Questions - 1997 Projects

Questions \ Data Sources	Document Analysis	Direct Observation	Interview RE (pre job)	Interview RE (post-job)	Contractor (pre-job)	Contractor (on-site)	Contractor (post-job)	QC/QA Project Bidders	QC/QA Project Non-bidders	Interview Task Group	Trainees (post-training)	Trainees (post-job)	Testing Personnel	Interview Trainer	Interview Sub-contractors
#1 Was the product, AC and components, consistently within the specifications?	X	X													
#2 Did the specification work? Can the specification work? Will the specification work?				X			X								
#3 Did the contractor provide suitable quality, accept the responsibility for quality, and use suitable quality control methods to substantiate this?	X	X			X		X								
#4 Was the Contract biddable using these AC specifications?								X	X						
#5 Were the education and training efforts used by Caltrans and industry suitable and effective?	X					X					X	X			
#6 What did Caltrans do that was beneficial?				X			X								
#7 What does Caltrans need to do differently?				X			X								
#8 Was the RE or other staff readily available to address any and all problems arising from the specifications or the process?						X	X								
#9 Was Materials expertise readily available to the RE?			X	X											
#10 What would they do differently or how would they change the specification, manual, or process? Any recommendations for improvements?				X			X						X	X	X
#11 Were there disputes? If so, how were they resolved, and did they cause delays?				X			X								
#12 Were there any problems associated with the pay factors? Did they in fact encourage a better product, lesser product, or have no effect?				X			X								
#13 What literature considerations were utilized or are available for Caltrans' use?	X		X							X					
#14 Was there adequate communication among all participants? Should communication among all participants be more frequent or more open? Should communication among all participants be more timely? Did communication among all participants begin soon enough?				X			X						X		X
#15 Was the contractor's organizational structure designed to keep production and QC as separate functions?		X				X									
#16 What were the problems associated with timely sampling and test methods? Would other procedures or test methods have worked better?				X			X								
#17 What was found to be the usual practice for the contractor's QC organization for subcontracting for specialty testing or inspection?							X								X
#18 Was each subcontractor or testing consultant identified at the beginning of the job, including qualifications/credentials? Was each subcontractor or testing consultant determined to be credible at the conclusion of the job?							X								X
#19 Were there any external influences, (other Agencies?) that created problems or benefits?				X			X								

5.2 Training

The most consistent and significant finding relates to training. The need for training is a key source of agreement across all interview types (Caltrans and contractor; across the various levels of Caltrans and contractor hierarchy; pre-job, on-site, and post job interviews; as well as, interviews of trainees). A significant majority of interviewees believe there is a need for more examples and follow-up training.

This should not be interpreted as a criticism of the orientation sessions provided by Terrie Bressette at the start of the program. Indeed, when asked what Caltrans did that was beneficial to implementation, the most common response was that some training was provided.

Numerous comments were made about the need for training at all levels. The need for training at the highest levels of both Caltrans and contractor organizations was evidenced by the number of "I don't know," "no comment," and "no opinion" in these interviews. Many contractors commented on the lack of support for Caltrans field staff (Resident Engineers (REs) and inspectors) from the Caltrans organization. A strong commitment to learning about the specification is needed for the participants to be supportive of implementation.

In addition, many interviewees commented that it would be beneficial for Caltrans and contractor staff to complete some joint training at the beginning of the project to provide a common understanding of how QC/QA will be implemented on the job. While Caltrans may be hesitant to provide this training for liability reasons, alternatives providing joint training should be explored. A pre-job joint orientation facilitated by an independent third party should be required for discussion of key issues so that the parties can arrive at a common understanding prior to paving.

In the second interim report, a complete analysis of interviews with trainees was provided.
In interviewing trainees, the primary question of interest to Caltrans was "Were the education and training efforts used by Caltrans and the industry suitable and effective?" To answer this question, interviews were conducted with individuals who attended training in District 4 (8 respondents) and District 7 (27 respondents). After analyzing the interview data, it was determined that there were not significant differences between the two districts. Thus, they have been combined in this discussion, and the following paragraphs describe the responses from the 35 total respondents. Every interviewee did not answer every question.

Trainees were asked if the material covered in the Caltrans training session was relevant to the new specification. The majority (91%) felt that the material covered was relevant. Trainees were also asked if material was covered in sufficient depth. Nineteen respondents (61%) indicated that it was covered in sufficient depth, while twelve interviewees (39%) indicated that material was not covered in sufficient depth. In reading the responses to this question, it seemed that the difference of opinion centered on the intent of the session. Those who felt material was covered in sufficient depth generally felt that the intent was an introduction. Those who felt material was not covered in sufficient depth saw the session as the only opportunity to learn about the new specification before doing a job under the new specification since no "formal" follow-up training was scheduled.

Trainees were asked if the new QC/QA specification changes the way they monitor the paving process. Eighteen respondents (52%) indicated that it did change the way they monitor paving processes, while twelve respondents (34%) indicated that it did not change the way they monitor paving processes, and five respondents (14%) did not know if it would change the way they monitor paving operations. The results from this question are disturbing because 48% of the respondents did not have a clear understanding of the fact that the new specification should change the way they monitor the paving process. Only four trainees (12%) gave a clear description of the shift from Caltrans doing quality control to Caltrans doing quality assurance.

Trainees were asked if random sampling was clearly explained. The majority (71%) said that it was, while roughly one-third of them (29%) felt random sampling was not covered in sufficient depth. Unfortunately, when asked HOW random sampling would be used on the job, only eleven people's responses (29%) indicated an understanding of random sampling, and only one of the eleven gave a very clear and detailed response. Another nine trainees' (26%) responses indicated that they knew why random sampling was useful. Five trainees (14%) gave vague and incorrect answers which indicated a lack of understanding of random sampling and the remaining ten trainees (29%) admitted that they didn't know how random sampling would be used on the job.

Trainees were also asked what the objective of the new QC/QA specification was. Figure 5.1 portrays the responses to this question. Several trainees listed more than one objective so the total responses do not add to 35. Overall, the most widely held beliefs about the objective were that it was to shift the responsibility for quality to the contractor and that it was to improve the quality of the product.

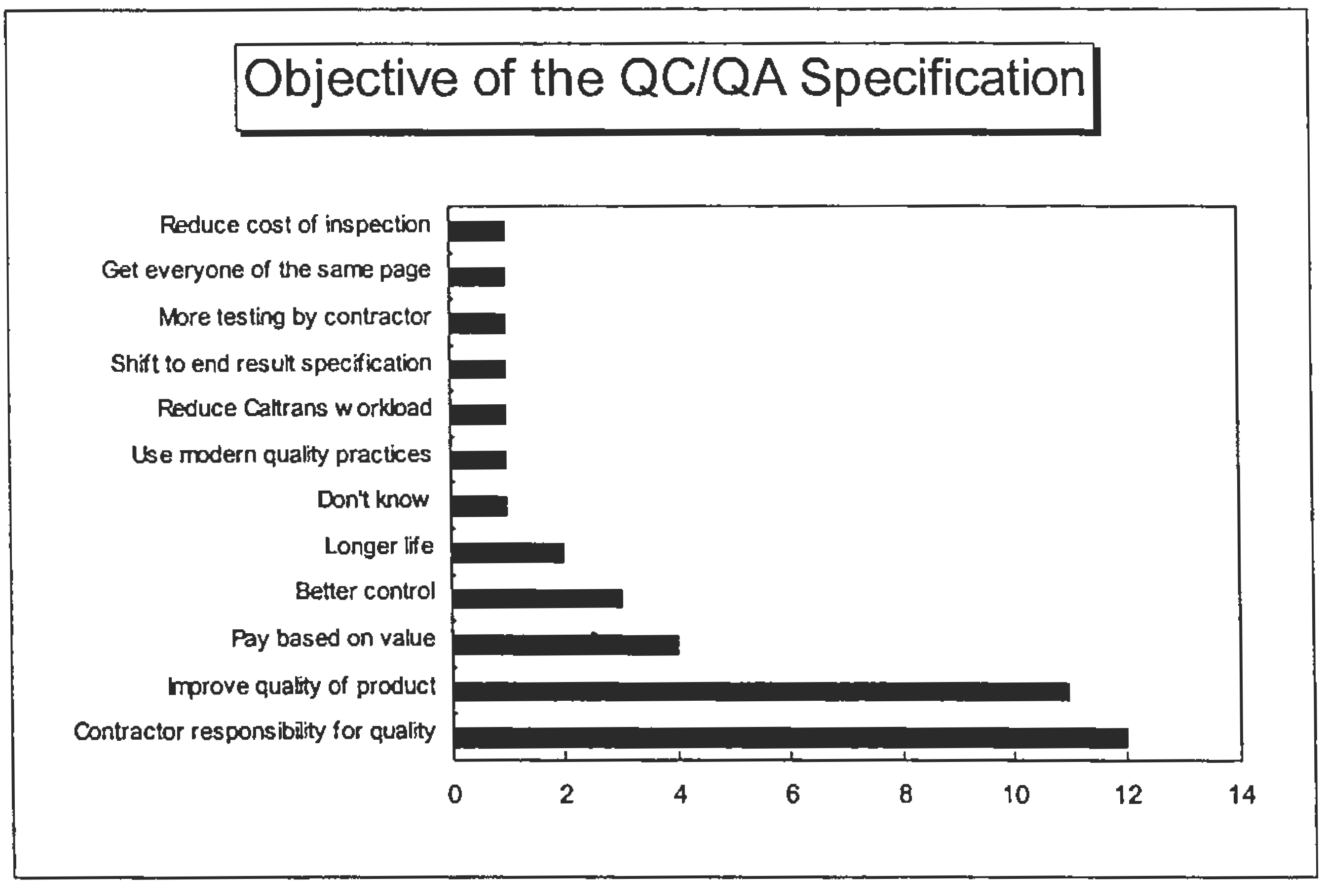

Figure 5.1 Objectives of the QC/QA Specification.

Trainees were asked what other training they have had . Figure 5.2 portrays their responses to this question. As the figure shows, the majority (71%) of the trainees have had no additional training.

Trainees were asked if the appropriate people were trained. Responses to this question were split: 15 people (44%) felt the appropriate people were trained; 14 people (41%) felt the appropriate people were not trained; and 5 people (15%) did not know. On this question, many people answered "yes", but their comments said "no". Therefore, these responses were counted as "no".

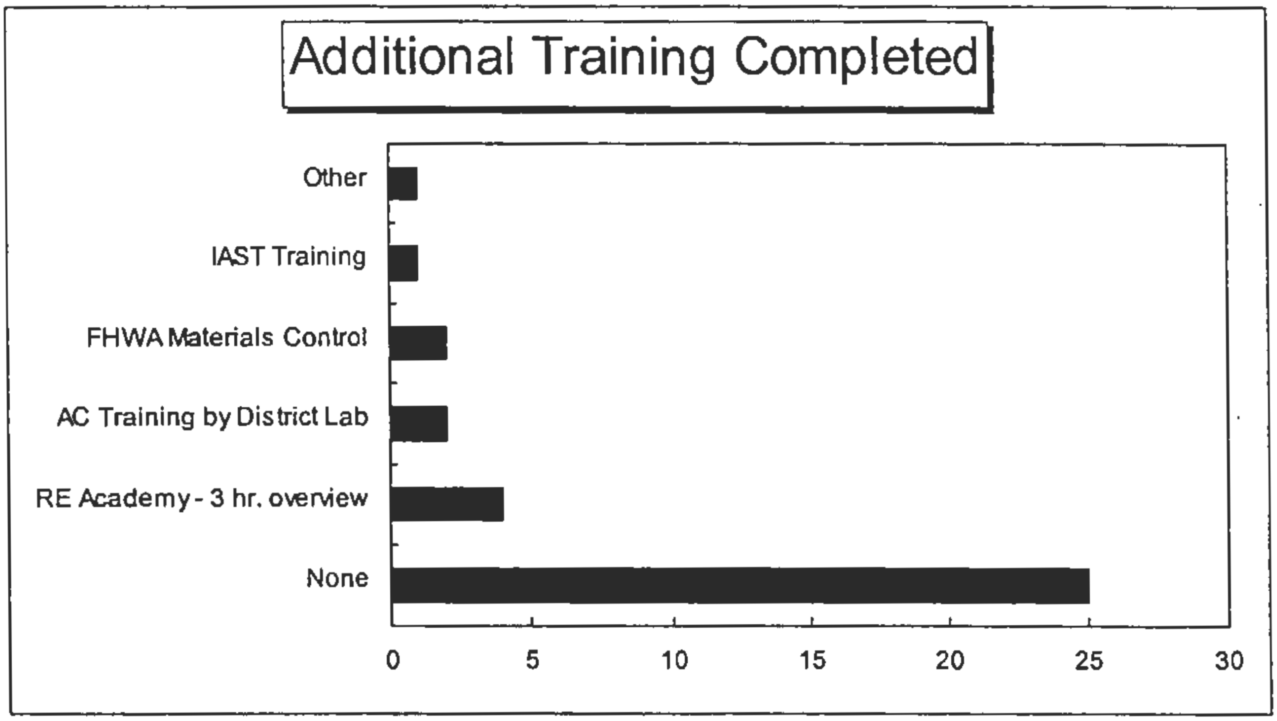

Figure 5.2 Additional Training Completed.

Trainees were asked, "If you had it to do over again, would you attend the training session?" Twenty-four trainees (69%) said they would attend the training session if they had it to do over, while eleven trainees (31%) said they would not attend again. Seven individuals expressed a need for the training to be reiterated after doing a QC/QA job, and five individuals expressed a desire for more detail to be provided in the training. In addition, trainees were asked if they would recommend the training to others. Responses to this question were consistent with the prior question. Twenty-five individuals (76%) would recommend it, and 8 individuals (24%) would not recommend it. One individual expressed a desire for more examples, and as in the previous question, two people requested more detail.

From these observations, it can be concluded that repeated exposure with increasing detail would be beneficial to the attendees. Section 6.2 in Chapter 6 discusses interview responses regarding additional information needed in training.

5.3 Implementation Issues

The second major area of findings in the interviews was in the area of implementation. For the purposes of this report, these findings have been organized into three areas: workability of specification, communication, and dispute resolution. Each area will be discussed in turn.

5.3.1 Workability of Specification

When asked "Can the specification work?" and "Will the specification work?", an overwhelming majority of respondents said yes. Many felt that improvements would need to be made to the specification in order for it to work. They felt that findings from NCE would need to be used to improve the program. Others commented that lessons learned should continue to be captured and incorporated in the future.

While the yes vote to the prior questions was overwhelming, the tone of responses to other interview questions suggested that there was more hesitation on the Caltrans side and that skepticism about the program increased as you traveled higher in the Caltrans organization.

A couple of comments from contractor personnel illustrate their perspective on this issue. One said, "*Our RE is a good RE. He's sometimes reluctant to make a decision, but I think that stems from Caltrans management not backing him.*" Another indicated, "*With the RE and his assistant, we've been able to work pretty well to accomplish the quality control objectives. Caltrans management, above the RE level, hasn't been, in my view, too cooperative. They promote partnering in the specifications and we did a partner session, but Caltrans management didn't really participate. Their idea of partnering stops at the RE level.*" Probably the most surprising comment along these lines was, "*The senior Caltrans administrators almost seemed hopeful to find problems and didn't participate in partnering.*"

5.3.2. Administration of Pay Factors

Pay factors were another key issue with the workability of the specification. A number of the contractor personnel commented that they believed the "bonus should be equal to the penalty." This comment refers to the potential to loss 10% through disincentive, while only having an opportunity to earn a 5% incentive. While many contractors would like the incentive to be raised to 10%, the 10% disincentive may have a greater impact on performance than a 10% incentive.

Interview respondents were consistent in their beliefs that the program's pay system does not allow for a simple method of payment for bonuses or penalties. Several RE's expressed concern over the method and manner of payment for compensation when the pay factor exceeds 1.00. Apparently, this has been handled in the field by adjusting the quantities on the job to account for the pay factor bonus, and either: 1) paying an extra quantity on each estimate, or 2) issuing a lump sum change order to pay the bonus. At that time, there does not seem to be a consistent procedure for handling this problem and no clear direction or example from Headquarters has been made available.

The current method of adjusting quantities to pay bonuses when the pay factor exceeds 1.00 means that the actual quantity of AC placed in the field does not match the quantity of AC paid for. This procedure does not provide a method for auditing actual quantities used in the field. In addition, all or nearly all of the contingency funds in the contract could be used up if a 5 percent bonus is paid, but these funds are typically meant to cover other unexpected costs. One contractor said that he was expecting to receive a bonus, but he did not know when he would receive it because there were no funds left.

The methods and procedures for payment of pay factor bonuses should be revised so that the quantities placed and the quantities paid for are accountable. A formal procedure for making adjustments to asphalt concrete payment (both positive and negative) based on application of pay factors should be developed by Headquarters and distributed. In addition, some consideration should be given to adding an automatic contingency (say 5 percent) to the asphalt cost up front in the contract or at the project design stage.

Many individuals were able to use the program provided by Caltrans, but a few others were unable to do so. The source of the problems seemed to be in the versions of software available, and in computer availability. These issues were voiced by both Caltrans and contractor personnel.

The majority of interview respondents felt that the incentives provided by the pay factors encouraged a better product. However, a handful of respondents made the point that a good contractor will do a good job whether he gets an incentive or not because of pride in doing a good job. The benefit of the pay factor comes from encouraging all contractors to produce a quality product, especially those on the lower end of contractor performance.

Contractor personnel were happy with pay factors and how they were administered. However, as many of them pointed out, they received a bonus. If they had not received bonuses, they thought they might have been more critical of the pay factors. In one instance, a contractor indicated that he was being penalized for something that was beyond his control. It was an issue with the asphalt which was the responsibility of his supplier. **In making the contractor responsible for quality with this new specification, it will be necessary to continue to enforce that the contractor is ultimately responsible for his/her work and the work of all of suppliers and subcontractors.** The contractor is responsible for working with his suppliers and subcontractors to produce a high quality pavement.

Overall, respondents were happy with the weighting factors used to calculate pay factors. However, there were a few specific comments which were noteworthy. These comments are provided in Table 5.2. In addition, interviewees were asked if they felt that the weighting factors accurately reflect pavement performance. Opinions on this issue were clearly split. Some of the comments from contractor personnel are provided in Table 5.3. Individuals who felt that the weighting factors reflected pavement performance did not make detailed comments. Therefore, the comments in Table 5.3 reflect opinions of individuals who felt the weighting factors did not reflect pavement performance.

There also seems to be some issues related to choosing not to report information that will have an impact on the job. For example, when asked if he had experienced any problems with pay factors, one Quality Control Manager replied, "*I did notice that if it falls below a 90% pay factor you're suppose to stop production. One day that should have been done. I don't think you should have to run a whole new test strip for that. I think that is a very negative thing to have in there. Once one thing drops out and they shut everything down, you're running the risk that somebody's going to decide, 'Maybe we shouldn't report that', so that doesn't serve anything at all.*"

Table 5.2 Selected Comments on Weighting Factors in Pay Factor Calculations.

RESIDENT ENGINEER'S COMMENTS:
I think it is fair. I think there should be given some weight to the smoothness of a project. Using a straight edge, we did find some areas that required grinding. I think we had approximately nine or ten locations that were either ground because they did not meet the straight edge requirement or there were areas where we had some coarse aggregate, some segregation on the surface of the mat that we ground. *I think that there should be other factors in there with percent voids, SE and stabilometer. I think the compaction being 40%, may be a little too high.* *The weighting factors are too high on compaction. Need one for voids, sand equivalents, and stability.* *I think that they are about right. If they do look at them, they should think about adding the sand equivalent test and stabilities.* *A little bit too much emphasis is put on the compaction and not enough emphasis is put on the plant. We need to make them more equal. The plant gradations need to receive more weighting in order to assure more conformity and uniformity. We need to put more emphasis on the plant's results. That might not mean longer lasting pavement as much as stronger compaction but compaction was never an issue on this project. The plant gradations; it was hard to keep them in line, always. In three occasions they were out of contract compliance but they were able to continue production and bring them in. If we are able to avoid these problems, I think we would have a better pavement.*
QUALITY CONTROL MANAGERS' COMMENTS:
Less weight for compaction and more weight for gradation. If density is to remain high (i.e. 50%) then clarification should be provided to the contractor that best pay factor will be obtained at 98% relative compaction -- which may not be the highest quality product. *As always the number 30 weighting factor has always been a bear for everybody. I understand why that screen is picked, but I'm not really sure the effect is appropriately applied because of production capability and it has a lot to do with material crushing. This is a very involved thing, it goes into blasting of rock or the mining or washing or the crushing and screening. There are a lot of limitations on production that affect that screen. It's common, regardless of how nice a product they make. So, as far as that goes, I think it should be opened up just a little bit. I understand why that screen is picked but I'm not sure that one is fair. In this particular case, because of this guy's production capabilities, it really hurt him.* *Compaction shouldn't be weighed so heavily either. Because the State has been on a method rolling system for so long, and the fact is that most road failures are not compaction related. Most road failures with a State mix are due to imperfections in the design and I think that the design process that Caltrans uses should be modified and tightened up. They did that a little bit by specifying voids in the mix. That was a giant and important step for them. I've had many mixes that had 6-7% voids in the mix and with a compaction spec of 95. Where are you at? 11% in the mat! I think that's pretty much standard knowledge that when you have over 7 to 8% voids in the compacted mat that you're going to have a shorter life in your roadway. Right now you still have the potential to be a 9% on the roadway. They need to do something else, keep that void in the mix spec. Lets keep that void in the mix spec, let's change what we're trying to do with it. There are other criteria because of the stability requirements now if you want to close something down, over 96%, you have to beat the hell out of it, you're going to damage the mat. So I think they have to concentrate on what they're actually looking for. They're not looking for the right properties, yet compaction is going to be that important.*
PROJECT MANAGER'S COMMENTS:
They weigh too heavily on the density, the higher the density the higher the pay factor, but the higher the density the lower the voids.

Table 5.3 Selected Comments on if Weighting Factors Accurately Reflect Pavement Performance.

QUALITY CONTROL MANAGERS' COMMENTS:
Gradation - I think those could be looked at to see if there's any way you can move the weighting factors around. For example, weighting factors for #30 and #200 are .08 and .1, respectively. Why are these the highest? By these being so highest, does it mean you get better material? By these being low, does it mean you get bad material? They should be able to show, by case history, that if you have low #30 material, you have bad material. I think this project has a good product out there. I think it's going to last them the years that they wanted it to last. Just because we have lost money on the #30 screen, that doesn't mean they got a bad roadway out there. *You need to have some kind of voids.* *I think there should be a little bit more grading.* *Compaction should go down and gradation should go up.* *I don't know. That's tough. I understand why they're measuring what they are but what I'm saying is that if you're going to measure those factors that way then you need to actually have a design that reflects those properties more sincerely.*
PROJECT MANAGERS' COMMENTS:
I think your voids and compaction are the two most important things that you can deal with. And there again, if you run Rices and Marshalls and get rid of the stupid Hveem mix design you'll know what your voids are on a daily basis. *I am not aware of any other factors that should be used. But on some projects, I think they have the profilograph specification, which is smoothness. I think that might be something that should be included.* *I thought they should specify a compaction requirement like they do on the gradings and they should set the compaction at 96% (+/-) where the upper limit would at least the amount of compaction effort you're putting into the mat and maintain some kind of void ratio in the actual mat.* *I think aggregate sand equivalents, gradations, coring, and possibly Marshall stabilities should be considered.*
VICE-PRESIDENTS' COMMENTS:
Well there are certain other things that could affect pavement performance, but these are a good start. You could get in a situation where you have decreased air voids and potential rutting or bleeding that the pay factors don't really address. I think that it would be important in the future to monitor the air voids to make sure that you're staying within a certain range. Like I said, perhaps we should look at monitoring air voids just to make sure that we aren't getting, over compacted mix and reducing the air voids to such an extent that it causes problems with the pavement. I think that factor probably needs to be added to make sure that you don't over compact the mix. *They weight the oil content and the compaction very heavily and I think that those are important parts of the pavement performance. I do have a concern about a test that Caltrans may be thinking about adding to this and that is the stability. I have a real concern for that. Stability is a mix design parameter. Obviously, Caltrans takes stabilities as you make the mix, as do we. We send them out. If Caltrans ever decides to make stability a pay factor item, I think there's going to be a real problem, just based on what I see. We have this very high stability during mix design and we have below the minimum of 37 while we process the material. I don't know why. Personally, I suspect the test. I really think it is a very difficult test to repeat under operational conditions versus lab conditions.* *There is no difference in performance for a pavement with a compaction of 96.5% versus a pavement of 95.5%, yet there is a penalty with a pavement of the latter.*

5.3.3 *Testing and Test Methods*

With respect to testing, test methods must be consistent between Caltrans and contractor organizations. One would expect that variations in testing procedures would lead to differences in test results. Both contractor and Caltrans personnel suggested that a third party lab might be the best approach to insuring valid results and consistent test procedures.

There was considerable agreement between Caltrans and contractor personnel on what tests are most useful for controlling quality. Compaction (23 votes), gradation (22 votes), and asphalt content (20 votes) were the most frequent responses. Table 5.4 detailed responses to a question asking, "Are there any changes in test methods that you would recommend to improve quality?"

When asked what other tests should be added, the contractors were reluctant to suggest any additional testing. However, a few did mention some alternatives, and the REs contributed some as well. They included:

- Sand equivalents (7 responses)
- Stabilities/Stabilometer (4 responses)
- Profilograph (2 responses)
- Volumetric properties (VMA)
- Maximum theoretical specific gravity
- Use Rice's and Marshalls, and get rid of Hveem
- Voids control
- Destructive testing
- Mix temperatures
- Thin lift gauges

Table 5.4 Changes in Test Methods to Improve Quality.

RESIDENT ENGINEERS' COMMENTS:
I think that CTM 375 could be more clear in stating for the engineer's verification test, whose test max density he uses. For example, we initially used the contractor's. 1) We weren't getting ours back fast enough, and 2) I thought we were trying to verify his tests. But, I guess if you think about it, to really verify his tests, we should be doing CTM 375 completely separate from him, which would include coming up with our own test max density. I think that could be clearer in the method or in the QC/QA specification.
They had problems with the test method for splitting this new material and we apparently have problems with test methods between a plant or a lab that prepares mix design and our lab that does verification. I don't know where the problem is because we're getting repeated situations where we get a mix design from an approved lab and it doesn't verify.
The relative compaction is effected by moisture content (binder or water), so increased moisture means increased relative compaction. But voids decrease. So life of pavement is decreased.
Yes. I think that they should change CTM 375 by increasing the minimum percent compaction to 97.5%. The test method for FTMDs needs to be more easily read and understood. Also, the test method for asphalt content by ignition oven needs to be more easily understood. I think they need to put some teeth in the specification to penalize people not following the test methods or cheating the specification.
Yes, probably that when we get two "out-of-compliance" gradations we need to be able to have the ability to immediately increase state sampling for verification and have a formula which gives us a t-critical factor that absorbs the additional sampling instead of making it easier to comply. The way that the t-critical works is that the more numbers the easier it is to comply. It seems like when we have to institute more verification when we have some out-of-spec. gradations that shouldn't make it easier for the gradations to comply with the intent of the QC/QA program.
Add the stabilometer specification.

Table 5.4 (continued) Changes in Test Methods to Improve Quality.

QUALITY CONTROL MANAGERS' COMMENTS:
Without elaborating too much I think that CTM 375, which is in the process of being changed, does need to be changed. I think there is quite a few things in there that if not anything else need to be brought into line with QC/QA. It was used previously just to test pavement, but here they need to reconcile a few things. Probably the mix design procedure should be revised to take into account QC/QA. For example, the old procedure requires a minimum of 4% air voids (4% or more as they call it). QC/QA requires 3 to 5. Now the intent is still to be close to 4% but there is still some interpretation there. Little things might be looked at there (CTM 366 and 367). CTM 304, 308 (compaction of bituminous materials and specific gravity of bituminous materials) should probably be revised for QC/QA. CTM 125 (sampling), which incorporates every material (under the sun, so to speak; you have concrete admixtures, you have water sampling). You have quite a few materials there that you are actually looking at and have to be certified for where here we are only using it for asphalt concrete. That could be, not changed necessarily, but looked at a little differently for certification purposes. *Yes, I think the oil content should be taken from samples at the plant. There is too much probability sample segregation in the field which will lead to an inaccurate oil content test result.* *Probably the biggest issue would be voids. I guess Caltrans doesn't use a Rice test, and they just do all calculated out of theoretical specific gravities. I think there's some problem there, where if they would use the actual test Rice values it'd be more accurate than those calculated out specific gravities.* *Use the same test for verification. If we do it by hand, they should do it by hand. The same test is used for voids, stability and lab test maximum density.* *Yes. Splitting polymer materials.* *There needs to be some changes to the test method for the cook-off oven for the oil content. I don't think that the procedure that they have is correct. I don't think you come up with the correct results.* *Yes, I think the oil content should be taken from samples at the plant.*
PROJECT MANAGERS COMMENTS:
You can eliminate all the testing requirements, with the exception of compaction, and you could do that by coring and doing a Rice gravity on it. And that compared to pounding the Marshalls and checking the nuclear density gage every once in a while. Which is what you do anyway at mix design time. And compare that to the nuclear density gage. Especially when you go to two lift paving. It's ridiculous. I think you can almost go to a method specification. If the ambient temperature doesn't change and the dry gradings are the same, and the oil specific gravity is not going to change a noticeable amount anyway, you're not going to have any problems. I think they should use the nuclear gage to watch the counts only on the job. You can do just like on the airport job that we're doing right now. Take a core in the joint and a core in the mat every five hundred tons and call it good for the day for compaction.

5.3.4 Communication

Overall comments on communication were very positive. Interviewees seemed almost offended by the number of questions that related to communication, since it wasn't a problem from their perspective. The only problems with communication detected through the interviews were conflicts between Caltrans and the contractors. It seemed as though each party was accustomed to the adversarial relationship and didn't know how to change it. Role clarification over time should help this situation. When asked what changes could be made to communication timing to make it more effective, the responses included:

- Time frame for verification results should be improved. (4 responses)
- Daily meeting with the Resident Engineer, Quality Control Manager, Project Manager. (2 responses)
- Weekly project meetings. (2 responses)
- Give RE more authority. (2 responses **from contractors**)
- State staff should have cell phones / pagers. (2 responses)
- Co-training would improve communication.
- More partnering.

5.3.5 Dispute Resolution

Disputes on the projects tended to be informal rather than formal. According to the interviews, disputes that led to delays were primarily related to the test strip. Verification of the test strip was the source of the problem, and the verification was usually tied to getting timely results back from the Caltrans labs.

Based on the interviews, other likely sources of the informal disputes (or disagreements) include role ambiguity due to the change in roles required by the new specification, and issues with loss of control, job security, and lack of trust on the part of Caltrans personnel. These sources are implied by the tone of interviews with Caltrans personnel and by contractor comments.

5.3.6 Resources

As discussed in the previous section, a few of the REs seem to be having difficulty with making the transition to their new role. Their interpretation of the contractor doing quality control is for the contractor to monitor their operation in the same way the RE previously monitored it. Contractors repeatedly commented on the RE not having the support of the Construction Engineer or Caltrans administration. However, it is interesting to note that the same complaints were not consistently voiced by the REs themselves.

Contractor interviews included references to the RE such as "He tried," and "He was doing his best." In many cases, the contractors felt that Caltrans had put the REs in uncomfortable positions by not giving them adequate training and by not giving them the opportunity to become familiar with the specification. With a few exceptions, contractors had very positive things to say about Caltrans' field personnel and about Terrie Bressette.

Suggestions were made that the RE should be more accessible. Suggested solutions included having cell phones or pagers, or being given home phone numbers since the REs were often unreachable when they were needed during paving. The contractors felt that the RE should be as accessible as they are.

There was significant praise of Terrie Bressette. It was clear from both Caltrans and contractor comments that she is well respected and that her contribution is appreciated. However, she is a limited resource. Caltrans expectation of Ms. Bressette to "do it all" creates a bottleneck in the implementation process. Many interviewees suggested that she needed additional support and that her capabilities should be leveraged effectively.

Caltrans and contractor personnel both felt that their inquiries for additional materials expertise were handled effectively. Most sought additional materials expertise from labs (both Caltrans and independent labs), and felt that their questions were successfully addressed. They felt the labs were easy to reach and that materials personnel were helpful.

Unfortunately, comments on materials testing personnel were at the opposite extreme. Complaints about the timeliness of test results (primarily from Caltrans labs, but also from some independent labs) were widespread. This issue was second only to the training issue as a significant opportunity for improvement. Many requested that Caltrans make a commitment to a feasible time frame for returning verification results and to staff their labs accordingly.

The quality assurance portions of the QC/QA specifications indicate that Caltrans is responsible for verification of the Contractor's proposed mix design, verification of the test strip, and routine verification tests for acceptance. These requirements constitute a large commitment in resources (personnel and equipment) on the part of the State to ensure that verification activities are accomplished without undue delay to construction activities.

A key issue that has been noted on approximately 65 percent of the projects is that verification results are not available at the time they are needed to make effective decisions with regard to acceptance. This common problem was noted by resident engineers, Caltrans lab technicians, and many contractors' staff. Some resident engineers expressed concern over Caltrans labs not being able to keep up with the QA testing demands on QC/QA projects. Specifically, determining asphalt content and theoretical maximum densities appeared to be the primary tests in which results were significantly delayed. However, delays were also noted for asphalt binder and aggregate tests. In several of the cases, it took two weeks or more to get QA test results back from Caltrans labs. On one project, there were problems with the asphalt cement supply and QA test results were not available until five weeks *after* the job had been completed.

Other comments from resident engineers indicated a desire for the State to be able to keep up its end of the bargain for quality assurance testing. Many resident engineers feel that Caltrans needs to provide timely test results in the same time frame as that required of the Contractor. In addition, the Contractor has to store split samples for third party testing if a problem should arise. Ultimately, storage space becomes an issue when two to three weeks worth of samples cannot be discarded due to the lack of verification test results.

Caltrans lab technicians have voiced concerns that more resources, specifically additional technicians, are necessary to accommodate all the testing requirements of the QC/QA specification. In one case, overtime was not approved for lab personnel to verify the mix design by the time the test strip was ready to be paved. Consequently, there was a delay in the construction activities solely due to lack of resources for QA testing.

Untimely QA test results were also a major concern for contracting personnel. Similar to the opinions of some resident engineers, QC managers voiced that the specification requirements for timely QC test results should also apply to QA test results. The major concern for the contractor is that untimely QA verification results require the contractor to pave at risk. Stopping construction activities to wait for QA test results is not an option due to the enormous time constraints contractors have during the busy construction season. Therefore, as one Vice President stated, "we are really out on the hook," when QA test results are delayed by two to three weeks.

One option that should be considered is for Caltrans to put in writing what the Contractor can expect for turn-around time for QA testing with contingencies in case of delays. For example, Caltrans has time constraints on how long it can review a concrete mix design. If Caltrans does not fulfill that within the time frame, costs may be incurred by the State. Similar measures could be considered for verification testing. For example, if the State cannot verify the contractor's test results within a reasonable time frame, the specification could indicate what happens next.

Based on the comments above, it appears that additional resources (personnel and equipment) are needed to ensure that verification test results are made available to all parties so that critical decisions can be made in a timely manner. It should be noted that Caltrans has acknowledged the importance of timely QA test results and is in the process of setting up internal performance standards to ensure that this issue is addressed.

5.4 Contractor's Organization

5.4.1 Quality Control versus Production

When asked how they would balance managing quality and paving fast, contractors repeatedly commented that this was not a new issue. They realize they have a responsibility to produce a quality product while maximizing production. The one issue that did come up in these interviews concerned the timeliness of test results, both quality control testing and verification testing. Test methods and procedures which can provide good information in a timely fashion are desperately needed.

In reviewing the interviews, there were a number of comments which highlighted concerns about the contractors' quality control. While a significant majority of interviewees (Caltrans and contractor personnel) felt that random sampling was necessary, in describing the method used to obtain random samples, it was apparent that random sampling was indeed not used. When random numbers are published in the QC Plan, they are not truly random because production can be tailored to the sampling times.

In questions concerning the use of quality control charts, multiple contractors indicated that they were only producing the charts to comply with the specification, and that they were not being used to manage the quality of the pavement. Only the more sophisticated contractors understand the advantage of using the control charts. One contractor said that they were actually still waiting for Caltrans verification results to make changes in lieu of the control charts and since those are slow, they aren't able to make timely changes. Most of the contractors do not understand the benefits of control charts because they have not been trained on the techniques. This is an education issue that can be addressed by training.

Probably the most frightening comments came from a few contractors who said that quality control was not their responsibility that they had sub-contracted it. One contractor even suggested that there was no problem with doing more testing than the specification requires and only reporting the best test results in order to maximize pay factor.

Training should insure that the contractors understand the value of quality control in improving quality and profitability. In addition, if the specification punishes them for reporting honest answers and actual data, good information will not be forth-coming. The current mind-set of "the state will shut us down" must be replaced through training with a more pro-active mind-set in which contractors think the following: "If I have a problem with my results, I have the responsibility to identify the problem and correct it. If I don't identify the problem and correct it, I will be shut down. If I do identify it and correct it, I minimize the negative results." Further, when contractors understand that quality control will improve profitability, even the less responsible contractors will improve quality. This mind-set will evolve with experience. Actions to accelerate this process include emphasis during training and tracking quantified benefits (such as provided in this final report) which should be communicated to contractors.

5.4.2 Subcontractor Relations

Most contractors subcontracted some or all of the testing and about a third of the projects subcontracted some inspection. When asked what role private labs should play, responses indicated they were used for activities such as testing, inspection, reporting, writing the QC Plan, verification, mix design, and quality management. The advantage of using subcontractors was believed to be the ability to supplement expertise and qualifications, as well as the low capital investment required. Disadvantages of using subcontractors included role ambiguity, conflict over test results, and having more to coordinate and control.

Most subcontractors were selected based on prior experience, and were selected prior to bid. The contractors knew their credentials and did not change subcontractors during the project. About half of the subcontractors were asked to make competitive bids, and approximately half of the contractors said low bid was a factor in making their decision. The contractors were pleased with the subcontractors' performance, and there was only one case where the contractor indicated that they would not use that subcontractor's services in the future.

5.5 Bidding

The primary question of interest to Caltrans with respect to bidding is "Was the contract biddable using the QC/QA AC specification?" In order to answer this question, both bidders and non-bidders were interviewed. Thirty-two bidders and twenty-four non-bidders were interviewed. Every interviewee did not answer every question.

Figure 5.3 portrays bidder and non-bidder views on the ability to bid of projects under the new QC/QA specification. As the figure shows, the majority of the respondents felt that the QC/QA projects are biddable. Four of the bidders commented that it was necessary to incorporate a risk factor into bids of QC/QA jobs. One bidder said that he would not bid on another QC/QA job, and another commented that contractors with in-house QC/QA have an advantage on bidding these jobs. A non-bidder commented that using the current specification, very large projects are biddable, but small projects are not biddable.

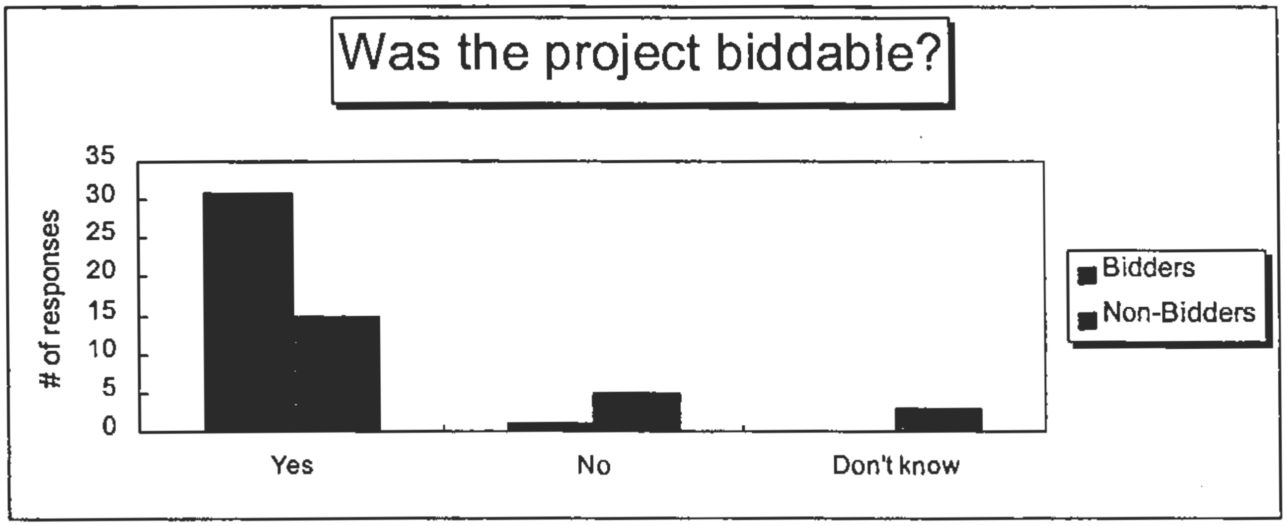

Figure 5.3 Was the project biddable?

Another non-bidder suggested, "They are biddable ... for companies that have a full staff and understand it, but for smaller companies that don't have the staff or understand it, they are not biddable." A non-bidder stated, "We cannot afford the risk." Finally, a non-bidder commented, "I have my doubts about prime contractors doing their own QC/QA - there is too much conflict of interest. It's a case of the fox watching the henhouse. The owner should be responsible for QC and whether they hire a third party lab ... is their business."

Both bidders and non-bidders were asked if they had attended an orientation session prior to making a decision to bid. Responses are shown in Figure 5.4. As shown, most of the interviewees did not attend a Caltrans orientation session prior to bidding or making a decision not to bid.

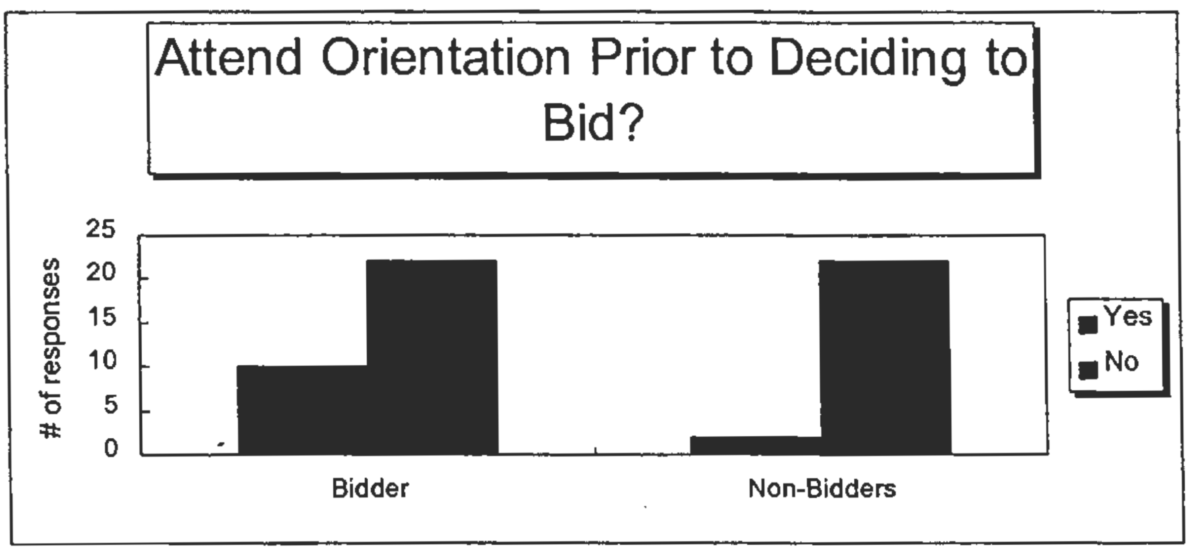

Figure 5.4 Was Orientation Attended Prior to Deciding to Bid?

Non-bidders were asked if the new QC/QA specification impacted their decision not to bid. Figure 5.5 shows that 71% indicated that the QC/QC specification did not impact their decision not to bid. When asked specifically why they did not bid, the responses varied considerably. Figure 5.6 indicates the range of responses which reiterate that the QC/QA specification only kept a few (5 of 24) from bidding.

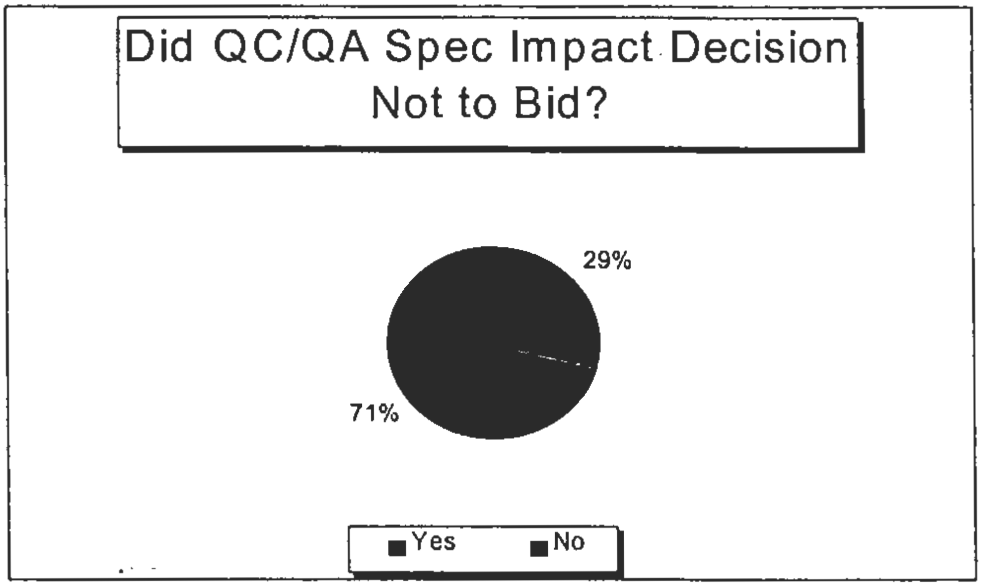

Figure 5.5 Did the QC/QA Specification Impact Decision to Bid?

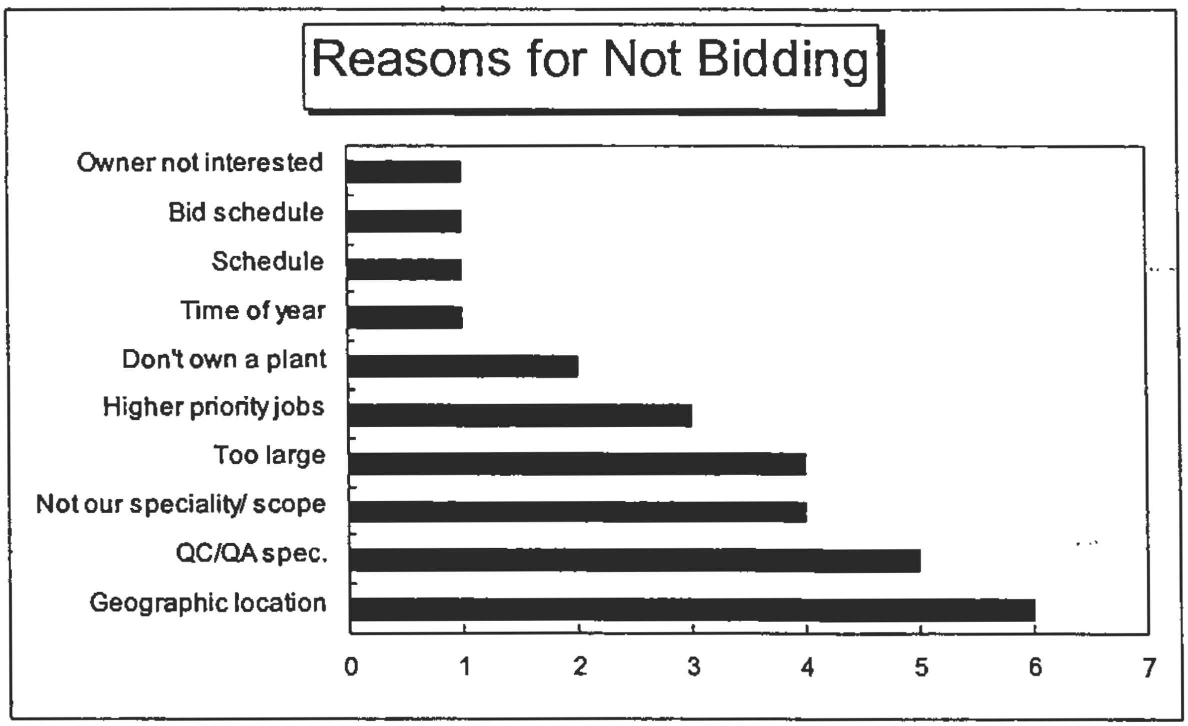

Figure 5.6 Reasons for Not Bidding

Bidders were asked if the QC/QA specification had an impact on their bid for the project. 31 respondents (97%) indicated that it did impact their bids, and 26 respondents (81%) indicated that they increased the bid to include the cost of performing the QC/QA. According to the bidders, the impact on bid prices varied significantly. The impact per ton ranged from $1 to $5.

Bidders were asked if they reviewed the QC/QA specification prior to bidding. Twenty-six of them (81%) indicated that they had reviewed the specification prior to bidding, while five (16%) had not. The final respondent (3%) indicated that the lab had reviewed the specification prior to bidding. Bidders were asked if the QC/QA specification was understandable. Nineteen respondents (59.5%) said that they were understandable, while eleven (34.5%) indicated they were not and two respondents (6%) did not know if they were understandable. One respondent indicated in his comments that the specification was tedious and another commented that the specification was vague.

The bidders were asked if they had sufficient time to prepare their bids. Thirty of them (94%) said that they had sufficient time, while two of them (6%) did not have sufficient time to prepare their bids.

The overall conclusion is that contracts are biddable using the QC/QA AC specification. This conclusion is supported by interviews conducted with both bidders and non-bidders.

5.6 Suggestions for Improvement

Before outlining suggestions for improvement, it is important to establish what went well with implementation so that as changes are made beneficial practices are not eliminated. Responses to the question, "What did Caltrans do that was beneficial to implementation?", are presented in Figure 5.7.

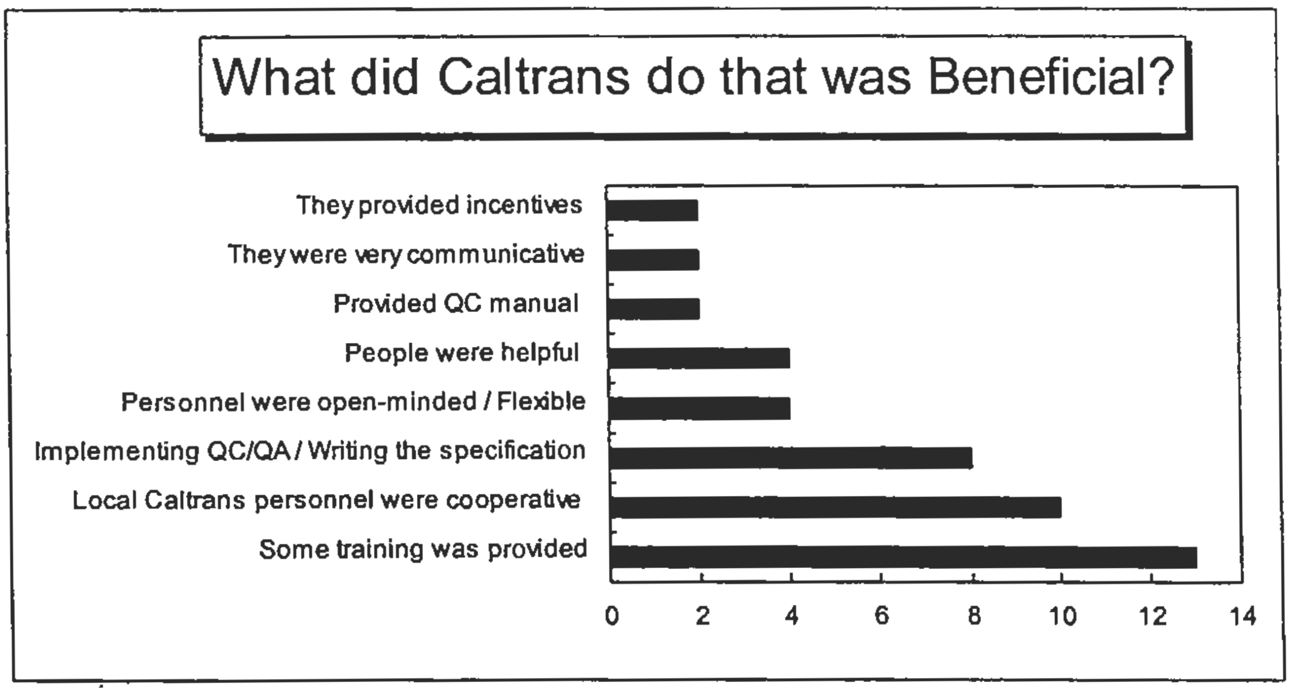

Figure 5.7 What did Caltrans do that was Beneficial?

When asked what needs to be done for the specification to work, the most frequent response was that the specification should be refined, revised, and clarified. The second most frequent response was that more training is needed. A full list of responses is provided in Table 5.5. An interesting observation is that five people felt that the specification should be loosened and five felt that it should be tightened.

Table 5.5 What's Needed for the Specification to Work?

RESPONSE SUMMARY:
Refine / Revise / Clarify specification. (21 responses)
More training is needed. (14 responses)
The State should enforce the specification. (8 responses)
Timely verification testing. (6 responses)
The specification should be flexible / loosen specification. (5 responses)
The specification should be tightened. (5 responses)
Reduce testing frequencies. (3 responses)
Continue independent specification review for improvement. (2 responses)
Simplify specification. (2 responses)
Clarify testing coordination. (2 responses)
Inspection should be done by a third party. (2 responses)
Improve mix design approval process. (2 responses)

When asked what Caltrans did that made it difficult to implement the specification, there was considerable agreement, as seen by the responses summarized in Figure 5.8.

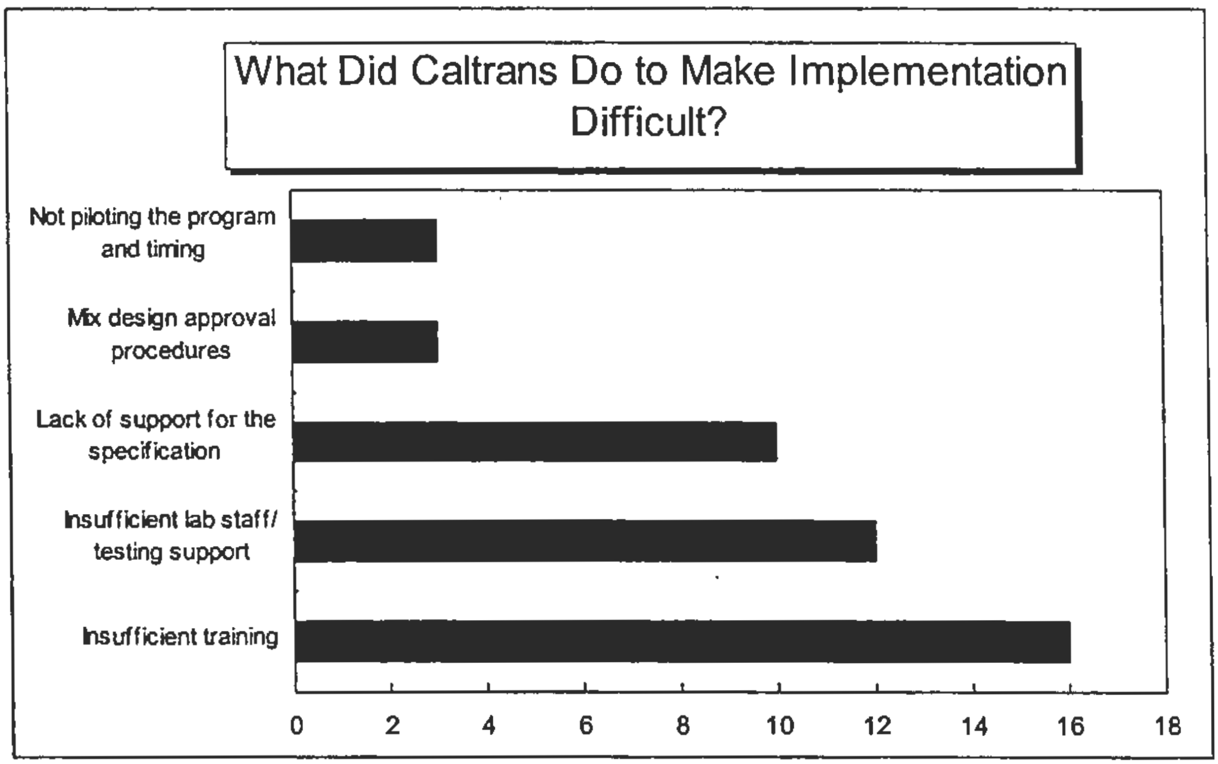

Figure 5.8 What Did Caltrans Do to Make Implementation Difficult?

When asked what Caltrans should have done differently, training was again the overwhelming response. A full listing of responses to this question is found in Figure 5.9. Changes which interviewees would recommend that Caltrans make to the specification are found in Figure 5.10 and recommended changes to the orchid manual are found in Figure 5.11. Finally, Table 5.6 provides a listing of other recommendations from individuals which were not reinforced by multiple comments. This listing is compiled from all of the improvement-oriented questions. The interviewees felt these recommendations were critical, and it is important that these recommendations be heard by Caltrans. Thus, a comprehensive listing is provided.

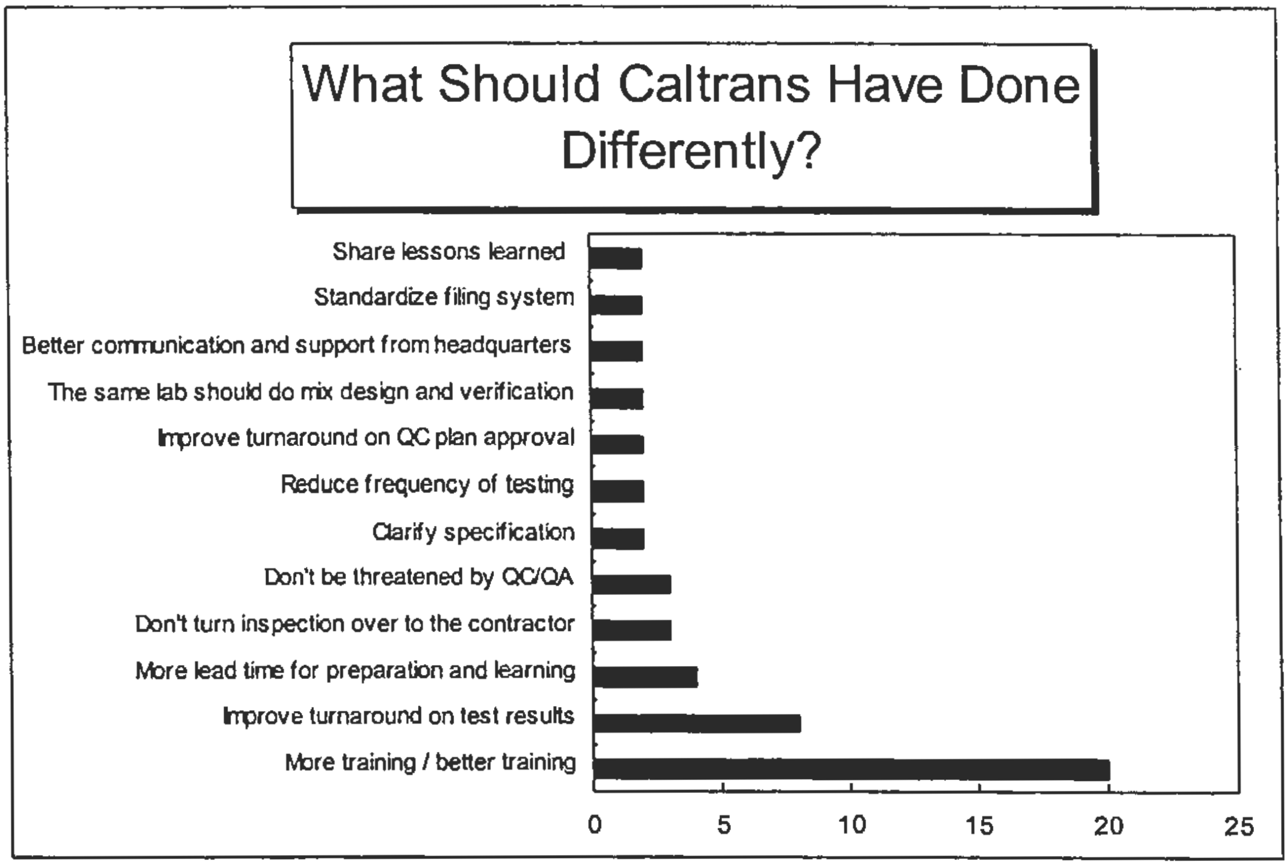

Figure 5.9 What Should Caltrans Have Done Differently?

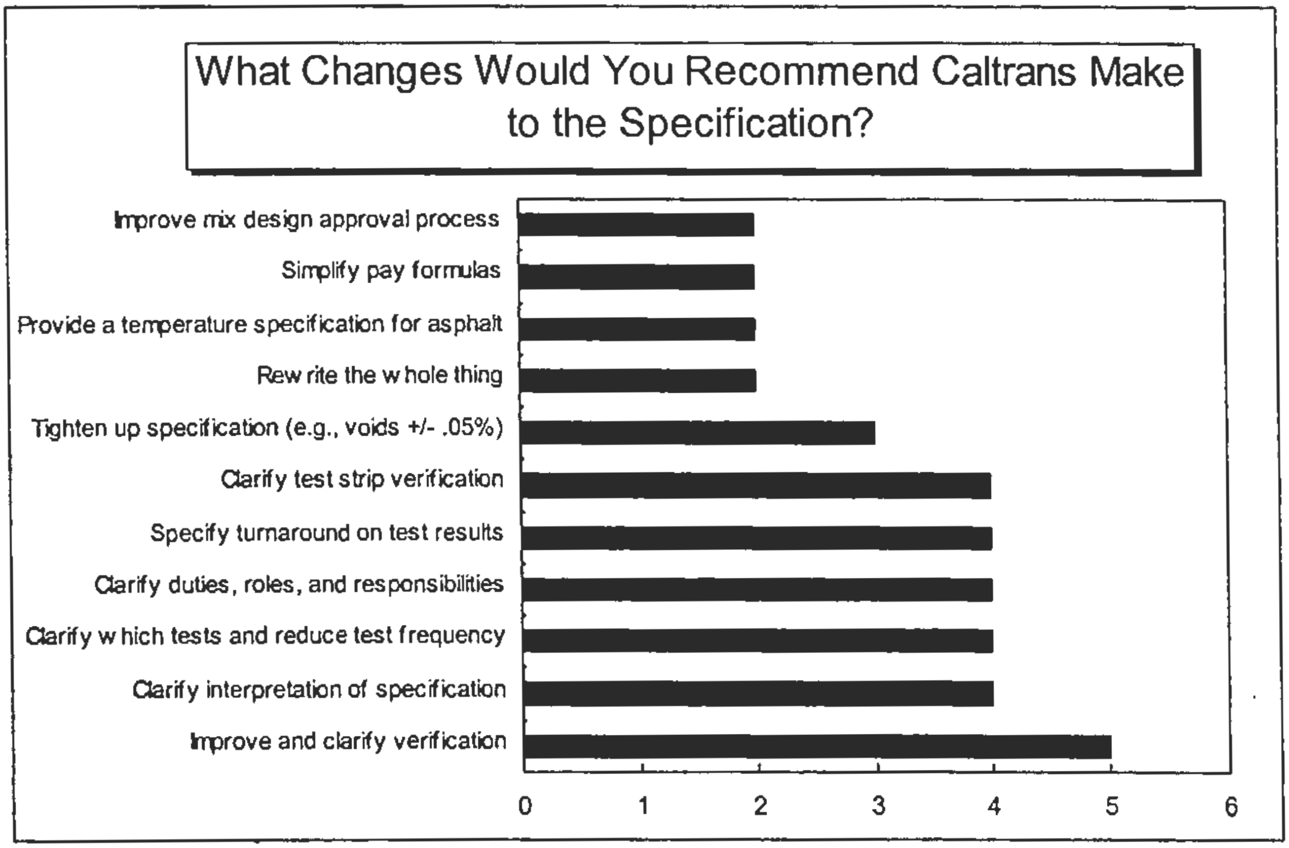

Figure 5.10 What Changes Would You Recommend Caltrans Make to the Specification?

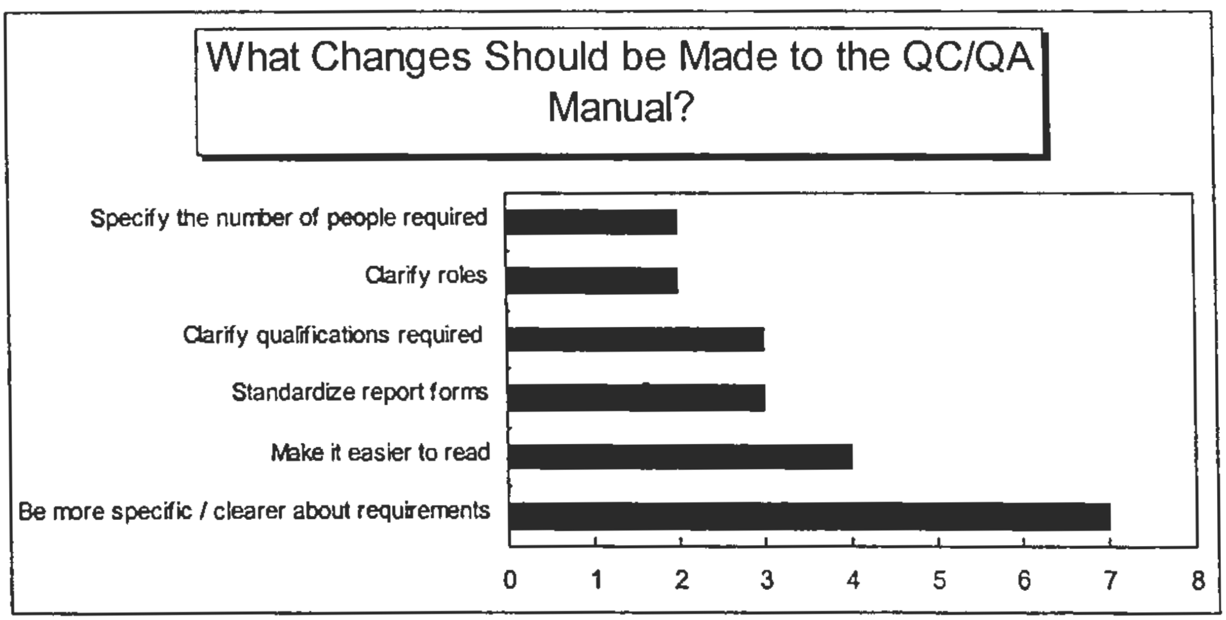

Figure 5.11 What Changes Should be Made to the QC/QA Manual?

Table 5.6 Singular Recommendations that were not Reinforced by Multiple Respondents.

INDIVIDUAL RESPONSE SUMMARY:
Revise "orchid" manual.
It's difficult to locate information in the Orchid Manual.
Use the same lab for mix design and verification testing.
The state should be committed to the effort.
More cooperation is needed.
Separate tester from inspector.
There should be a decertification process.
Proper street inspection is needed.
Constant input is needed from the RE / tester.
Improve communication.
Create a result based specification.
Joint educational session.
Use of thin lift gauge.
Caltrans personnel should support specification.
Improve test strip verification.
Loosen asphalt in mix design verification.
Reduce testing frequency.
The RE should be more involved.
Caltrans should have timely response on QC/QA issues.
Get contractor involved in revising specification.
Offer a non-QC/QA choice based on conditions.
More realistic criteria for using QC/QA.
Compaction requirements should be realistic.
Improve verification process.
Eliminate nuclear density gauge for pay.
Don't duplicate inspectors.
Revise mix design.
Revise test strip.
Revise dispute resolution.
Oil content should be checked at the plant.
The state should be better prepared.
Software problems with pay factor calculations should be corrected.
Clarify what they want.
Don't control information to protect liability.
Improve communication.
The state should support their REs.
Timely turnaround on test results.
Incorporate partnering.
Standardize report forms.
Clarify reporting requirements.
Clarify backup testing requirements.
Clarify test frequency and methods.
Have one lab do all testing.

Table 5.6 (Continued) Singular Recommendations that were not Reinforced by Multiple Respondents.

INDIVIDUAL RESPONSE SUMMARY:
Clarification of FTMD and LTMD.
Improve mix design.
Define AC leveling – pay factor wise.
Commitment to not backing down from contractor.
Give more power to the RE.
A designated third-party lab should run all tests.
Qualifications of the QC inspector should be specified.
Require QC to be done by a subcontractor.
Simplify the specification.
Tighten compaction requirements.
Street inspection should not be done by the contractor.
Standardize process for pay adjustment.
Clear reporting expectations for QC reporting.
QC tester separate form QC inspector.
More training.
Labs must be staffed to handle load.
Standardize procedures for the test strip.
Standardize procedures for daily operation.
Simplify software for statistical evaluation.
Add pay factors for voids, sand equivalents, and stability.
Clarify specification.
Explain the 96% minimum compaction.
QC testers should be separate from production.
CTM 375 is very difficult to follow.

********This Table was not used

Table 5.6 What Should Caltrans have done Differently?

RESPONSE SUMMARY:
More training / better training (20 responses).
Turnaround on test results (8 responses).
More lead time for preparation and learning (4 responses).
Don't turn inspection over to the contractor (3 responses).
Don't be threatened by QC/QA (3 responses).
Clarify specification (2 responses).
Reduce frequency of testing (2 responses).
Turnaround on QC plan approval (2 responses).
The same lab should do mix design and verification (2 responses).
Better communication and support from headquarters (2 responses).
Standardize filing system (2 responses).
Share lessons learned (2 responses).

Table 5.7 What Changes Would You Recommend Caltrans Make to the Specification?

RESPONSE SUMMARY:
Improve and clarify verification (5 responses).
Clarify interpretation of specification (4 responses).
Clarify which tests and reduce test frequency (4 responses).
Clarify duties, roles, and responsibilities (4 responses).
Specify turnaround on test results (4 responses).
Clarify test strip verification (4 responses).
Tighten up specification (e.g., voids +/- .05%) (3 responses).
Rewrite the whole thing (2 responses).
Provide a temperature specification for asphalt (2 responses).
Simplify pay formulas (2 responses).
Improve mix design approval process (2 responses).

Table 5.8 What Changes Should be Made to the Orchid Manual?

RESPONSE SUMMARY:
Be more specific / clearer about requirements (7 responses).
Make it easier to read (4 responses).
Standardize report forms (3 responses).
Clarify qualifications required (3 responses).
Clarify roles (2 responses).
Specify the number of people required (2 responses).

6. Training

This chapter reviews the need for training and discusses example plans for training personnel involved with QC/QA, including:

- A summary of training that was accomplished
- A review of the need for training,
- Interview responses regarding the information needed during the training,
- Types of training needed for various levels of personnel; management, engineers, and technician,
- Suggestions for administration of training programs,
- Recommendations for maintenance of the training programs.

The primary foundation necessary in successfully implementing a new program, such as the new quality management program, is a thorough education and understanding of the program and the specifications. Without the knowledge that is necessary to administer and comply with the specification, good construction practices are more difficult to accomplish. Consequently, the overall performance of the asphalt concrete pavement may not achieve the expectations for which it was designed. Considering these repercussions, a proper training program needs to be initiated to educate all personnel involved in the construction of hot-mix asphalt concrete pavements using the QC/QA specification.

NCE established in Interim Report # 1 that proper training needs to play a very important role in the successful implementation of the QC/QA specification. From the limited data available at the time of Interim Report #1, there was a specific trend among respondents that a level of frustration arose in implementing the specification primarily because of a lack of understanding of the specification, mix design procedures, and California Test Method (CTM) details. There was also confusion in the definition of roles and responsibilities.

6.1 Summary of Training Efforts by Caltrans

In April 1996, immediately following development of the QC/QA specification and after a very short introduction to the paving community at large, Caltrans began implementing the specification on asphalt concrete paving projects with more than 10,000 tons of Type A or Type B asphalt concrete mix. In order to introduce the new QC/QA specification, Caltrans developed different training programs targeted for the following audiences:

- Construction Engineers and Staff (District Level)
- Construction Testers (Lab and Field)
- Contractors and material suppliers

These training sessions were designed to familiarize the participants with the specification and to answer questions regarding implementation.

One and one-half day training sessions were conducted at the district level for resident engineers and testing personnel. During the first construction season (1996), districts with QC/QA projects were included. For 1997 and 1998, all districts were included. Approximately one-half of these sessions were attended by contractors and private testing labs.

In addition to the district training sessions, informational presentations have been made to District Directors and Division Chiefs. Additional presentations and meetings have been held with contractors/producers and industry groups (such as NCAPA and APA).

6.2 Review of Interview Responses

Responses from training session participants from Districts 4 and 7 were presented in Interim Report #2. In support of the conclusions drawn in Interim Report #1, there appears to be a trend that the training may have been insufficient and not detailed enough to provide the participants with the education necessary to administer and adhere to the specification requirements.

Findings from the interviews were presented in Chapter 5. The results indicated that a significant majority of interviewees believe that there is a need for additional training. This finding was consistent across all interview types (Caltrans and contractor; and their levels of hierarchy; pre-job, on-site, and post-job interviews; as well as interviews of trainees). Many contractors commented on the lack of support for Caltrans field staff (Resident Engineers (REs) and inspectors) from the Caltrans organization.

During the interview process, trainees were asked if material was covered in sufficient depth. Nearly 40 percent of the interviewees indicated that material was not covered in sufficient depth. Those who felt material was not covered sufficiently saw the session as the only opportunity to learn about the new specification before doing a job under the new specification. Consequently, they were looking for more than just an introduction.

Therefore, a need exists to provide a training program to educate personnel on the specification, relevant test methods, and roles and responsibilities. In addition, as specifications are modified from year to year and test methods are revised, there also exists a need to provide continuous training to keep all participants up-to-date on current construction practices. The inclusion of this chapter is a direct response to misunderstandings and misinterpretations of the specification, as well as the benefits that can result from a thorough knowledge of the specification and all that it encompasses. The following sections are broad guidelines for a proposed training program.

6.3 Types of Training Needed

As discussed earlier, there is a need for a training program to successfully implement, administer, and comply with the quality management program and QC/QA specification. The next step in the development of a training program is to establish who needs to be trained. In other words, the roles and responsibilities for all personnel, for both quality control and quality assurance, need to be defined. This section focuses on the personnel, for both Caltrans and contractors, that would benefit from training, as well as a general scope of the training that would provide them with the necessary foundation to sufficiently understand and interpret the quality management program and the QC/QA specification. In addition, since Caltrans and contractors need to work together on construction projects, the training should be a formalized cooperative effort between the contracting industry and Caltrans. Therefore, a common language needs to be utilized if Caltrans and contractors are to attend the same training sessions.

During the interview process, trainees were asked what other training they have had. The majority (71%) of the trainees have had no additional training. Trainees were also asked what additional material should be covered in the training. Figure 6.1 displays the responses to this question. As shown in the figure, the most frequently requested change is to include more examples in the training session.

Trainees were asked if the appropriate people were trained. Responses to this question were split: 15 people (44%) felt the appropriate people were trained; 14 people (41%) felt the appropriate people were not trained; and 5 people (15%) did not know. On this question, many people answered "yes", but their comments said "no". Therefore, these responses were counted as "no".

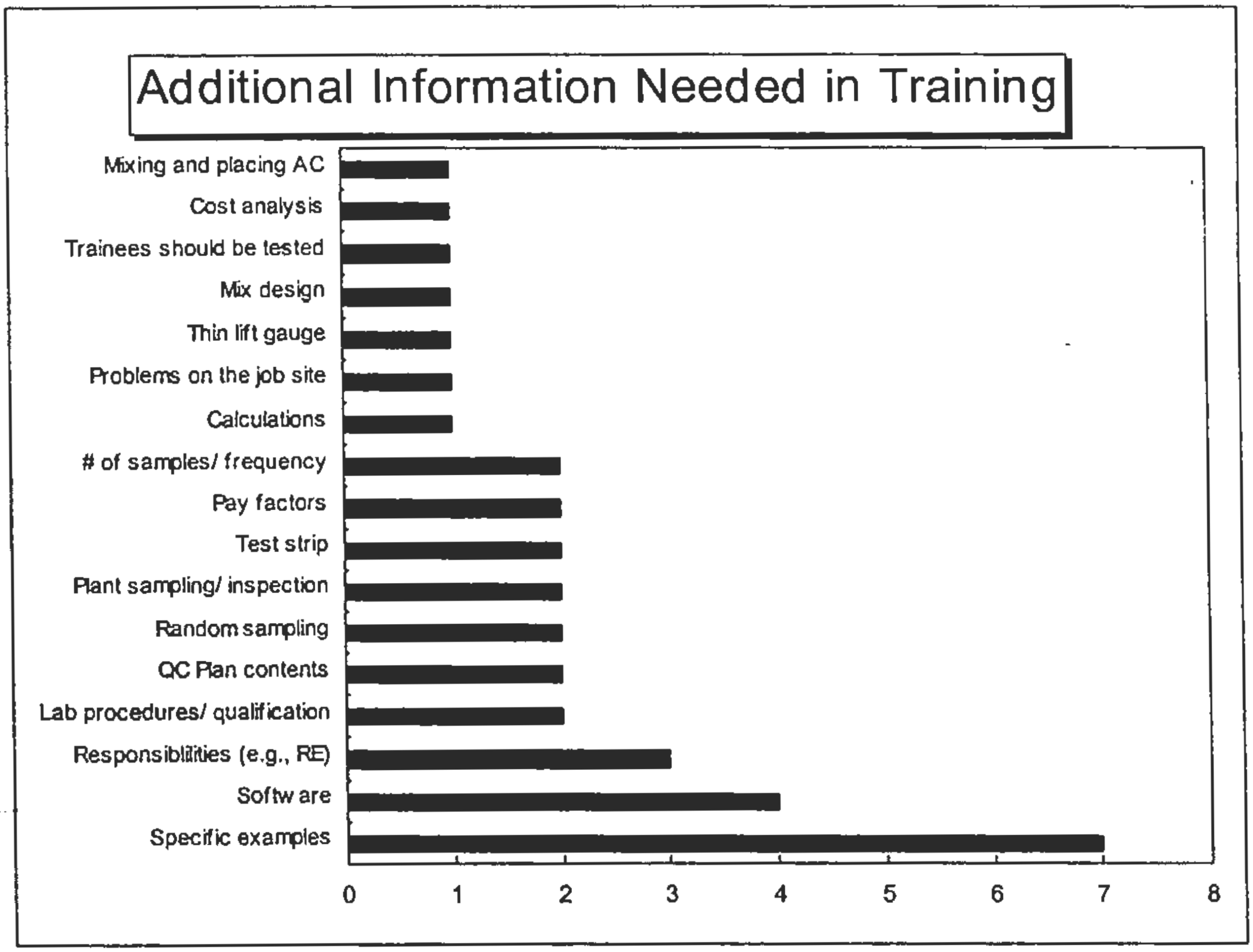

Figure 6.1 Additional Information Needed in Training

This section has been broadly categorized to include three levels of training for: management, engineers, and technicians (testers and inspectors).

6.3.1 Management Level

Training at the management level includes the personnel (both Caltrans and contractor) in charge of directing or controlling projects constructed using the QC/QA specification. Some examples of the personnel who would benefit from this type of training would be project managers, construction engineers, and division chiefs. The training should focus on providing a broad overview of the quality management program, i.e. how the program works. The benefits and the costs of providing quality control and/or quality assurance should be addressed, as well as the impacts of utilizing this type of specification. In addition, the resource requirements for both quality control and quality assurance should be included in the training to provide personnel at the management level the necessary information to appropriately staff QC/QA projects. Other areas deemed appropriate to include in the training at the management level should be added as necessary.

6.3.2 Engineers

Training at the engineering level should focus on the personnel most intimately involved in QC/QA projects, such as resident engineers and quality control managers. The training should focus on how to implement the specification and should provide participants with a technical understanding of the quality management program. This would include mix design procedures, relevant test method details, statistical procedures, and specification requirements. In addition, the interpretation and presentation of data should be addressed, with additional focus on the differences between specification limits and control limits for data tracking. It is also important for personnel at this level to know and understand the differences between quality control and quality assurance. Therefore, training should include defining the responsibilities of quality control and quality assurance, as well as the distinctions between the two.

Part of the training program will need to address the organizational structures of both Caltrans quality assurance and the contractor's quality control. The roles and responsibilities of all personnel working on a project need to be clarified and defined. In addition, the hierarchy of authority needs to be established for both organizations. This would alleviate some of the confusing conditions now existing on construction projects by defining the personnel who are accountable for specific aspects of the construction process. In particular, the organizational structure of the contractor needs to be well defined. This is especially important in understanding the role of the quality control manager and knowing how he/she fits into the contractor's organization. Examples of contractor's organizational structures and the position of the quality control manager were described in Chapter 3.

6.3.3 Technicians (Testers and Inspectors)

Laboratory and field testers are the personnel, for both Caltrans and contractors, who are responsible for the asphalt concrete mix design, sampling and splitting of the asphalt concrete mix, and all the test methods that are necessary to provide quality control and quality assurance. Inspectors are the personnel, for both Caltrans and contractors, that inspect the paving procedures and product to ensure that the material and construction processes are providing the expected outcome of a quality pavement which meets project requirements.

At this point, it is important to stress that there are two distinct needs for this group of personnel: training and certification. Training is necessary to provide participants with a basic understanding of their roles and responsibilities under the QC/QA specification. Certification is necessary to ensure that all testers and inspectors working on QC/QA projects are qualified. The QC/QA specification needs to require certification of testing and inspection personnel in order to ensure future success.

First, with the issue of training for technicians, the focus should be on the roles and responsibilities of testers and inspectors under the QC/QA specification. Technicians need to have a conceptual understanding of how collected data are used. In addition, the general feedback received to date regarding inspectors is that there exists a need to define an inspector's responsibilities and to distinguish the differences between quality control inspection and quality assurance inspection. It is important to note that the general responsibilities remain similar, regardless of quality control or quality assurance; inspectors for both Caltrans and the contractor need to be aware of all the procedures and processes involved in the production and placement of asphalt concrete. The distinction is in the role and/or quantity of inspection.

Quality control inspection is addressed in the specification. In Section 39-3.03 "Quality Control Inspection, Sampling, and Testing," the specification covers the role and responsibilities of a QC inspector. In addition, the specification states that "The Contractor shall provide quality control inspection on the project at all times asphalt concrete paving operations are in progress." Therefore, the contractor must have inspection for materials, plant operations, and placement operations at all times that paving is in progress.

Currently, the QC/QA specification does not address the issue of quality assurance inspection. It addresses sampling and testing, but not inspection. Therefore, the transition to the QC/QA specification has led to questions being raised by Caltrans inspectors, such as: How often is a Caltrans inspector required to be at the plant or the construction site? Is quality assurance inspection 10% of the time, as with quality assurance sampling and testing? What type of authority does a Caltrans inspector have? Can the inspector stop paving or do they have to go through the resident engineer? Does a quality assurance inspector address a paving problem or is that taking control of the contractor's work?

In general, confusion exists regarding the amount of inspection that should be conducted by a quality assurance inspector and the amount of authority a quality assurance inspector has. A training plan needs to be established to address these issues, define the role of a quality assurance inspector, and distinguish the difference between quality control inspection and quality assurance inspection.

Secondly, with the issue of certification, all technicians involved in construction projects using the QC/QA specification need to be certified. The QC/QA specification and quality control plan should both require that testers and inspectors have adequate experience and training and be certified. It is important to note that this is a separate issue from training. The training discussed above would be in addition to a certification program. The training would provide participants with an understanding of the QC/QA specification and requirements. The certification would provide participants with the knowledge of the relevant test methods and certify their qualifications to work on QC/QA projects. By requiring certification, Caltrans would ensure that all technicians working on construction projects using the QC/QA specification are qualified, thus eliminating the current problems which have originated from a lack of knowledge of test methods. In addition, a decertification process should also be included.

6.4 Administration of Training

Once an acceptable training program has been developed, the next step in the incorporation of such a training program is determining who performs the training. Specifically, what group or agency will provide the resources and staff to conduct the training program. In addition, the development and administration of a training program needs to have financial support in order to accomplish the intended goals of educating all relevant personnel involved in asphalt concrete pavement construction There are essentially two different options suggested for the administration and funding of the training program: an industry group or an educational institution. These are discussed in more detail below.

6.4.1 Industry Group/Caltrans Formalized Cooperative Effort

The first option suggested for conducting a training program is using an industry group, such as the Northern California Asphalt Producers Association (NCAPA). The concept behind this option is that Caltrans would sponsor or certify the training by the industry group, making it more advantageous for contractors to attend. If Caltrans did not sponsor the training, there would be no incentive for contractors to attend and thus defeat the purpose. Using this option, both Caltrans and contractors would send the appropriate people to the training program.

Obviously, the benefit of this type of administration is that Caltrans would be released from any liability as they are not conducting the training. However, by sponsoring or certifying the training, they encourage the attendance of the contractors' personnel. Caltrans could also require the attendance of their own employees. Therefore, all construction personnel on an asphalt concrete paving projects could be educated using this option.

The disadvantages of using an industry group is resource availability. Specifically, who would instruct the course? Who would provide the necessary resources and laboratory space? In spite of the obvious benefits of this option, there are also limitations due to available resources.

An example of a situation in which this type of partnering, with an industry group and a department of transportation, succeeded was in Oregon. The industry group, the Asphalt Pavement Association of Oregon (APAO), met with the Oregon Department of Transportation (ODOT) and agreed to develop a training program. APAO administered the training by hiring a third party to develop and teach the course. ODOT provided all laboratory facilities, classrooms, and equipment for the training. APAO waived the fees for ODOT employees as ODOT paid for the training by loaning all facilities. APAO charged the private industry, such as contractors, to provide the funds to cover the remainder of the costs. This is an example of a successful implementation, administration, and funding of a training program using a partnering tactic between a state agency and an industry group.

6.4.2 Educational Institution

The other option for administering a training program would be to have an educational institution conduct the training. Caltrans would pay for the development of the training program and the Local Technical Assistance Program (LTAP) within Caltrans would administer the training. The use of T^2 centers, such as the one at the University of California at Berkeley, would provide the training to employees of Caltrans and contractors. In addition, the program would need to be certified by Caltrans in order to encourage the attendance of the private industry, which would aid in providing additional funds for the training. This option creates many of the same benefits as with having an industry group conduct the course, with Caltrans being relinquished from any liabilities and contractors being encouraged to attend.

6.4.3 Example of a Multiple State Joint Effort Training Program

A unique option potentially available to aid in the administration of a training program is to involve the participation of surrounding states. Several states, including California, could cooperate in incorporating a single program to standardize testing and sampling procedures, inspection, and other aspects of construction, and provide a certification process as well. An example of such a training program, specifically geared toward technicians, is the New England Transportation Technician Certification Program (NETTCP).

NETTCP is the joint effort of six New England states, Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont, in implementing a technician certification program. Working together with the FHWA and the highway industry throughout New England, NETTCP jointly develops training and certification courses that are supported by each of the New England states and are commonly specified by each of them. These courses are in a number of technical areas including hot mix asphalt, Portland cement concrete, and soils/aggregate.

The objectives of the program are to increase the knowledge of laboratory and field testers, reduce problems associated with test results differences, eliminate the issue of reciprocity of having individual state certification programs, and to move forward in standardization of test methods and procedures used by the six New England states.

6.5 Future Outlook

Once a training program has been established and administered, continuous improvement of the program will result from ongoing assessment of its performance and the benefits it is providing to the attendees. The training program needs to be routinely evaluated to determine if the material is being taught correctly and in a format that is understandable and beneficial. The instructors who are teaching the course need to be evaluated as well, to ensure that they are providing the necessary education to attendees in a sufficient manner. In addition, the course material needs to be examined on a regular basis to determine if it is pertinent to current construction practices.

Regular assessments of the training program will identify if the program is accomplishing its mission of educating the appropriate personnel and creating a larger understanding of the quality management program and the QC/QA specification. These assessments will also allow for adjustments to the training program to ensure that the relevant information continues to be taught in an acceptable format.

In addition, since test methods change and specifications are modified from year to year, an established training program should be provided for all the aforementioned personnel on a routine basis. In the cases of testers and inspectors, recertification should be required. Continuous and ongoing training, coupled with certification requirements, will ensure that the proper construction practices will be followed from year to year. Ultimately, asphalt concrete pavements in California will demonstrate the benefits from educated project personnel.

7. Evolution of the Specification

Caltrans began implementing statistical quality assurance (SQA) in their construction specifications for asphalt concrete in April 1996. The new QC/QA asphalt specification was phased in immediately. Rather than beginning with a few pilot projects, all projects after April 1996 with asphalt concrete paving which met the following criteria were to be constructed under the QC/QA specification:

1. Projects with a minimum of 10,000 tons of asphalt concrete,
2. Asphalt concrete is Type A or Type B,
3. Aggregate gradation is ½" or ¾".

As part of this change in construction control methods, Caltrans selected NCE to conduct a third party, independent review of the implementation process and to identify issues and suggest changes. Caltrans has also worked closely with an advisory committee which includes representatives from Caltrans, FHWA, contractors, testing laboratories, and industry groups. Since the time that the specification was first implemented, the specification has evolved each year as Caltrans has incorporated revisions. This process is ongoing and specification revisions for the 1998 construction season were nearly complete as of May 1998. However, no final draft has yer been made available to NCE.

It is important to note that a few of the test methods have been modified as a result of the QC/QA specification. Caltrans Test Method 375, which addresses compaction testing using the nuclear density gage, was revised and is still undergoing extensive revisions. In addition, new test methods have been added to measure maximum density in the field (FTMD) and for measuring asphalt content with the ignition oven.

Caltrans and the Caltrans/Industry advisory group had decided that unless some insurmountable problems arose, the QC/QA specifications would remain unchanged for at least one year in order to provide an opportunity to evaluate the performance of the specifications through the use of a reasonably large number of projects and to ensure that all projects would be using the same specifications.

7.1 1996 Specification Revisions

Following initial implementation in April, there were a few revisions made in the middle of the 1996 construction season. These revisions were mostly to correct typographical errors and clarify certain situations and are noted below:

- A revised version of the specification was issued on June 10, 1996 which corrected some typographical errors for the calculation of lower quality index (Q_L), the calculation of composite pay factor (PF_C), Line 31 of Table 39-1, and the formula for the t-test.

- A draft memorandum was issued on August 1, 1996 which provided guidelines for dealing with multiple plant production units supplying a single paver, sampling for asphalt content and gradations at the plant, use of the thin lift nuclear density gage, mix design verification, and verification testing and payment.

- On September 27, 1996, a contract addendum was added to projects with total asphalt thicknesses less than 60 mm to allow the Contractor to use thin lift backscatter type nuclear gages, provided the Contractor provides a gage for Caltrans to verify the results.

7.2 1997 Specification Revisions

In March 1997, a joint meeting was held with both Caltrans and Contractor representatives who were involved in QC/QA projects in 1996 or were currently on an active QC/QA project. The purpose of the meeting was to listen to the experiences of both parties with the specification, determine what parts of the specification worked and what needed improvement, make suggestions for improvements, and allow participants to exchange experiences among themselves. As a result of the meeting, issues and suggested changes were summarized into three categories:

1. Issues that could and should be addressed immediately
2. Changes that are necessary, but require more background work
3. Desirable changes that require major investigation or changes

Starting in June 1997, the Caltrans/Industry group began work on several items, mostly in the first category. Drafts of the revised specification were prepared and discussed at several committee meetings. A draft final version of Revision 2 to the specification was prepared in January 1998, but was not final as of May 1998, and was not made available to NCE. Some of the changes anticipated in Revision 2 of the specification are[1]

- Clarification of the areas that had been identified as vague or confusing,
- Language that is consistent and deletion of contradictions,
- A definition of "lot" that better reflects the quality received, project staging, and contract administration constraints,
- A better definition of the process and/or purpose of mix design and approval, test strip start-up, verification testing, and dispute resolution,
- Standards for smoothness and pay factors that reflect the addition of smoothness.

Similarly, the QC manual is also being revised to clarify vague or confusing areas, add topics not addressed in the first manual, define qualifications and responsibilities, and provide standard inspection and test forms. Caltrans Test Method 375 is also being modified to accept "thin lift" gages and to provide for engineer quality assurance.

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[1]Development of Quality Control/Quality Assurance Specifications Using Statistical Quality Assurance for Asphalt Concrete Pavements in California, Paper submitted to Transportation Research Board, J. Dobrowalski and T. Bressette, January 1998.

7.3 Other Planned Revisions

Work on the following changes which are "necessary, but require background work"[1] is also underway.

- Addition of new AC materials - e.g. open graded AC, AC base, rubberized AC
- Addition of QC/QA standards and a statistical quality analysis of lime treated aggregate in AC
- Addition of qualities which affect workmanship, e.g. thickness and transitions

The following "desirable changes that require major investigation or changes"[1] are also being addressed.

- A database of test results to analyze specification effectiveness and to relate pay factors to quality
- Exploring the potential for Caltrans and other western states in establishing standard material test standards, common training standards, and certification processes

Future work that Caltrans is planning for changing the specification includes[1].

- Analyzing pay factors to bring them in line with plant and street operating characteristics and making the incentive/discentive represent extended life expectations
- Clarifying and ensuring that the concept of the start up strip is recognized
- Incorporating research that more closely relates material characteristics to extended life
- Establishing more joint Caltrans/Industry training and pre-job training
- Extending QC/QA to all AC types
- Extending QC/QA to bases and subbases so that roadway projects will be completely QC/QA
- Examining extending the principals of quality control, including QC plans and QC mangers to all projects
- Evaluating test methods to determine if it is possible to develop uniform test methods for the Western States
- Establishing a uniform Western States inspection and testing program

8. Other States

In order to provide a frame of reference for comparisons with the California specifications, a brief review of selected QC/QA specifications from other states was accomplished. It should be recognized that analyses of the interviews and the pay factor data were the primary objectives of this project. The review of practices from other states was a relatively low priority, but it was thought that a comparison would provide perspective for a few key issues. The states that were included in the review were New York, Maine, Nevada, Minnesota and Oregon. This is, by no means, a comprehensive list of states that are involved in QC/QA practices. Rather, it serves as a sampling of the various practices being implemented to date.

The primary objectives in this comparison was to study how each specification handles a few key issues as follows:

- Lot size,
- Sampling procedures for QA,
- Pay factor elements, and
- Density testing method.

The results of the comparison are shown in Table 8.1.

In addition, a brief tabulation of other items was made that other states address that are not currently addressed in the Caltrans specification.

- All of the other states reviewed use split sampling for performing quality assurance testing. Independent samples for verification are only obtained if the splits samples show materials are out of specification.
- Nevada includes in the pay factor a sub-factor for ride quality. A ride quality lot is defined as the area of asphalt placed in one production lot. There is no ride quality sub lot.
- Minnesota also has incentive payments for ride quality but it is a flat dollar amount which increases with increased ride quality.
- In Nevada, gradation testing is performed on the residue sample from the ignition oven test. In other words, asphalt content testing and aggregate gradation testing are performed on the same sample.
- Nevada has a QC/QA specification for open-graded mixes.
- Maine includes a provision for small quantity projects. Small quantity projects are those projects that defined as those projects with asphalt quantities less than 1000 metric tonnes.
- New York has begun a QC/QA specification for Superpave mixes. The only element evaluated for the pay factor is percent air voids as determined by the Superpave gyratory compactor. New York has phased the implementation of its QC/QA specification with full implementation to occur by the year 2000.
- In Minnesota, many properties are evaluated during the production and placement process, namely gradation, VMA, asphalt content, air voids, compaction and ride quality. All of these items can contribute to a penalty (payment of less than 100%) if the tests results are sufficiently out of spec, but only compaction and ride quality have incentives attached to them.

Table 8.1 Comparison With Other States.

States	Sublot Size (metric tonnes)	Lot Size	Routine QA Sampling	Pay Factor								Density Testing Method
				Use QC data	Range	Elements						
						Grad-ation	% AC	Com-paction	wc%[2]	% Air Voids	Ride	
California	500	Total job (each mix)	Independent (random)	✓	0.70-1.05	✓	✓	✓				% density (calibrated nuclear gauge)
New York	1125	One day's production	Split sampling (random)	✓	0.85-1.05					✓[3]		Superpave
Maine	400-500	3 or more sublots	Split sampling (random)	✓	0.75-1.05	✓	✓	✓				Rice
Nevada	1000	4 sublots	Split sampling	✓	0.70-1.05	✓	✓	✓			✓	Gmm
Minnesota	1000	One day's production	Split sampling (random)	✓	0.70-1.04[1]			✓			✓[4]	optional[5]
Oregon	1000	Total job (each mix)	Split sampling	✓	0.85-1.05	✓	✓	✓	✓			optional[6]

[1] for compaction only
[2] moisture content
[3] Superpave gyratory compactor
[4] flat dollar amount for each segment of ride quality evaluated
[5] An option exists to use cores or nuclear gauge (correlated at a test strip) so long as one method is used throughout process
[6] A control strip method (rolling pattern) can be used, but only for a maximum pay factor of 1.0. A moving average maximum density method can be used for a maximum pay factor of 1.05.

Appendix A

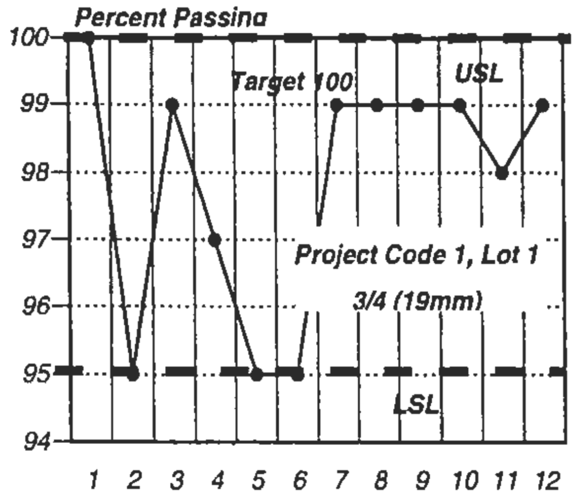
Data and Summaries

Project Code	Pages	Disk Reference	Remarks
1	A-2 - A-9	416 Z11 (98-3202)	3 Lots
2	A-10 - A-14	418 Z11 (98-3204)	
3	A-15 - A-18	420 Z11(98-3206)	
4	A-19 - A-22	422 Z11(98-3208)	
5	A-23 - A-25	424 Z11(98-3210)	
6	A-26 - A-30	426 Z11(98-3212)	
7	A-31 - A-35	428 Z11(98-3214)	
8	A-36 - A-39	430 Z11(98-3216)	
9	A-40 - A-43	432 Z11(98-3218)	
10	A-44 - A-46	434 Z11(98-3220)	
11	A-47 - A-50	436 Z11(98-3222)	
12	A-51 - A-54	438 Z11(98-3224)	
13	A-55 - A-57	440 Z11 (98-3226)	
14	A-58 - A-60	442 Z11(98-3228)	
16	A-61 - A-68	446 Z11(98-3232)	3 Lots
17	A-69 - A-72	448 Z11(98-3234)	

Code >	Project Code 1. Lot 1							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
1	100	61	46	37	22	5.0	4.00	96.2
2	95	63	40	34	22	5.0	4.85	94.4
3	99	66	42	36	23	5.0	4.78	94.6
4	97	68	44	35	21	5.0	4.70	95.0
5	95	64	43	34	21	5.0	4.79	95.6
6	95	67	44	37	21	5.0	4.44	96.3
7	99	69	45	35	22	5.0	4.85	96.6
8	99	69	42	36	22	5.0	4.84	96.2
9	99	69	44	34	22	5.0	5.07	96.2
10	99	68	46	36	22	4.0	4.55	96.2
11	98	66	43	35	22	5.0	5.16	97.9
12	99	69	44	34	22	2.0	4.84	97.9
Count	12	12	12	12	12	12	12.00	12
Max	100.0	69.0	46.0	37.0	23.0	5.0	5.16	97.9
Min	95.0	61.0	40.0	34.0	21.0	2.0	4.00	94.4
Range	5	8	6	3	2	3.0	1.16	4
Mean	97.8	66.6	43.6	35.3	21.8	4.67	4.74	96.09
Std. Dev.	1.85	2.68	1.73	1.14	0.58	0.888	0.30	1.104

Code >	Project Code 1. Lot 2							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
20	99	67	48	35	19	4.0	4.98	96.8
21	98	68	48	35	19	5.0	5.08	96.8
22	97	64	45	33	18	5.0	4.81	96.7
23	97	68	46	31	14	4.0	4.97	96.7
24	96	69	50	36	20	5.0	4.89	96.7
25	99	73	52	36	18	5.0	4.93	97.3
26	99	66	48	36	20	5.0	5.07	97.5
27	98	67	47	31	16	4.0	5.17	97.5
28	97	67	45	33	18	5.0	5.05	97.5
29	99	69	53	40	22	5.0	5.10	97.5
30	97	65	50	35	19	5.0	5.02	97.5
Count	11	11	11	11	11	11	11	11
Max	99.0	73.0	53.0	40.0	22.0	5.0	5.2	97.5
Min	96.0	64.0	45.0	31.0	14.0	4.0	4.8	96.7
Range	3	9	8	9	8	1.0	0	1
Mean	97.8	67.5	48.4	34.6	18.5	4.73	5.01	97.14
Std. Dev.	1.08	2.38	2.66	2.58	2.11	0.467	0.103	0.385

Code >	Project Code 1. Lot 3							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
13	97	64	42	32	17	4.0	4.65	97.0
14	99	72	53	38	20	5.0	4.66	97.0
15	99	71	53	37	19	5.0	5.01	97.0
16	97	72	55	38	19	5.0	4.80	97.0
17	98	71	55	37	18	4.0	4.66	96.7
18	97	72	55	39	21	6.0	4.79	96.6
19	97	73	55	39	21	6.0	4.72	96.6
20	97	66	48	35	20	5.0	4.65	96.6
21	98	69	51	36	18	5.0	4.72	98.8
22	98	70	49	37	20	5.0	4.85	97.9
23	98	69	49	34	18	5.0	4.58	97.6
24	98	74	50	36	20	5.0	4.79	98.7
25	99	73	54	39	21	6.0	4.56	97.0
26	97	73	53	37	20	5.0	4.48	97.7
27	97	72	52	38	21	5.0	4.54	96.8
28	97	67	48	34	16	4.0	4.52	96.6
29	97	68	49	37	20	5.0	4.69	96.9
30	98	73	54	38	21	5.0	4.55	97.4
31	99	72	54	41	22	6.0	4.45	97.5
Count	19	19	19	19	19	19	19	19
Max	99.0	74.0	55.0	41.0	22.0	6.0	5.0	98.8
Min	97.0	64.0	42.0	32.0	16.0	4.0	4.5	96.6
Range	2	10	13	9	6	2.0	1	2
Mean	97.7	70.6	51.5	36.9	19.6	5.05	4.67	97.23
Std. Dev.	0.81	2.73	3.42	2.12	1.57	0.621	0.141	0.665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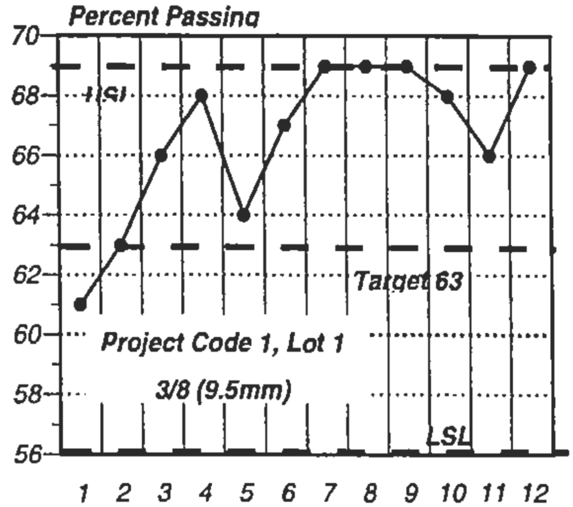
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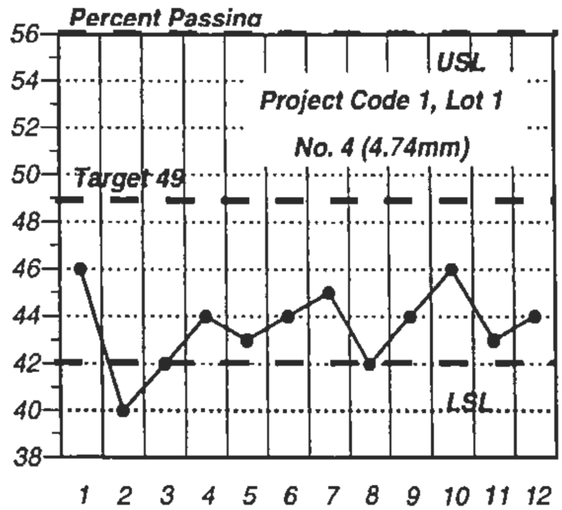
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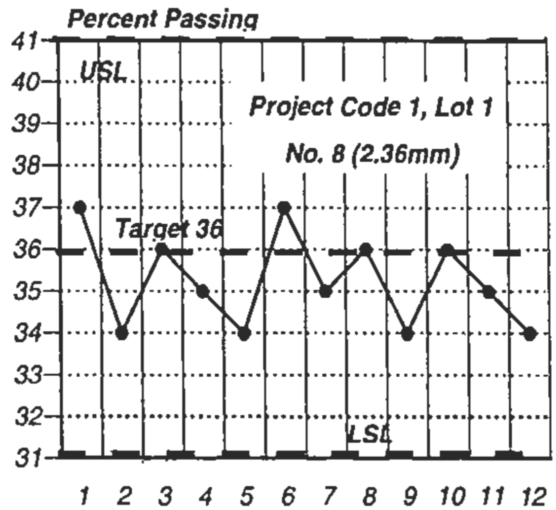
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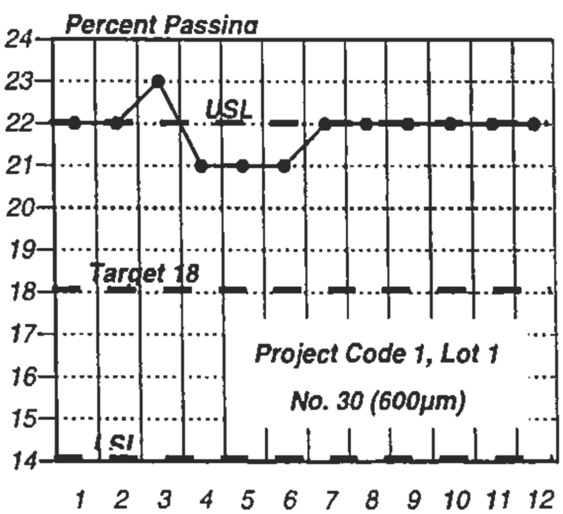
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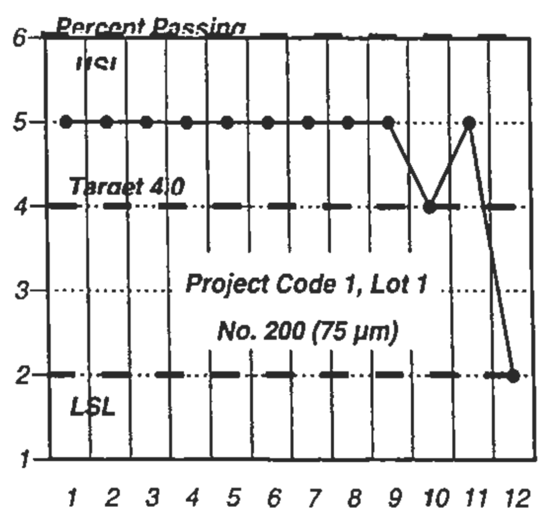
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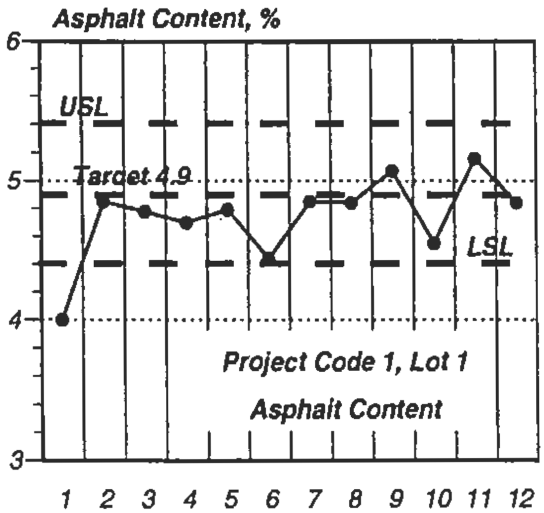
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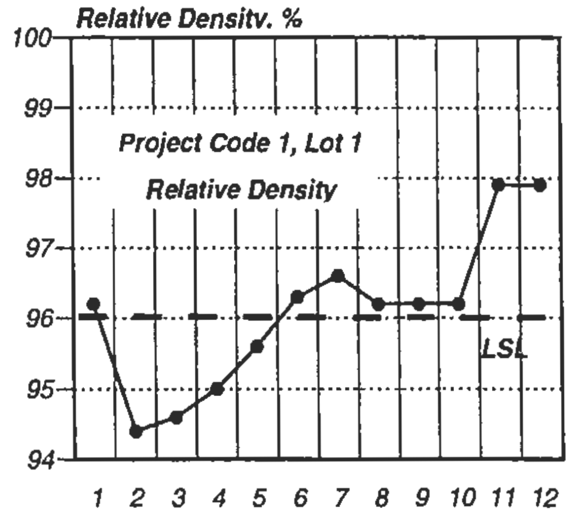
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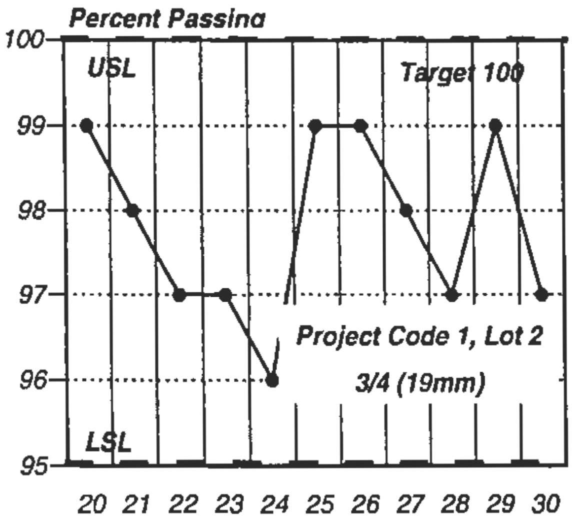
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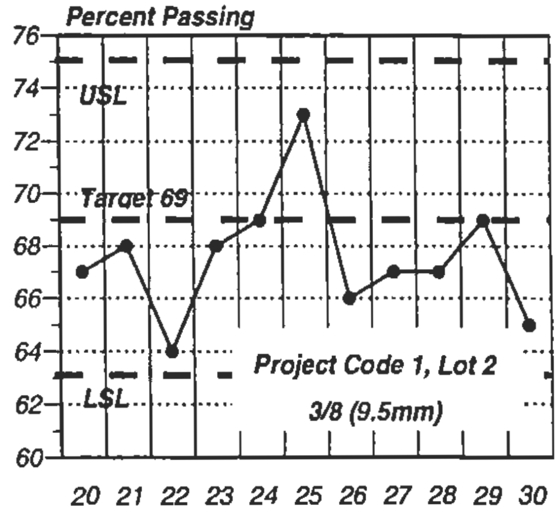
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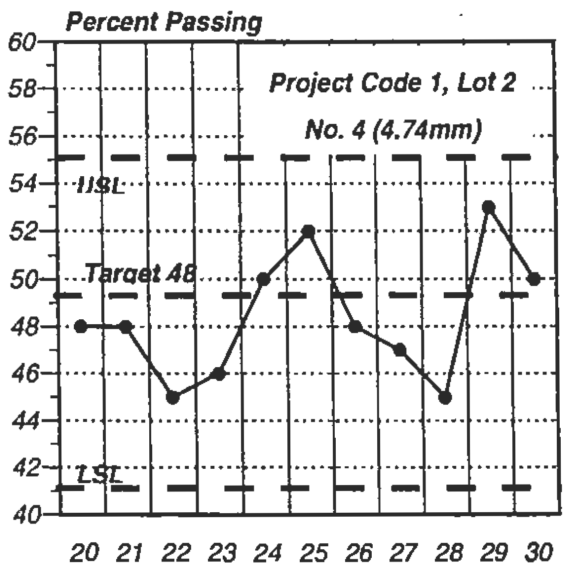
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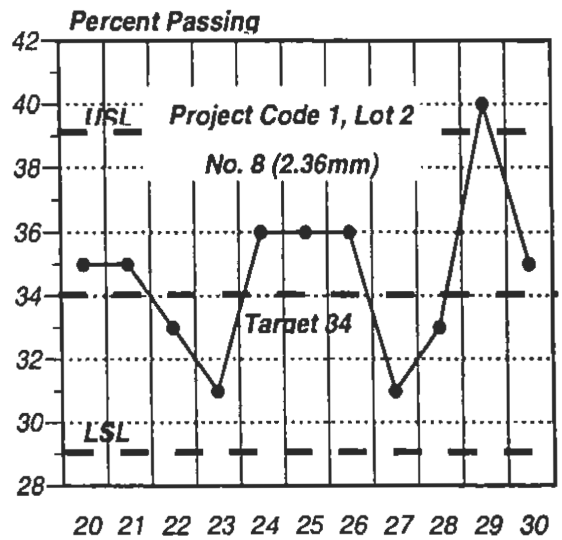
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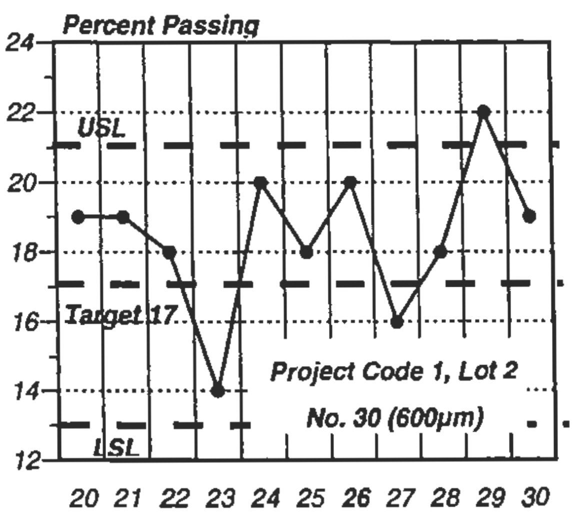
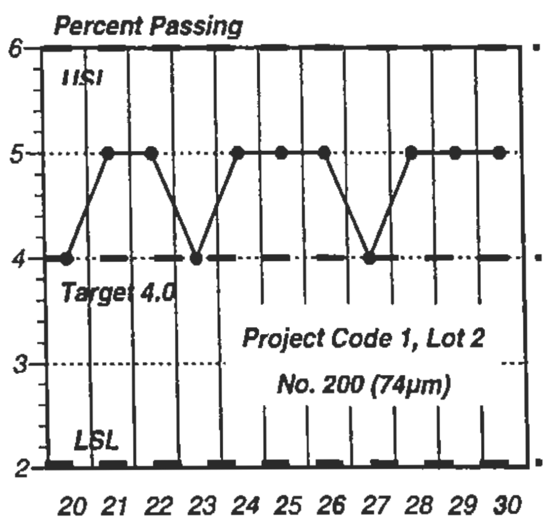
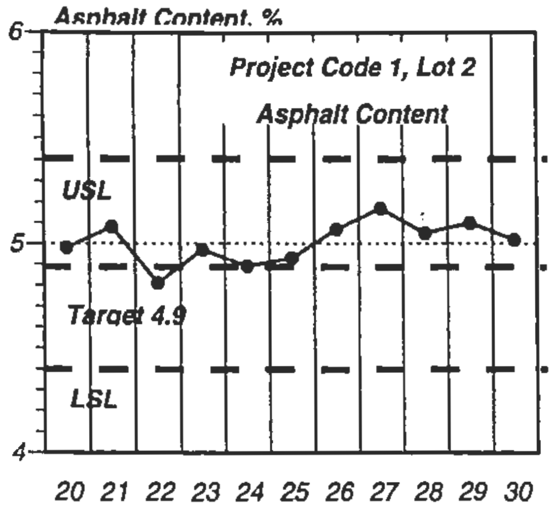
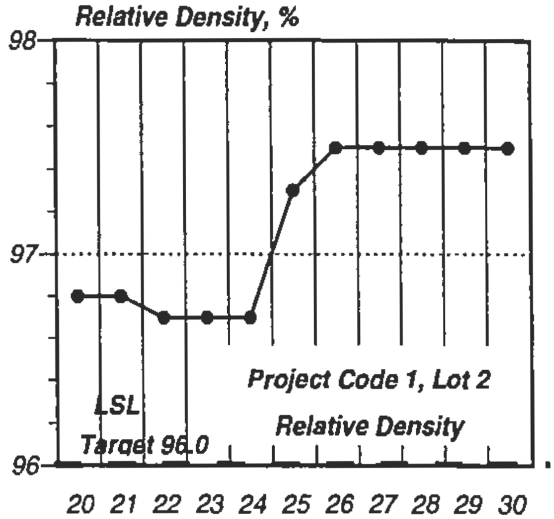
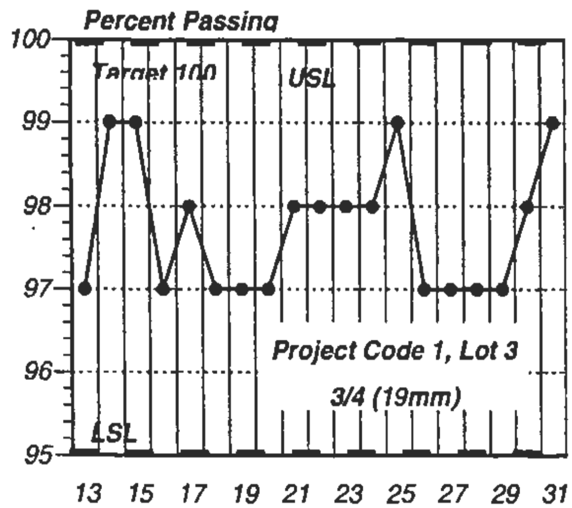
28
20 21 22 23 24 25 26 27 28 29 30

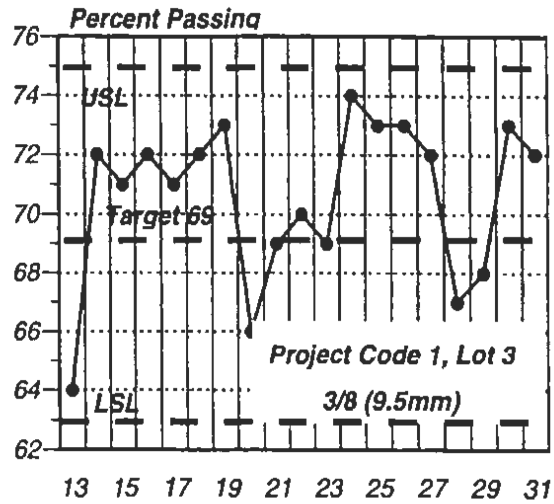

Percent Passing
USL
Target 17
Project Code 1, Lot 2
No. 30 (600µm)
LSL
24
22
20
18
16
14
12
20 21 22 23 24 25 26 27 28 29 30

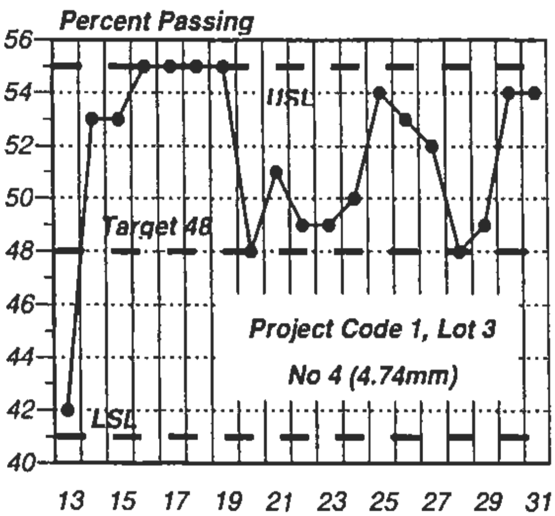

Percent Passing
USL
Target 4.0
Project Code 1, Lot 2
No. 200 (74µm)
LSL
6
5
4
3
2
20 21 22 23 24 25 26 27 28 29 30

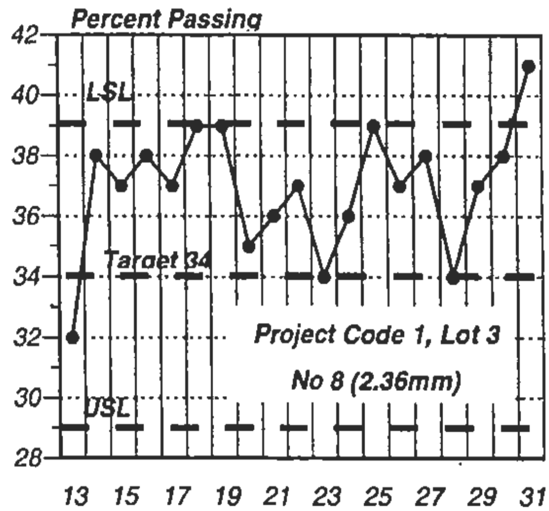

Asphalt Content, %
Project Code 1, Lot 2
Asphalt Content
USL
Target 4.9
LSL
6
5
4
20 21 22 23 24 25 26 27 28 29 30

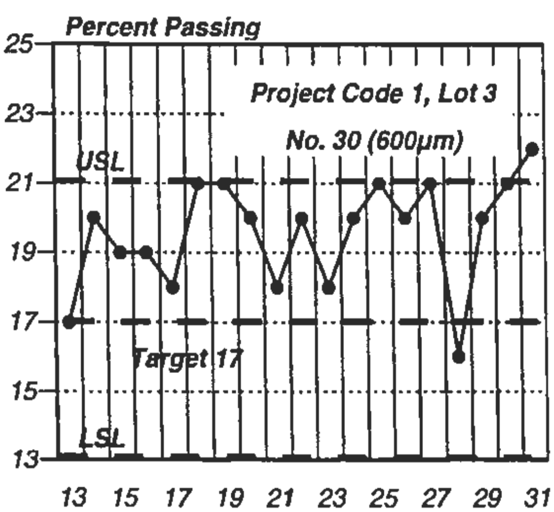

Relative Density, %
Project Code 1, Lot 2
Relative Density
LSL
Target 96.0
98
97
96
20 21 22 23 24 25 26 27 28 29 30

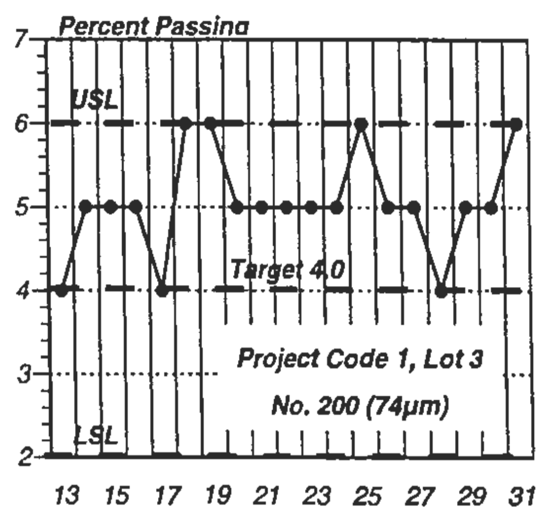

Percent Passing
Target 100
USL
LSL
Project Code 1, Lot 3
3/4 (19mm)
100
99
98
97
96
95
13 15 17 19 21 23 25 27 29 31

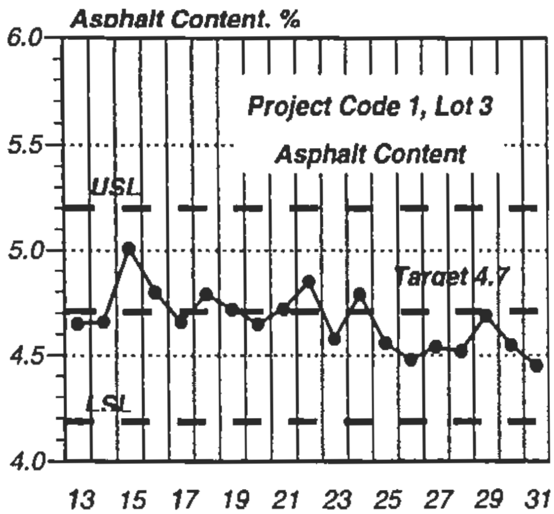

Percent Passing
USL
Target 69
LSL
Project Code 1, Lot 3
3/8 (9.5mm)
76
74
72
70
68
66
64
62
13 15 17 19 21 23 25 27 29 31

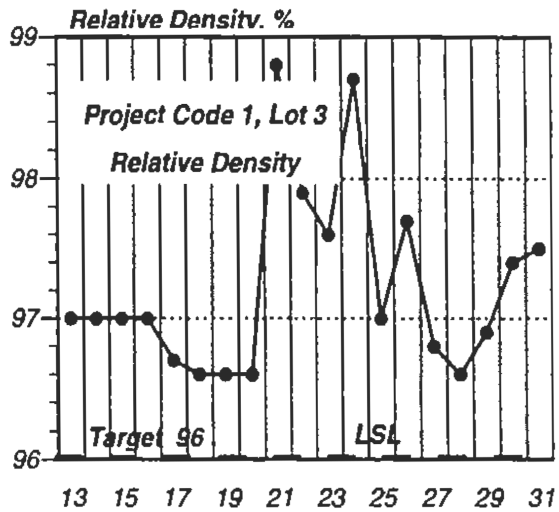

Percent Passing
USL
Target 48
LSL
Project Code 1, Lot 3
No 4 (4.74mm)
56
54
52
50
48
46
44
42
40
13 15 17 19 21 23 25 27 29 31


Percent Passing
LSL
Target 34
USL
Project Code 1, Lot 3
No 8 (2.36mm)
42
40
38
36
34
32
30
28
13 15 17 19 21 23 25 27 29 31


Percent Passing
Project Code 1, Lot 3
No. 30 (600µm)
USL
Target 17
LSL
25
23
21
19
17
15
13
13 15 17 19 21 23 25 27 29 31


Percent Passing
USL
Target 4.0
Project Code 1, Lot 3
No. 200 (74µm)
LSL
7
6
5
4
3
2
13 15 17 19 21 23 25 27 29 31

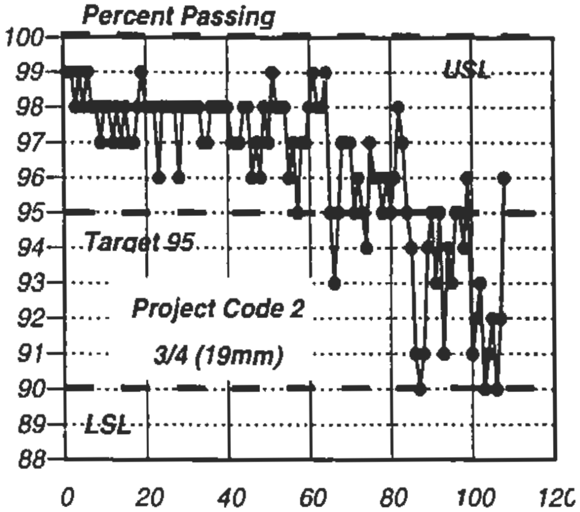

Asphalt Content, %
6.0
5.5
5.0
4.5
4.0
Project Code 1, Lot 3
Asphalt Content
USL
Target 4.7
LSL
13 15 17 19 21 23 25 27 29 31

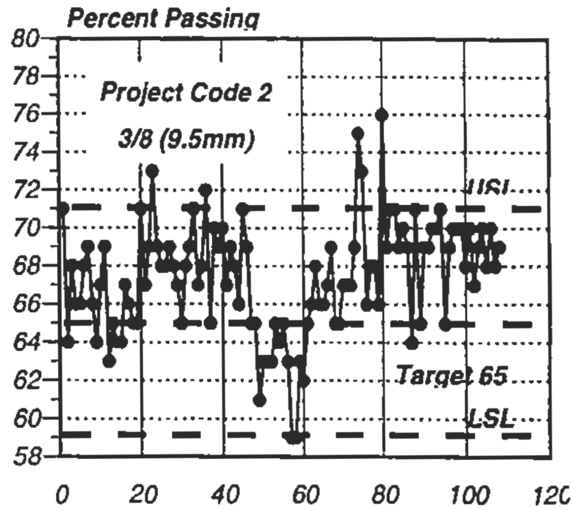

Relative Density, %
99
98
97
96
Project Code 1, Lot 3
Relative Density
Target 96
LSL
13 15 17 19 21 23 25 27 29 31

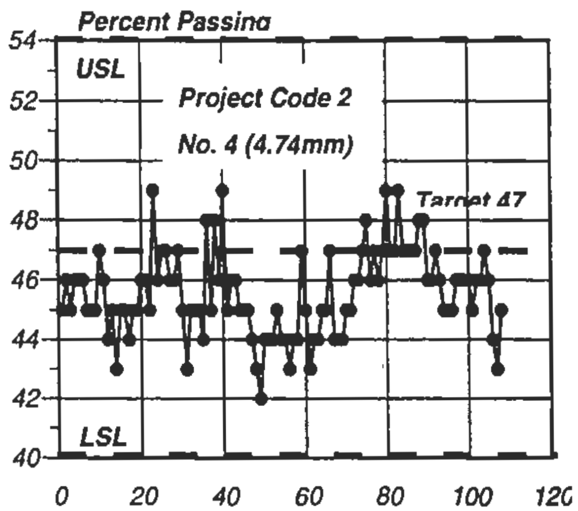
Code > Sub Lot	2 3/4	3/8	4	8	30	200	AC	Compact.
1	99	71	45	34	16	5.0	4.5	98.8
2	99	64	46	35	17	3.0	4.4	97.5
3	98	68	45	34	16	4.0	4.5	98.8
4	99	66	46	33	18	5.0	4.6	97.6
5	98	66	46	34	16	4.0	4.5	97.7
6	99	68	46	32	13	3.0	4.3	98.8
7	98	69	45	35	17	3.0	4.7	98.7
8	98	66	45	36	19	3.0	4.5	98.4
9	97	64	45	37	19	3.0	4.5	97.4
10	98	67	47	36	17	3.0	4.3	97.8
11	98	69	46	36	19	5.0	4.3	98.8
12	97	63	44	37	19	3.0	4.6	98.3
13	98	65	45	36	18	3.0	4.6	98.8
14	97	64	43	35	19	4.0	4.5	99.2
15	98	64	45	37	20	3.0	4.5	99.9
16	97	67	45	34	15	3.0	4.7	99.4
17	97	66	44	37	21	3.0	4.7	99.8
18	98	65	45	36	19	2.0	4.5	99.5
19	99	65	45	36	18	3.0	4.4	98.3
20	98	71	46	38	21	5.0	4.3	98.1
21	98	67	46	37	18	2.0	4.4	98.2
22	98	69	45	35	17	2.0	4.2	98.0
23	96	73	49	38	20	2.0	4.7	97.5
24	98	69	46	36	18	4.0	4.4	98.2
25	98	68	47	37	18	3.0	4.5	97.7
26	98	68	47	37	18	4.0	4.4	97.7
27	98	69	46	35	17	3.0	4.5	98.1
28	96	68	46	36	17	3.0	4.4	97.7
29	98	67	47	35	17	3.0	4.4	97.4
30	98	65	45	36	18	3.0	4.4	97.6
31	98	68	43	33	16	5.0	4.3	98.1
32	98	69	45	38	21	3.0	4.5	97.9
33	98	71	45	36	19	3.0	4.4	97.9
34	97	67	45	36	20	3.0	4.5	97.8
35	97	68	44	36	18	3.0	4.3	98.0
36	98	72	48	36	16	3.0	4.2	97.8
37	98	65	45	36	17	3.0	4.6	97.2
38	98	70	48	38	20	3.0	4.5	97.7
39	98	69	46	35	17	3.0	4.3	97.1
40	98	70	49	38	18	3.0	4.4	97.1
41	97	67	45	36	18	3.0	4.5	97.2
42	97	69	46	32	17	3.0	4.4	98.9
43	97	68	46	36	18	3.0	4.5	98.2
44	98	66	45	36	17	3.0	4.4	98.6
45	98	71	45	37	20	3.0	4.3	98.5
46	96	69	45	36	18	3.0	4.3	98.8
47	97	65	44	37	20	3.0	4.4	98.7
48	96	65	43	36	20	3.0	4.3	98.1

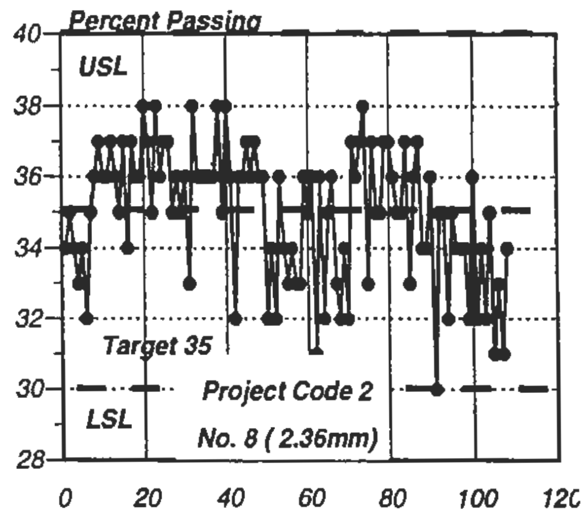
Code >	2							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
49	98	61	42	36	17	3.0	4.4	98.3
50	97	63	44	32	14	3.0	4.2	97.4
51	99	63	44	34	16	3.0	4.6	97.5
52	98	63	44	32	15	4.0	4.5	96.9
53	98	65	45	36	14	3.0	4.1	97.3
54	98	64	44	34	15	3.0	4.4	97.6
55	96	65	44	33	15	3.0	4.5	97.4
56	97	63	43	34	15	3.0	4.5	98.0
57	95	59	44	33	13	3.0	4.3	97.7
58	97	59	44	33	13	3.0	4.4	97.5
59	97	63	47	36	17	3.0	4.5	96.9
60	98	62	45	35	17	3.0	4.4	96.8
61	99	65	43	36	16	3.0	4.3	97.4
62	98	66	44	31	13	3.0	4.2	97.0
63	98	68	44	36	19	3.0	4.5	96.9
64	99	66	45	32	13	3.0	4.7	97.3
65	95	66	45	35	17	3.0	4.3	96.8
66	93	67	47	36	18	3.0	4.3	97.3
67	95	69	44	33	15	3.0	4.4	97.3
68	97	65	44	32	13	3.0	4.5	97.2
69	97	65	44	34	16	3.0	4.4	97.7
70	97	67	45	32	13	3.0	4.4	97.2
71	95	67	45	37	19	3.0	4.6	97.0
72	96	67	46	36	18	3.0	4.6	97.6
73	95	69	46	37	17	3.0	4.5	97.6
74	94	75	47	38	19	3.0	4.5	96.7
75	97	73	48	33	15	3.0	4.5	97.3
76	96	66	46	37	17	3.0	4.4	97.8
77	96	68	47	35	13	3.0	4.3	97.7
78	95	68	46	35	14	3.0	4.2	98.0
79	96	66	47	37	18	3.0	4.3	97.7
80	95	76	49	37	18	3.0	4.4	97.3
81	96	69	47	36	16	3.0	4.3	98.0
82	98	71	47	35	13	3.0	4.5	97.4
83	97	71	49	35	15	3.0	4.4	97.1
84	95	69	47	37	17	3.0	4.3	96.7
85	94	70	47	33	13	3.0	4.3	96.8
86	91	69	47	36	16	3.0	4.6	96.8
87	90	64	47	37	18	3.0	4.4	97.6
88	91	71	48	34	13	3.0	4.5	97.9
89	94	65	48	34	16	3.0	4.3	97.6
90	95	69	46	36	19	3.0	4.4	97.5
91	93	69	46	30	13	3.0	4.3	97.2
92	95	70	47	35	16	4.0	4.2	97.1
93	91	70	46	35	16	3.0	4.4	97.1
94	94	71	45	32	15	3.0	4.4	97.1
95	93	65	45	35	17	3.0	4.4	97.8
96	95	69	45	34	15	3.0	4.4	97.4

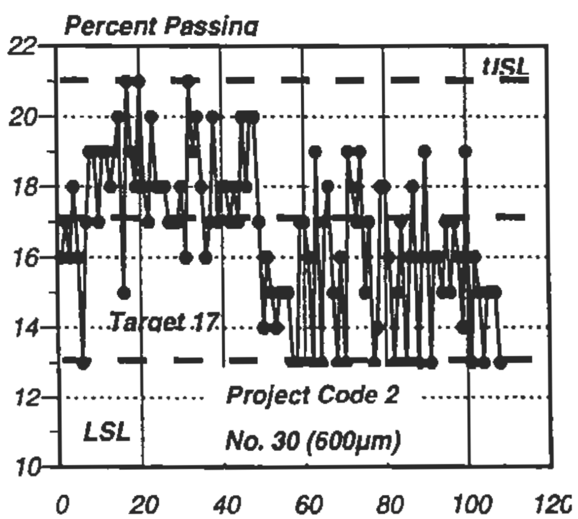
Code >	2							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
97	95	70	46	34	17	3.0	4.3	97.1
98	94	.70	46	34	16	3.0	4.3	97.4
99	96	70	46	32	14	3.0	4.3	97.8
100	91	68	46	36	19	3.0	4.4	97.5
101	92	70	45	32	13	3.0	4.4	97.2
102	93	67	46	34	16	3.0	4.5	97.3
103	90	69	46	32	15	3.0	4.4	97.2
104	91	70	47	35	13	3.0	4.5	97.3
105	92	68	46	31	15	3.0	4.5	97.1
106	90	70	44	33	15	3.0	4.6	97.4
107	92	68	43	31	15	3.0	4.5	97.8
108	96	69	45	34	13	3.0	4.4	97.2
Count	108	108	108	108	108	108	108	108
Max	99	76	49	38	21	5	5	100
Min	90	59	42	30	13	2	4	97
Range	9	17	7	8	8	3	1	3
Mean	96.3	67.4	45.6	35.0	16.6	3.12	4.42	97.73
Std. Dev.	2.32	2.97	1.44	1.86	2.18	0.524	0.123	0.675

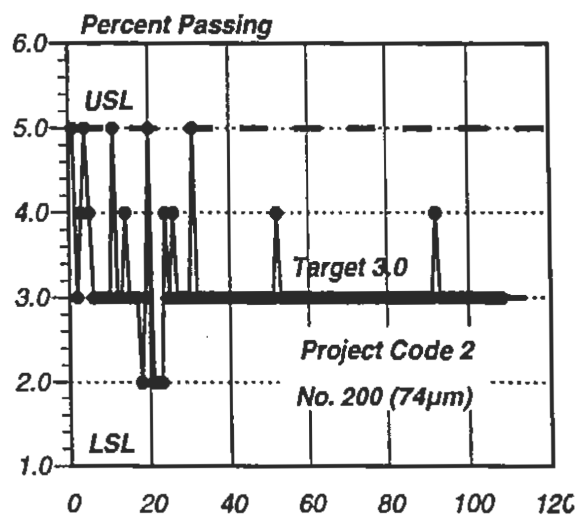

Percent Passing
100
99
98
97
96
95
94
93
92
91
90
89
88
USL
Target 95
Project Code 2
3/4 (19mm)
LSL
0
20
40
60
80
100
120

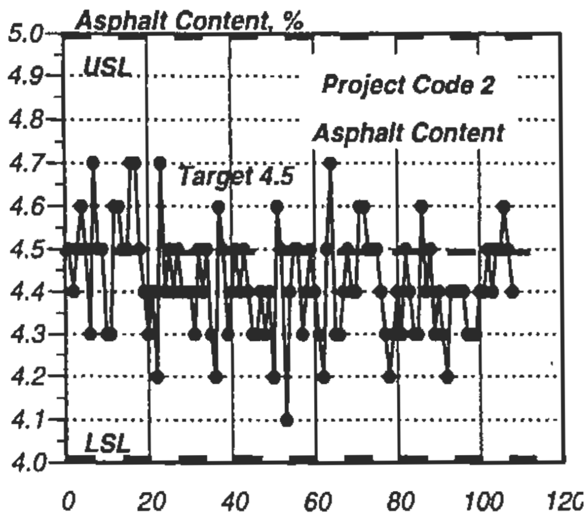

Percent Passing
80
78
76
74
72
70
68
66
64
62
60
58
Project Code 2
3/8 (9.5mm)
USL
Target 65
LSL
0
20
40
60
80
100
120

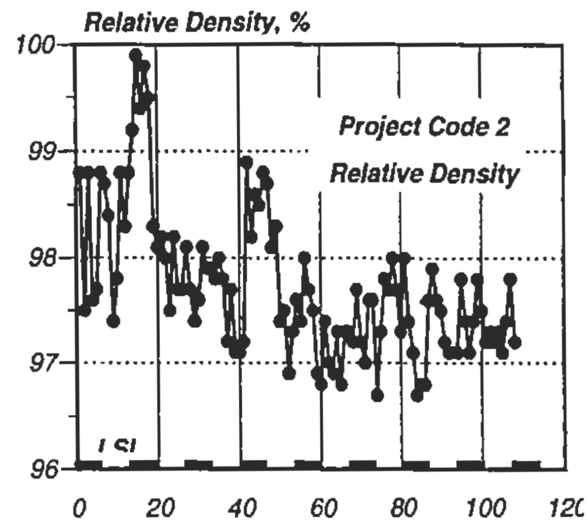

Percent Passing
54
52
50
48
46
44
42
40
USL
Project Code 2
No. 4 (4.74mm)
Target 47
LSL
0
20
40
60
80
100
120


Percent Passing
40
38
36
34
32
30
28
USL
Target 35
Project Code 2
No. 8 (2.36mm)
LSL
0
20
40
60
80
100
120


Percent Passing
22
20
18
16
14
12
10
USL
Target 17
Project Code 2
No. 30 (600µm)
LSL
0
20
40
60
80
100
120

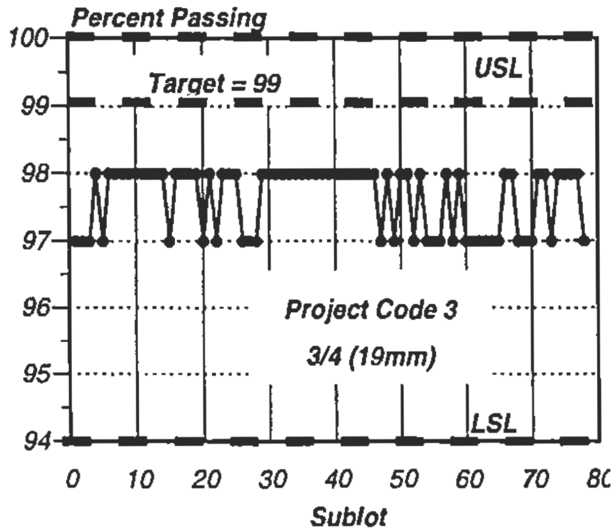

Percent Passing
6.0
5.0
4.0
3.0
2.0
1.0
USL
Target 3.0
Project Code 2
No. 200 (74µm)
LSL
0
20
40
60
80
100
120

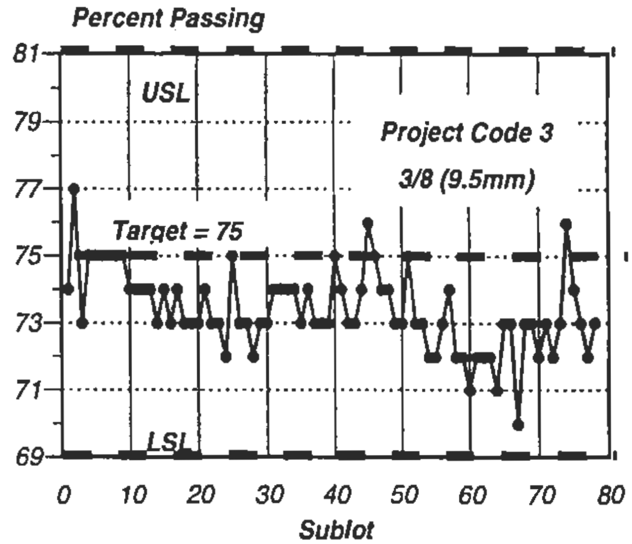

Asphalt Content, %
USL
Project Code 2
Asphalt Content
Target 4.5
LSL
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
0
20
40
60
80
100
120

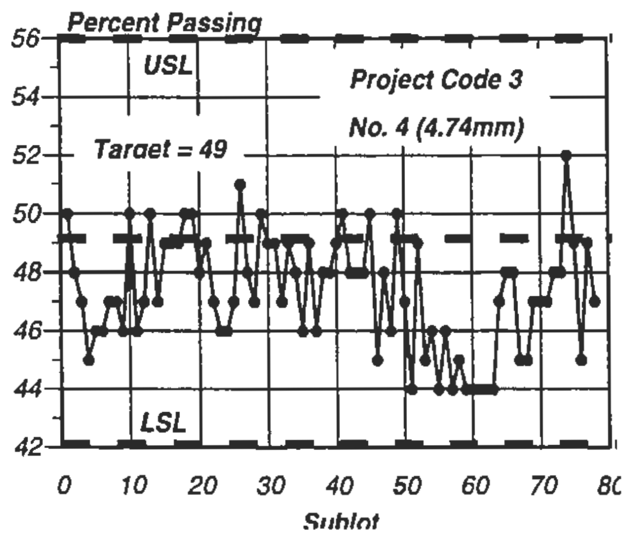

Relative Density, %
Project Code 2
Relative Density
100
99
98
97
96
0
20
40
60
80
100
120

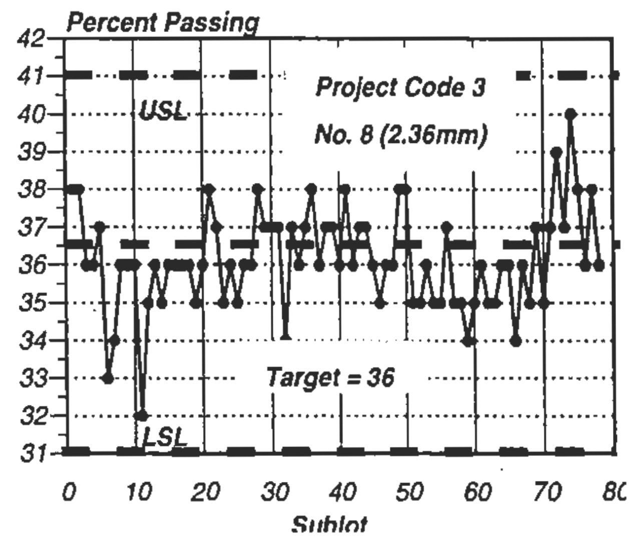
Code > Sub Lot	3 3/4	3/8	4	8	30	200.0	AC	Compact.
1	97	74	50	38	24	3.7	6.0	97.4
2	97	77	48	38	22	4.1	5.8	97.8
3	97	73	47	36	23	3.9	5.8	98.7
4	98	75	45	36	24	3.6	5.7	99.1
5	97	75	46	37	24	3.7	6.0	98.2
6	98	75	46	33	19	3.5	6.0	98.7
7	98	75	47	34	21	3.5	6.0	98.2
8	98	75	47	36	23	3.7	6.0	100.0
9	98	75	46	36	23	3.5	5.9	100.0
10	98	74	50	36	20	3.4	5.9	98.7
11	98	74	46	32	23	3.7	6.1	98.7
12	98	74	47	35	21	3.9	5.9	99.1
13	98	74	50	36	22	3.4	6.0	99.1
14	98	73	47	35	22	3.5	5.9	98.7
15	97	74	49	36	24	3.7	5.9	99.1
16	98	73	49	36	22	3.6	6.1	99.6
17	98	74	49	36	22	3.7	5.9	99.6
18	98	73	50	36	22	3.6	5.9	99.6
19	98	73	50	35	23	3.7	6.0	99.6
20	97	73	48	36	23	3.4	5.8	99.1
21	98	74	49	38	23	3.5	6.0	99.1
22	97	73	47	37	22	3.9	6.2	100.0
23	98	73	46	35	22	3.6	6.0	100.9
24	98	72	46	36	23	4.1	6.2	100.0
25	98	75	47	35	21	3.6	5.9	100.4
26	97	73	51	36	22	3.7	5.9	100.0
27	97	73	48	36	23	3.5	6.1	100.9
28	97	72	47	38	23	3.9	5.8	100.0
29	98	73	50	37	23	4.2	5.8	100.9
30	98	73	49	37	23	3.8	6.1	100.4
31	98	74	49	37	23	3.5	5.9	99.1
32	98	74	47	34	22	4.0	5.9	100.0
33	98	74	49	37	24	3.8	6.2	100.0
34	98	74	48	36	23	3.7	5.8	100.4
35	98	73	46	37	23	3.7	6.1	100.9
36	98	74	49	38	24	3.4	6.1	98.7
37	98	73	46	36	23	3.4	6.3	100.0
38	98	73	48	37	21	3.2	5.9	100.4
39	98	73	48	37	23	3.4	5.7	100.0
40	98	75	49	36	23	3.1	5.8	100.0
41	98	74	50	38	24	3.4	5.8	98.2
42	98	73	48	36	21	3.1	5.9	100.4
43	98	73	48	37	23	3.8	5.7	99.6
44	98	74	48	37	24	3.5	6.1	100.4
45	98	76	50	36	23	3.6	6.2	96.9
46	98	75	45	35	24	3.7	5.9	97.8
47	97	74	48	36	24	3.8	5.9	98.2
48	98	74	46	36	22	3.6	6.0	96.1
49	97	73	50	38	24	3.4	6.4	97.4
50	98	73	47	38	24	3.7	6.0	97.4
51	98	75	44	35	22	3.9	5.8	96.9

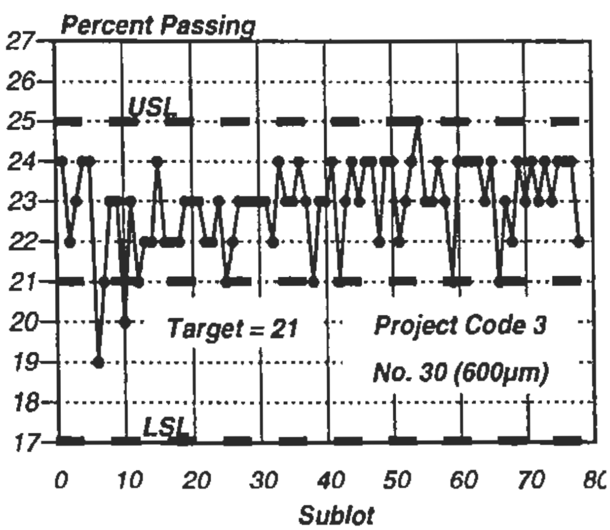
Code >	3							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
52	97	73	49	35	23	3.9	6.0	97.8
53	98	73	45	36	24	4.0	5.7	96.9
54	97	72	46	35	25	3.3	5.7	96.9
55	97	72	44	35	23	3.2	5.9	98.3
56	97	73	46	37	23	3.8	6.1	97.8
57	98	74	44	35	24	3.5	5.7	97.4
58	97	72	45	35	23	3.9	5.8	97.8
59	98	72	44	34	21	3.5	6.2	97.8
60	97	71	44	35	24	4.0	5.8	98.3
61	97	72	44	36	24	4.0	5.7	98.3
62	97	72	44	35	24	4.0	5.8	98.7
63	97	72	44	35	24	3.5	5.9	98.3
64	97	71	47	36	23	3.6	6.0	98.3
65	97	73	48	36	24	3.8	5.8	98.7
66	98	73	48	34	21	3.8	5.7	97.8
67	98	70	45	36	23	3.2	6.3	98.3
68	97	73	45	35	22	3.3	6.1	98.3
69	97	73	47	37	24	3.3	5.9	98.3
70	97	72	47	35	23	3.7	5.9	98.7
71	98	73	47	37	24	3.7	6.2	97.8
72	98	72	48	39	23	3.9	6.1	98.3
73	97	73	48	37	24	3.3	5.6	98.3
74	98	76	52	40	23	3.9	5.9	98.3
75	98	74	49	38	24	3.5	6.1	98.3
76	98	73	45	36	24	3.7	6.2	98.3
77	98	72	49	38	24	3.1	5.8	98.3
78	97	73	47	36	22	3.4	5.8	98.3
Count	78	78	78	78	78	78	78	78
Max	98	77	52	40	25	4.2	6.4	100.9
Min	97	70	44	32	19	3.1	5.6	96.1
Range	1	7	8	8	6	1.1	0.8	4.8
Mean	97.6	73.4	47.3	36.1	22.9	3.63	5.94	98.83
Std. Dev.	0.48	1.20	1.93	1.33	1.11	0.252	0.168	1.113

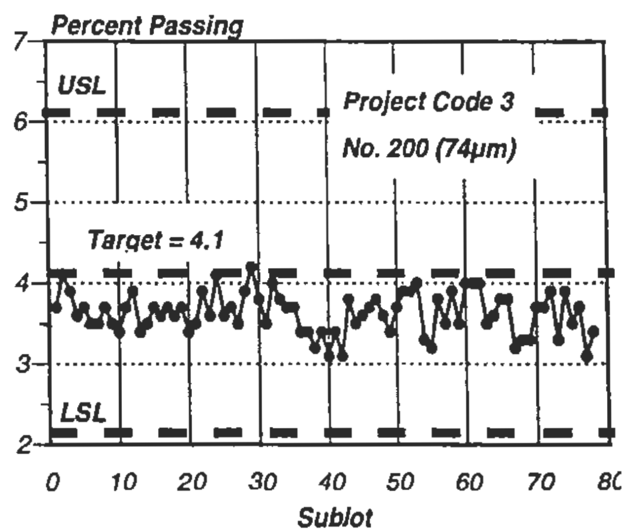

Percent Passing
100
99
98
97
96
95
94
Target = 99
USL
Project Code 3
3/4 (19mm)
LSL
0
10
20
30
40
50
60
70
80
Sublot

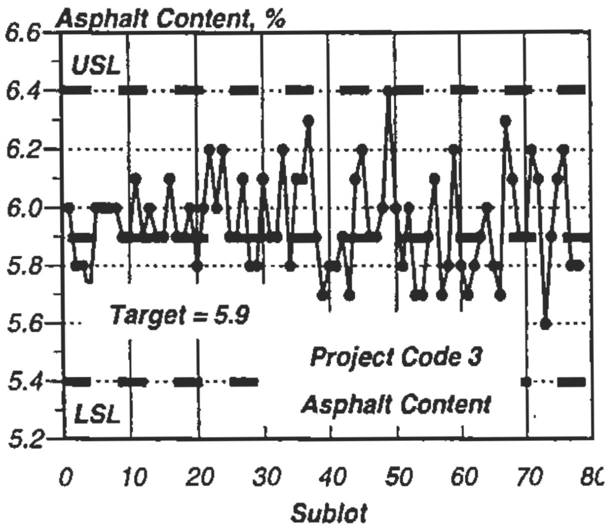

Percent Passing
81
79
77
75
73
71
69
USL
Project Code 3
3/8 (9.5mm)
Target = 75
LSL
0
10
20
30
40
50
60
70
80
Sublot

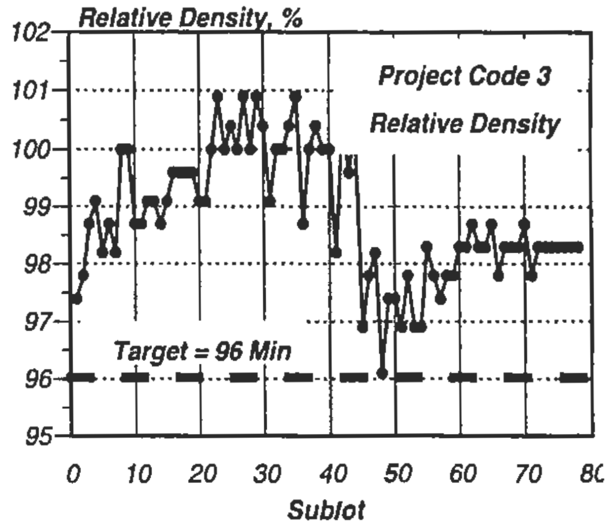

Percent Passing
56
54
52
50
48
46
44
42
USL
Project Code 3
No. 4 (4.74mm)
Target = 49
LSL
0
10
20
30
40
50
60
70
80
Sublot


Percent Passing
42
41
40
39
38
37
36
35
34
33
32
31
USL
Project Code 3
No. 8 (2.36mm)
Target = 36
LSL
0
10
20
30
40
50
60
70
80
Sublot


Percent Passing
27
26
25
24
23
22
21
20
19
18
17
USL
Target = 21
Project Code 3
No. 30 (600μm)
LSL
0
10
20
30
40
50
60
70
80
Sublot

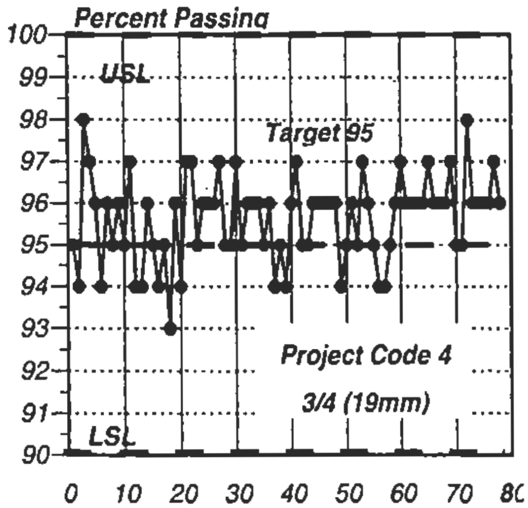

Percent Passing
7
6
5
4
3
2
USL
Project Code 3
No. 200 (74μm)
Target = 4.1
LSL
0
10
20
30
40
50
60
70
80
Sublot

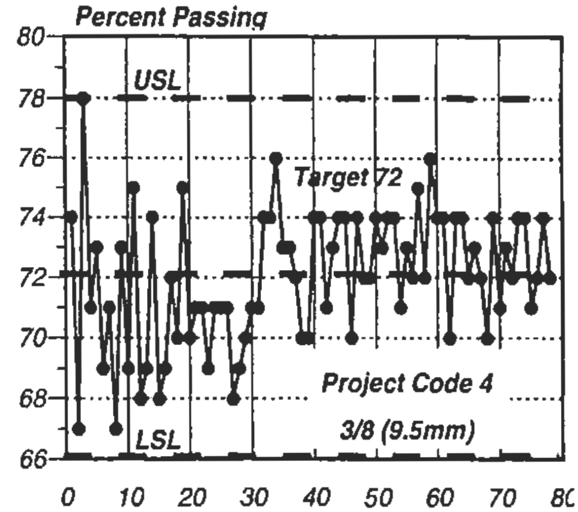

Asphalt Content, %
USL
LSL
Target = 5.9
Project Code 3
Asphalt Content
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
0 10 20 30 40 50 60 70 80
Sublot

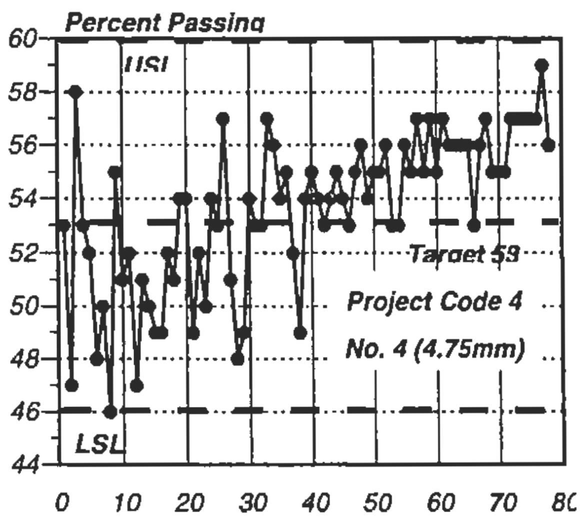

Relative Density, %
Project Code 3
Relative Density
Target = 96 Min
102
101
100
99
98
97
96
95
0 10 20 30 40 50 60 70 80
Sublot

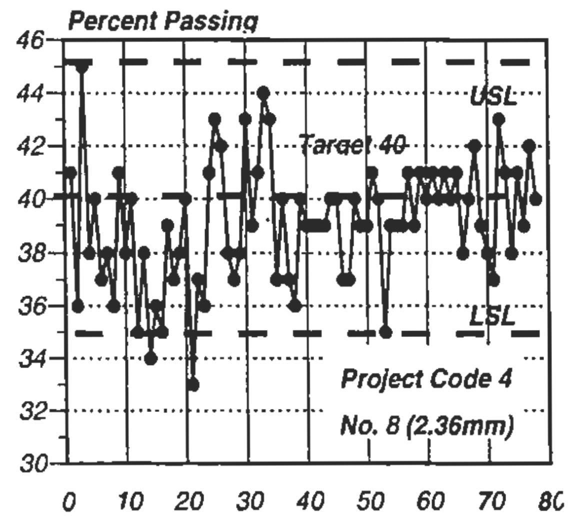
Code > Sub Lot	4 3/4	3/8	4	8	30	200	AC	Compact.
1	95	74	53	41	23	4.2	4.5	98.3
2	94	67	47	36	20	4.6	4.5	98.3
3	98	78	58	45	25	4.7	4.3	98.8
4	97	71	53	38	20	4.0	4.5	97.1
5	96	73	52	40	23	5.3	4.5	97.9
6	94	69	48	37	20	4.6	4.3	97.1
7	96	71	50	38	21	4.2	4.5	98.3
8	95	67	46	36	20	4.1	4.1	97.9
9	96	73	55	41	23	4.7	4.9	98.3
10	95	69	51	38	20	3.0	5.3	99.2
11	97	75	52	40	20	4.5	4.6	98.8
12	94	68	47	35	18	3.8	4.8	98.3
13	94	69	51	38	19	4.4	4.8	98.3
14	96	74	50	34	17	4.4	5.1	99.2
15	95	68	49	36	20	4.8	5.1	98.3
16	94	69	49	35	18	4.5	4.9	99.2
17	95	72	52	39	20	4.5	5.1	98.3
18	93	70	51	37	19	4.0	5.1	97.5
19	96	75	54	38	20	5.3	5.0	97.6
20	94	70	54	40	21	5.0	5.3	97.1
21	97	71	49	33	15	4.0	5.3	95.9
22	97	71	52	37	20	4.2	5.1	96.3
23	95	69	50	36	19	4.6	5.0	96.7
24	96	71	54	41	22	5.2	4.5	97.6
25	96	71	53	43	25	5.0	5.0	97.9
26	96	71	57	42	23	4.0	5.0	96.3
27	97	68	51	38	20	3.6	4.9	96.3
28	95	69	48	37	20	3.2	4.7	96.7
29	95	70	49	38	20	3.9	4.9	96.7
30	97	71	54	43	23	4.3	4.6	97.1
31	95	71	53	39	21	3.8	4.9	100.0
32	96	74	53	41	21	3.6	4.5	96.7
33	96	74	57	44	23	4.4	4.9	97.1
34	96	76	56	43	23	4.8	4.6	96.7
35	95	73	54	37	18	4.0	4.6	96.7
36	96	73	55	40	21	3.9	4.8	97.6
37	94	72	52	37	20	3.8	5.1	97.6
38	95	70	49	36	17	3.1	4.8	97.5
39	94	70	54	40	21	4.5	4.6	97.9
40	96	74	55	39	20	4.3	4.7	98.7
41	97	74	54	39	19	4.0	4.9	97.9
42	95	71	53	39	20	4.1	4.9	98.3
43	95	73	54	39	19	3.6	4.6	99.8
44	96	74	55	40	19	3.1	4.9	99.2
45	96	74	54	40	21	4.6	5.0	98.8
46	96	70	53	37	17	3.5	4.9	98.8
47	96	74	55	37	17	3.7	4.9	98.8
48	96	72	56	40	20	3.8	4.7	98.8
49	94	72	54	39	20	4.5	4.6	98.3

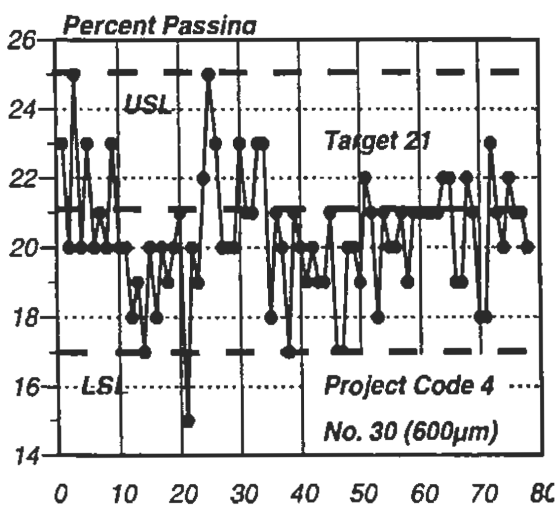
Code >	4							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
50	95	74	55	39	19	3.3	4.7	97.5
51	96	73	55	41	22	4.1	4.8	97.9
52	95	74	56	40	21	4.1	5.1	98.8
53	97	74	53	35	18	4.0	5.1	99.2
54	96	71	53	39	21	4.1	4.9	98.8
55	95	73	56	39	20	3.9	5.2	98.3
56	94	72	55	39	20	4.0	4.8	98.8
57	94	75	57	41	21	4.2	4.8	98.3
58	95	72	55	39	19	3.2	4.6	98.3
59	96	76	57	41	21	4.0	4.6	98.8
60	97	74	55	40	21	4.1	4.6	98.8
61	96	74	57	41	21	3.8	4.5	98.8
62	96	70	56	40	21	4.3	4.5	98.8
63	96	74	56	41	21	4.0	4.3	97.9
64	96	74	56	40	22	3.5	5.0	98.3
65	97	72	56	41	22	3.8	4.8	98.6
66	96	73	53	38	19	4.3	4.8	98.8
67	96	72	56	40	19	3.5	4.7	98.3
68	96	70	57	42	22	4.2	5.1	98.3
69	97	74	55	39	21	4.3	4.6	97.5
70	95	71	55	38	18	4.5	4.8	97.9
71	95	73	55	37	18	3.9	4.9	97.9
72	98	72	57	43	23	4.8	4.7	98.3
73	96	74	57	41	21	4.0	5.0	98.3
74	96	74	57	38	20	3.5	4.8	97.8
75	96	71	57	41	22	3.9	4.6	97.5
76	96	72	57	39	21	4.2	4.7	97.1
77	97	74	59	42	21	3.2	5.0	97.5
78	96	72	56	40	20	3.2	4.3	97.5
Count	78	78	78	78	78	78	78	78
Max	98.0	78.0	59.0	45.0	25.0	5.3	5.3	100.0
Min	93.0	67.0	46.0	33.0	15.0	3.0	4.1	95.9
Range	5.0	11.0	13.0	12.0	10.0	2.3	1.2	4.1
Mean	95.6	72.0	53.6	39.1	20.3	4.10	4.79	98.01
Std. Dev.	1.03	2.22	2.92	2.32	1.81	0.518	0.255	0.856

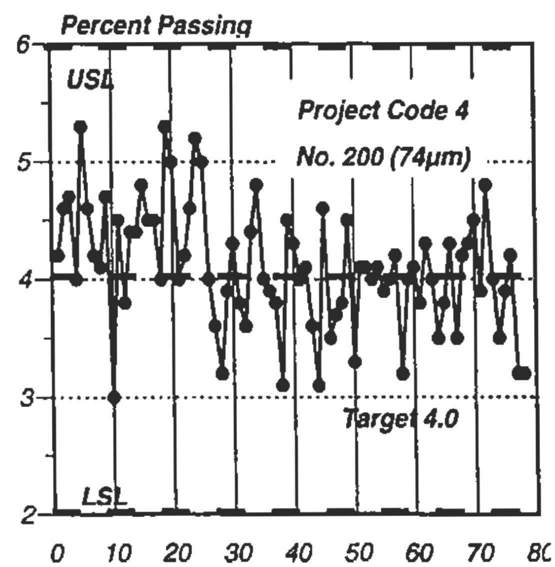

Percent Passing
USL
Target 95
Project Code 4
3/4 (19mm)
LSL
100
99
98
97
96
95
94
93
92
91
90
0 10 20 30 40 50 60 70 80

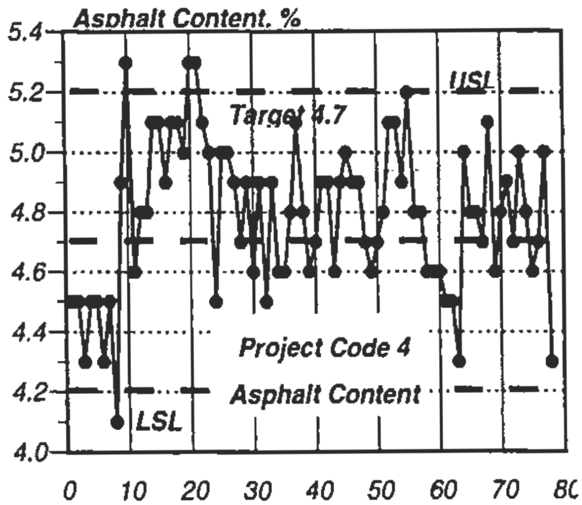

Percent Passing
USL
Target 72
Project Code 4
3/8 (9.5mm)
LSL
80
78
76
74
72
70
68
66
0 10 20 30 40 50 60 70 80

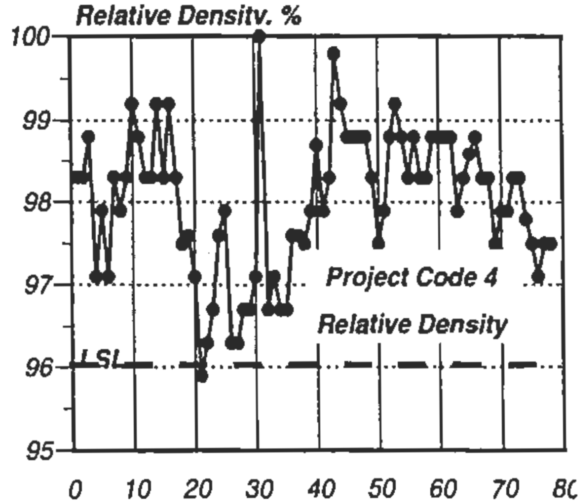

Percent Passing
USL
Target 53
Project Code 4
No. 4 (4.75mm)
LSL
60
58
56
54
52
50
48
46
44
0 10 20 30 40 50 60 70 80


Percent Passing
USL
Target 40
LSL
Project Code 4
No. 8 (2.36mm)
46
44
42
40
38
36
34
32
30
0 10 20 30 40 50 60 70 80

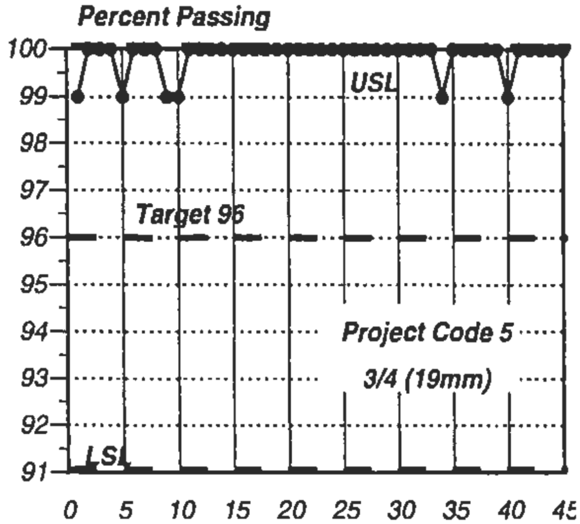

Percent Passing
USL
Target 21
LSL
Project Code 4
No. 30 (600µm)
26
24
22
20
18
16
14
0 10 20 30 40 50 60 70 80

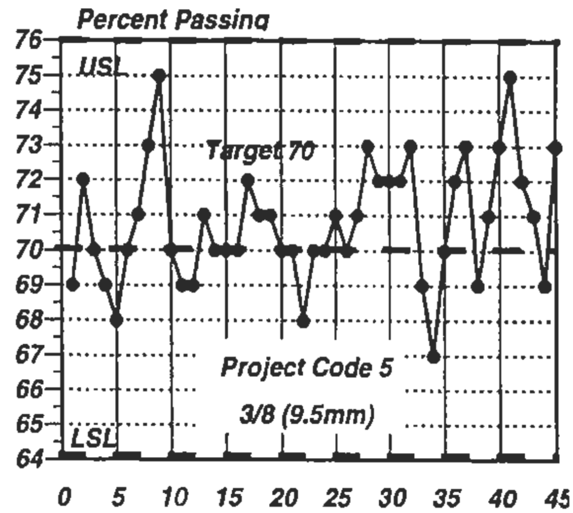

Percent Passing
USL
Project Code 4
No. 200 (74µm)
Target 4.0
LSL
6
5
4
3
2
0 10 20 30 40 50 60 70 80

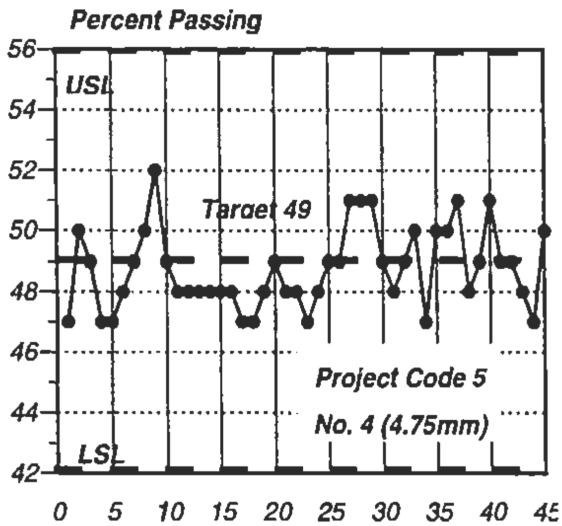

Asphalt Content, %
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
USL
Target 4.7
Project Code 4
Asphalt Content
LSL
0
10
20
30
40
50
60
70
80

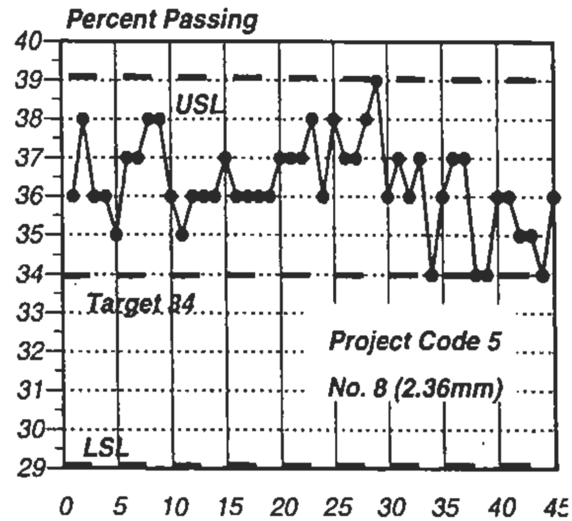

Relative Density, %
100
99
98
97
96
95
Project Code 4
Relative Density
LSL
0
10
20
30
40
50
60
70
80

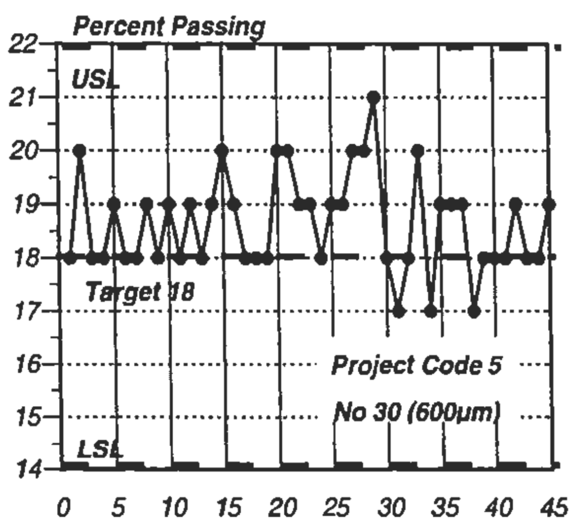
Code >	5							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
1	99	69	47	36	18	2.8	4.9	99.1
2	100	72	50	38	20	3.0	5.1	98.8
3	100	70	49	36	18	2.9	4.9	98.4
4	100	69	47	36	18	2.8	5.2	98.7
5	99	68	47	35	19	3.3	5.3	98.8
6	100	70	48	37	18	3.4	5.0	98.7
7	100	71	49	37	18	2.9	5.3	99.0
8	100	73	50	38	19	3.5	5.2	99.1
9	99	75	52	38	18	3.6	5.3	98.6
10	99	70	49	36	19	3.4	5.0	99.4
11	100	69	48	35	18	2.9	5.2	99.2
12	100	69	48	36	19	3.4	5.1	98.3
13	100	71	48	36	18	3.4	4.9	98.1
14	100	70	48	36	19	3.4	5.0	97.5
15	100	70	48	37	20	3.4	5.1	97.6
16	100	70	48	36	19	3.4	4.9	97.5
17	100	72	47	36	18	3.3	5.2	97.9
18	100	71	47	36	18	3.3	5.1	97.6
19	100	71	48	36	18	3.3	4.9	96.8
20	100	70	49	37	20	2.9	5.2	97.3
21	100	70	48	37	20	2.9	5.0	97.6
22	100	68	48	37	19	3.4	5.0	97.8
23	100	70	47	38	19	3.3	4.9	97.6
24	100	70	48	36	18	2.9	5.2	98.4
25	100	71	49	38	19	3.4	5.1	97.7
26	100	70	49	37	19	3.4	5.2	98.1
27	100	71	51	37	20	3.6	5.2	97.9
28	100	73	51	38	20	3.7	5.1	97.8
29	100	72	51	39	21	3.6	4.9	97.6
30	100	72	49	36	18	3.1	5.1	98.3
31	100	72	48	37	17	3.2	4.9	98.1
32	100	73	49	36	18	3.8	5.1	97.7
33	100	69	50	37	20	4.0	5.1	98.1
34	99	67	47	34	17	3.7	5.0	98.5
35	100	70	50	36	19	3.5	5.2	97.7
36	100	72	50	37	19	4.0	5.1	98.0
37	100	73	51	37	19	4.0	5.1	97.7
38	100	69	48	34	17	3.4	5.2	97.3
39	100	71	49	34	18	3.1	5.2	97.5
40	99	73	51	36	18	3.6	5.0	97.3
41	100	75	49	36	18	3.9	4.9	96.6
42	100	72	49	35	19	3.3	5.1	96.7
43	100	71	48	35	18	3.3	5.0	96.7
44	100	69	47	34	18	3.5	5.0	97.0
45	100	73	50	36	19	3.4	4.9	96.6
Count	45	45	45	45	45	45	45	45
Max	100	75	52	39	21	4.0	5.3	99.4
Min	99	67	47	34	17	2.8	4.9	96.6
Range	1	8	5	5	4	1.2	0.4	2.8
Mean	99.9	70.8	48.8	36.3	18.6	3.36	5.07	97.93
Std. Dev.	0.34	1.75	1.33	1.17	0.91	0.319	0.125	0.726

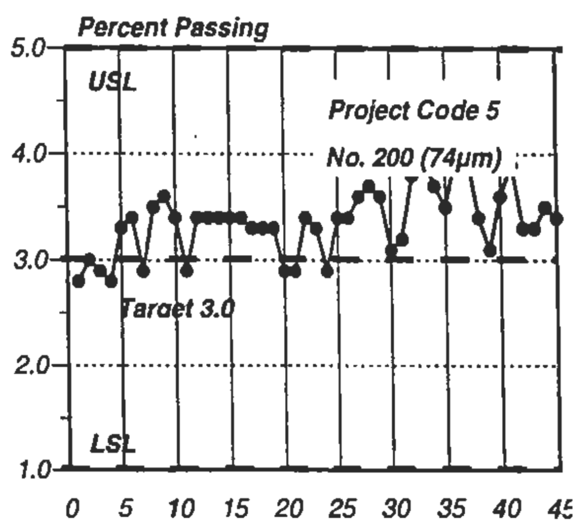

Percent Passing
USL
Target 96
LSL
Project Code 5
3/4 (19mm)

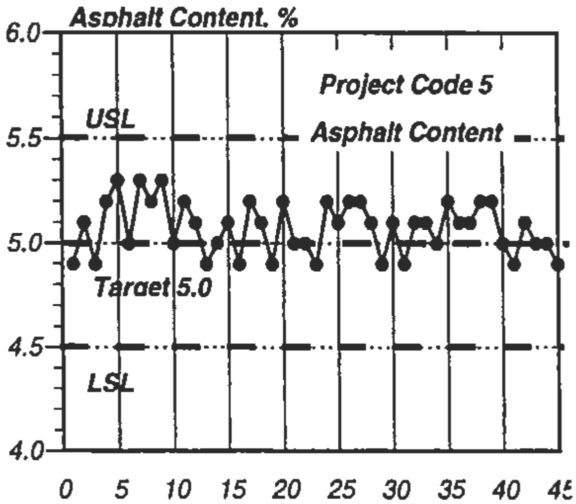

Percent Passing
USL
Target 70
LSL
Project Code 5
3/8 (9.5mm)

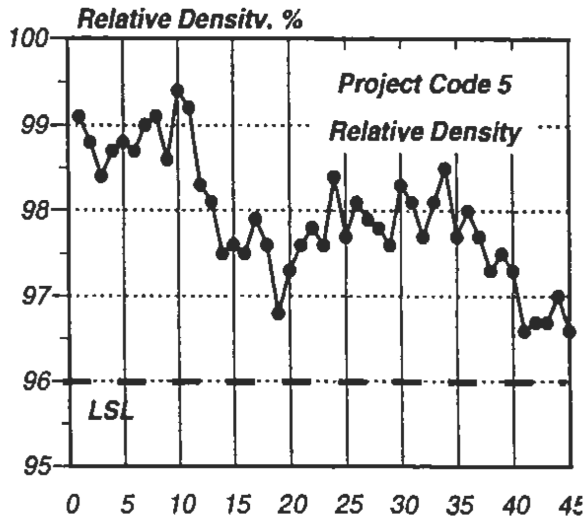

Percent Passing
USL
Target 49
LSL
Project Code 5
No. 4 (4.75mm)


Percent Passing
USL
Target 34
LSL
Project Code 5
No. 8 (2.36mm)


Percent Passing
USL
Target 18
LSL
Project Code 5
No 30 (600µm)


Percent Passing
USL
Project Code 5
No. 200 (74µm)
Target 3.0
LSL

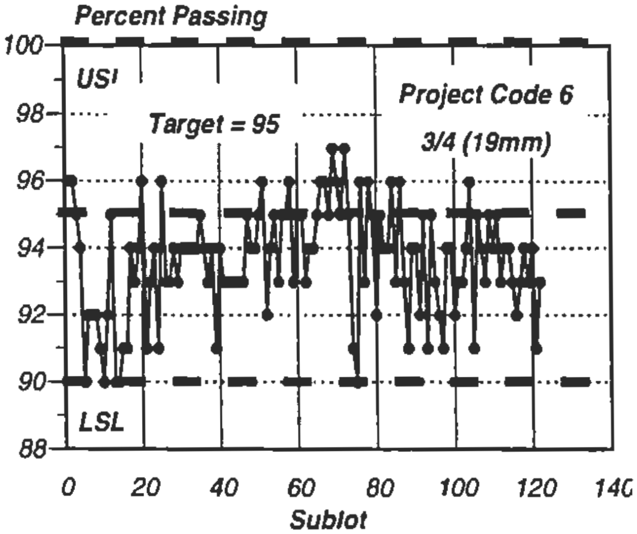

Asphalt Content, %
Project Code 5
Asphalt Content
USL
Target 5.0
LSL
6.0
5.5
5.0
4.5
4.0
0 5 10 15 20 25 30 35 40

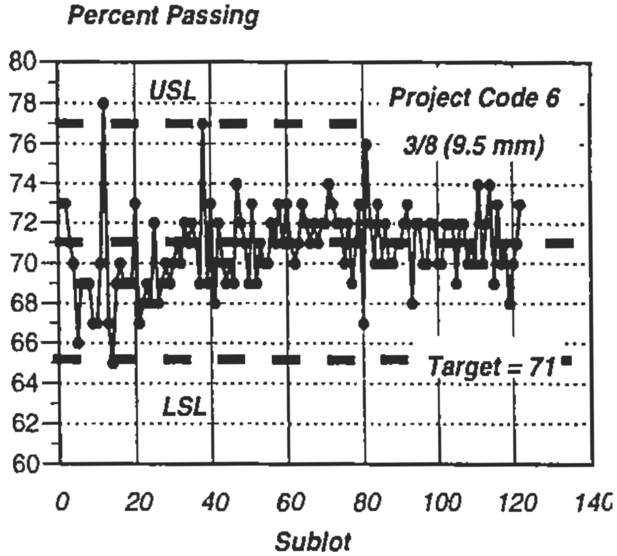

Relative Density, %
Project Code 5
Relative Density
LSL
100
99
98
97
96
95
0 5 10 15 20 25 30 35 40

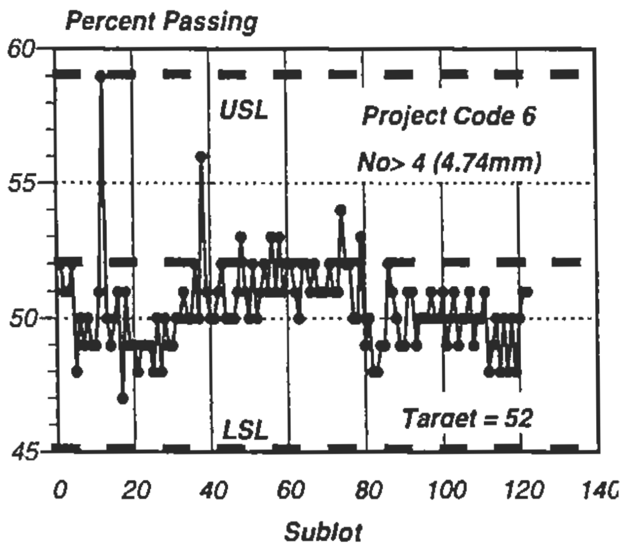
Code >	6							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
1	96	73	52	39	19	4.7	4.8	97.0
2	96	73	51	39	18	4.5	4.7	96.6
3	95	71	51	39	19	4.7	4.7	97.1
4	94	70	52	39	19	4.9	5.2	96.8
5	90	66	48	36	17	4.4	4.9	96.6
6	92	69	50	38	18	4.5	4.8	97.2
7	92	69	49	39	19	4.7	5.0	97.4
8	92	69	50	38	18	4.6	5.1	97.0
9	91	67	49	38	18	4.9	4.9	97.8
10	90	67	49	38	18	4.6	4.8	96.5
11	92	70	51	39	19	4.6	4.9	96.0
12	95	78	59	45	21	5.4	5.0	98.1
13	90	67	50	38	18	4.6	4.8	98.0
14	90	65	49	38	18	4.5	4.9	97.2
15	91	69	50	37	18	4.6	4.6	98.4
16	91	70	51	39	18	4.8	4.6	98.0
17	94	69	47	35	17	5.1	4.9	98.2
18	93	69	51	39	19	4.9	4.7	97.4
19	94	69	49	37	17	4.4	4.8	98.0
20	96	73	49	38	18	4.6	4.8	97.2
21	91	67	48	38	18	4.7	4.8	97.5
22	93	68	49	38	18	4.6	4.7	97.7
23	94	69	49	39	18	4.6	4.8	97.6
24	91	68	49	38	18	4.4	4.7	97.6
25	96	72	48	37	18	4.5	4.7	97.5
26	93	68	50	39	19	4.7	4.9	97.7
27	93	69	48	37	17	4.5	4.7	97.3
28	94	70	50	39	18	4.6	4.9	97.2
29	93	69	49	39	19	4.7	4.9	97.0
30	94	70	49	38	18	4.4	4.7	97.0
31	94	71	50	39	18	4.7	4.7	97.3
32	94	70	50	38	18	4.6	4.7	97.2
33	94	72	51	39	18	4.6	4.7	97.3
34	94	71	50	38	17	4.4	4.6	97.2
35	95	72	50	39	18	4.7	4.7	97.6
36	94	71	52	39	19	4.5	4.8	97.5
37	93	69	50	38	18	4.6	4.8	97.1
38	94	77	56	41	19	4.9	4.7	97.4
39	91	69	51	39	18	4.6	4.8	98.2
40	94	73	50	38	18	4.5	4.7	97.2
41	93	68	50	38	18	4.7	4.7	97.0
42	93	72	51	38	18	4.5	4.7	97.2
43	93	70	52	40	19	4.6	4.9	97.1
44	93	69	50	38	17	4.4	4.9	97.8
45	93	70	50	38	18	4.4	4.7	97.2
46	93	69	50	39	18	4.5	4.8	97.7
47	95	74	51	38	18	4.3	5.0	97.4
48	94	72	53	40	18	4.4	5.0	97.2
49	94	71	51	39	19	4.5	4.8	97.3
50	95	69	50	38	18	4.4	4.8	97.4
51	96	73	52	41	19	4.8	4.7	97.4

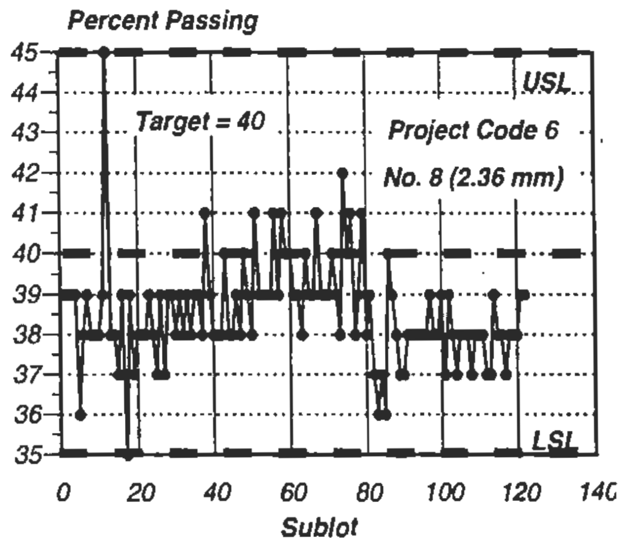
Code >	6, Cont'd.							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
52	92	69	50	39	19	4.7	4.9	97.4
53	94	71	51	39	18	4.6	4.8	97.3
54	95	70	52	39	19	4.6	4.7	97.3
55	93	70	51	39	19	4.6	4.9	97.0
56	95	72	53	41	19	4.8	4.7	97.3
57	95	71	51	39	19	4.6	4.7	97.0
58	96	73	53	41	20	4.9	4.8	97.1
59	93	71	51	40	19	4.6	4.8	97.2
60	95	73	52	40	19	4.7	4.8	97.5
61	95	71	52	39	18	4.4	4.8	96.9
62	93	70	51	39	18	4.6	4.9	96.8
63	94	71	50	38	17	4.3	4.8	97.6
64	94	73	52	40	19	4.7	4.8	96.4
65	95	72	52	39	18	4.6	4.7	96.4
66	96	71	51	39	18	4.5	4.9	96.2
67	96	72	52	41	19	5.0	4.7	96.3
68	95	71	51	39	18	4.6	4.8	96.6
69	97	72	51	39	18	4.6	4.7	96.6
70	96	72	51	39	18	4.7	4.7	96.2
71	95	74	52	40	19	4.9	4.6	96.2
72	97	73	51	39	18	4.6	4.7	96.5
73	95	72	51	38	18	4.4	4.7	96.5
74	91	72	54	42	19	4.7	4.7	96.4
75	90	70	52	40	19	4.7	4.7	96.8
76	96	72	52	41	20	4.8	4.8	96.5
77	93	69	50	38	17	4.2	4.6	96.7
78	96	71	50	39	18	4.3	4.7	96.5
79	95	73	53	41	20	5.1	4.7	96.5
80	92	67	49	38	17	4.2	4.7	97.4
81	95	76	50	39	19	4.7	4.6	96.9
82	94	72	48	37	18	4.4	4.8	97.5
83	94	70	48	36	17	4.3	4.7	96.8
84	96	73	49	37	18	4.6	4.7	97.0
85	93	70	49	36	17	4.4	4.7	97.0
86	96	72	52	40	19	4.8	4.8	97.3
87	93	70	51	39	18	4.7	4.7	97.9
88	91	70	50	38	18	4.4	4.6	97.2
89	94	71	49	37	18	4.4	4.8	97.2
90	94	71	49	37	18	4.4	4.6	96.9
91	92	72	51	38	17	4.4	4.7	97.2
92	95	73	51	38	17	4.6	4.8	97.6
93	91	68	49	38	17	4.5	4.9	96.8
94	95	72	50	38	18	4.7	4.7	97.0
95	93	72	50	38	17	4.5	4.6	97.1
96	92	70	50	38	18	4.6	4.7	97.0
97	91	70	51	39	19	4.8	4.7	96.7
98	94	72	50	38	18	4.6	4.5	97.0
99	94	72	50	38	18	4.6	4.7	96.8
100	92	70	51	39	19	4.7	4.9	97.3
101	93	70	49	37	17	4.3	4.6	97.0
102	93	72	50	39	18	4.6	4.7	96.8

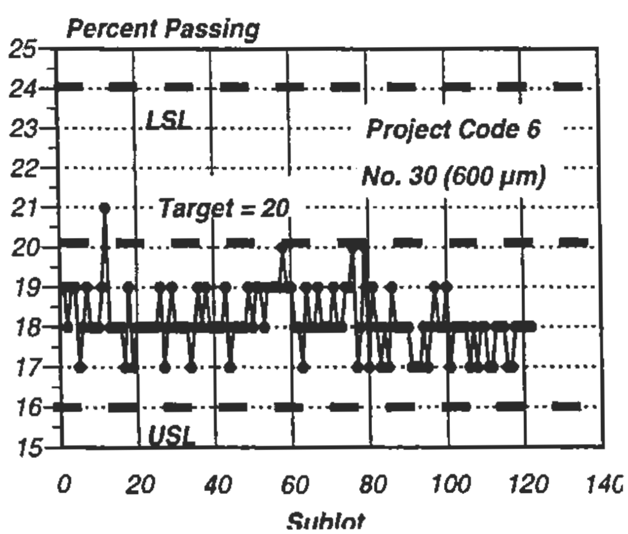
Code >	6, Cont'd.							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
103	94	72	51	38	18	4.6	4.7	96.5
104	96	72	49	37	18	4.6	4.9	97.4
105	91	69	50	38	18	4.6	4.8	97.1
106	95	72	50	38	17	4.5	4.5	97.0
107	94	72	51	38	18	4.6	4.8	97.0
108	93	70	49	37	17	4.5	4.5	97.0
109	95	71	50	38	18	4.9	4.6	97.0
110	94	70	50	38	18	4.6	4.8	97.0
111	95	74	51	38	17	4.4	4.7	97.0
112	93	70	48	37	17	4.4	4.6	97.0
113	94	72	49	37	18	4.5	4.6	97.0
114	94	74	50	39	18	4.6	4.5	97.0
115	93	69	48	38	18	4.6	4.6	97.0
116	92	73	50	38	17	4.6	4.6	97.0
117	93	70	48	37	17	4.9	4.6	97.2
118	94	71	50	38	18	4.5	4.4	97.0
119	93	68	48	38	18	4.5	4.7	97.0
120	94	70	50	38	18	4.5	4.4	97.0
121	91	71	51	39	18	4.6	4.4	97.0
122	93	73	51	39	18	4.6	4.7	97.0
Count	122	122	122	122	122	122	122	122
Max	97	78	59	45	21	5	5	98
Min	90	65	47	35	17	4	4	96
Range	7	13	12	10	4	1	1	2
Mean	93.6	70.8	50.4	38.5	18.1	4.6	4.80	97.12
Std. Dev.	1.65	2.07	1.60	1.29	0.76	0.19	0.132	0.447

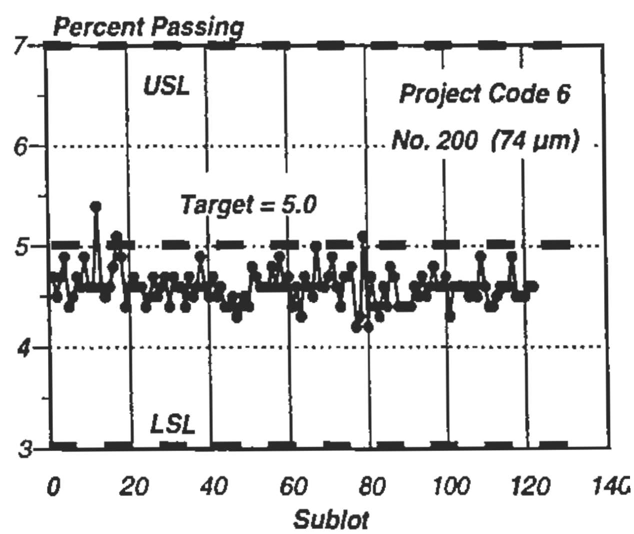

Percent Passing
USL
Target = 95
Project Code 6
3/4 (19mm)
LSL
Sublot

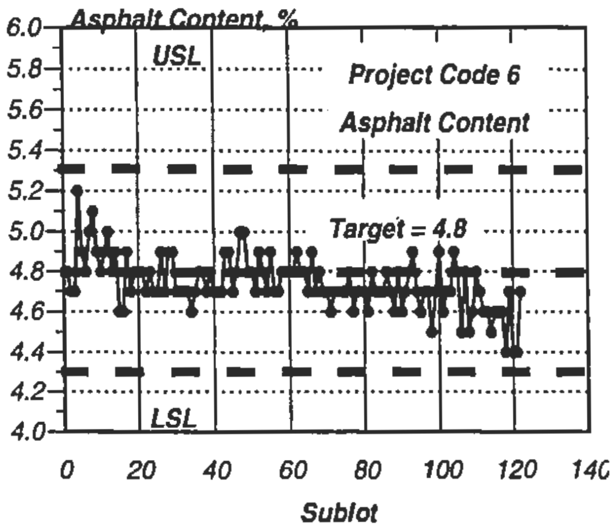

Percent Passing
USL
Project Code 6
3/8 (9.5 mm)
Target = 71
LSL
Sublot

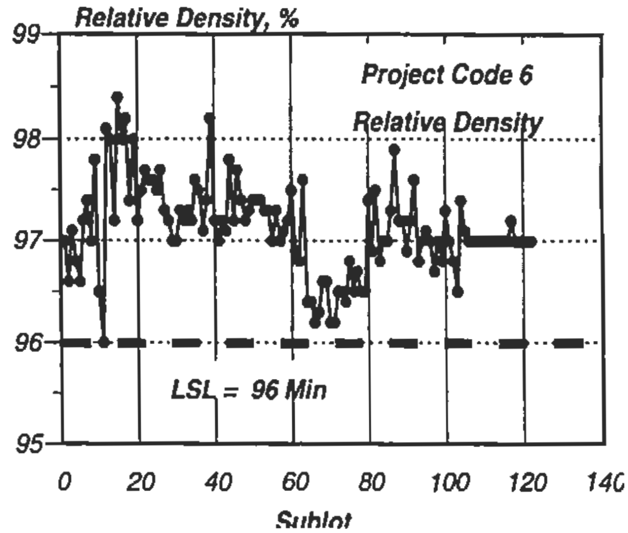

Percent Passing
USL
Project Code 6
No> 4 (4.74mm)
LSL
Target = 52
Sublot


Percent Passing
USL
Target = 40
Project Code 6
No. 8 (2.36 mm)
LSL
Sublot


Percent Passing
LSL
Project Code 6
No. 30 (600 μm)
Target = 20
USL
Sublot


Percent Passing
USL
Project Code 6
No. 200 (74 μm)
Target = 5.0
LSL
Sublot

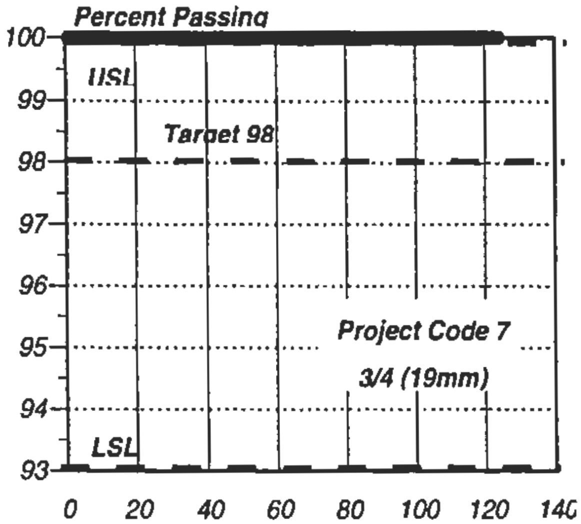

Asphalt Content, %
USL
Project Code 6
Asphalt Content
Target = 4.8
LSL
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
0
20
40
60
80
100
120
140
Sublot

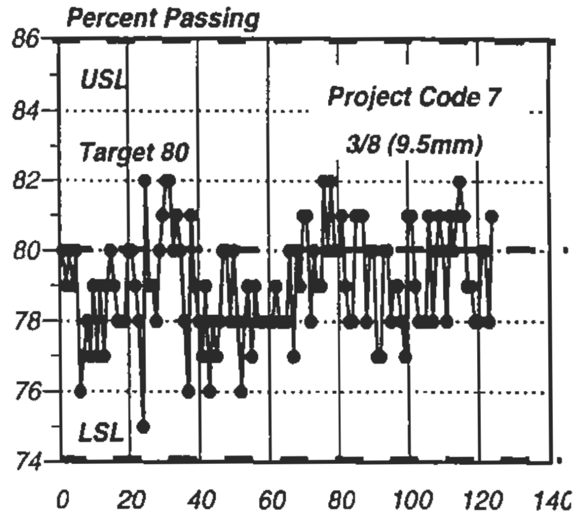

Relative Density, %
Project Code 6
Relative Density
LSL = 96 Min
99
98
97
96
95
0
20
40
60
80
100
120
140
Sublot

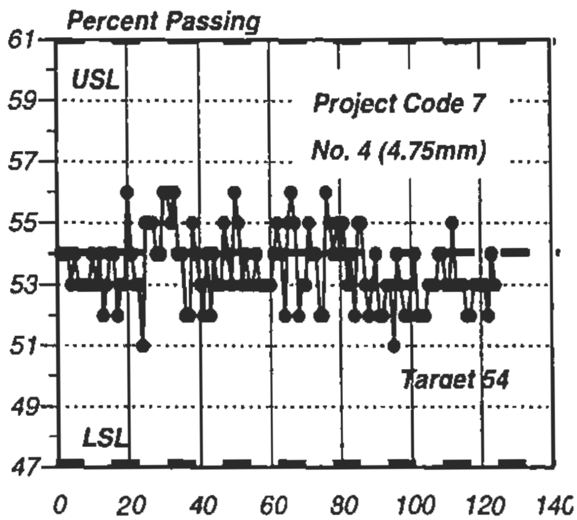
	Code >	7							
	Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
7	1	100	80	54	39	18	6.4	6.0	96.6
7	2	100	79	54	39	18	6.2	5.9	96.6
7	3	100	80	54	40	19	6.6	6.3	98.3
7	4	100	79	53	38	17	5.8	6.0	97.4
7	5	100	80	54	37	16	5.6	6.5	97.4
7	6	100	76	53	39	17	6.1	6.2	97.4
7	7	100	77	53	37	18	6.0	5.9	97.4
7	8	100	78	53	35	17	5.6	6.0	97.4
7	9	100	77	53	36	15	5.2	6.1	97.4
7	10	100	79	54	37	16	6.1	6.0	97.0
7	11	100	77	53	38	19	6.0	6.1	97.0
7	12	100	79	54	39	19	6.4	6.0	97.4
7	13	100	77	52	39	19	5.9	6.2	96.6
7	14	100	79	53	39	19	5.9	6.3	96.6
7	15	100	80	54	39	18	6.3	6.2	97.0
7	16	100	79	54	39	18	6.5	6.1	97.4
7	17	100	78	52	39	18	6.4	6.2	97.0
7	18	100	78	53	37	18	5.9	6.3	96.6
7	19	100	78	53	39	18	5.9	6.2	96.6
7	20	100	80	56	38	16	5.4	6.0	96.6
7	21	100	80	54	38	18	5.2	6.3	98.3
7	22	100	79	53	37	17	5.8	6.2	97.4
7	23	100	78	53	38	17	6.3	6.3	96.6
7	24	100	75	51	37	18	6.2	6.2	97.0
7	25	100	82	55	39	18	6.1	6.4	97.9
7	26	100	79	55	39	18	6.5	6.3	97.0
7	27	100	79	55	39	18	6.2	6.3	97.4
7	28	100	78	54	39	19	6.0	6.1	97.4
7	29	100	80	54	38	18	5.9	6.3	96.6
7	30	100	81	56	40	19	6.9	6.2	98.3
7	31	100	82	56	40	20	6.5	6.3	96.6
7	32	100	82	55	39	16	5.7	6.1	97.0
7	33	100	80	56	40	19	5.9	6.0	97.0
7	34	100	81	54	38	19	6.6	5.9	96.6
7	35	100	80	54	40	18	5.9	5.9	96.6
7	36	100	78	52	36	16	5.7	6.1	97.9
7	37	100	76	52	39	18	6.1	6.0	96.6
7	38	100	81	55	39	19	6.2	6.0	96.6
7	39	100	79	54	39	18	6.2	6.3	96.2
7	40	100	78	53	36	18	5.8	6.1	97.9
7	41	100	77	52	36	17	6.0	6.2	97.4
7	42	100	79	54	37	17	6.4	6.2	97.4
7	43	100	76	52	39	19	6.0	6.0	97.0
7	44	100	78	54	38	17	6.0	6.3	97.4
7	45	100	77	53	37	17	6.2	6.0	97.0
7	46	100	78	53	37	19	5.8	6.1	97.4
7	47	100	80	55	38	19	5.9	6.4	96.6
7	48	100	80	54	37	17	6.1	6.3	96.6
7	49	100	78	53	40	20	6.3	5.9	97.4
7	50	100	80	56	37	19	5.6	5.9	97.4
7	51	100	78	55	40	19	6.3	6.0	97.4

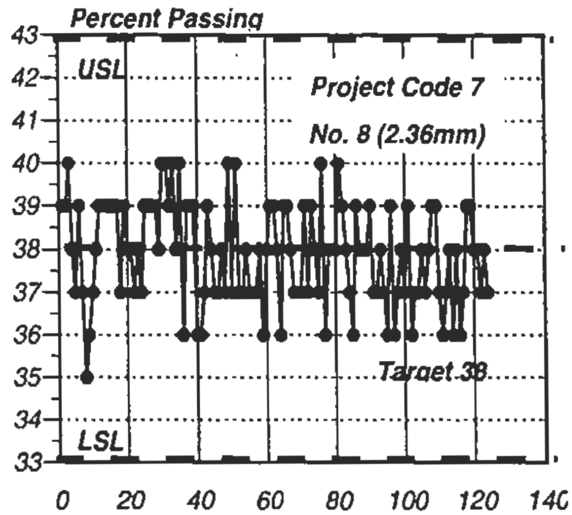
	Code > Sub Lot	7 3/4	3/8	4	8	30	200	AC	Compact.
7	52	100	76	53	37	17	6.2	6.2	97.9
7	53	100	78	54	37	18	6.1	6.0	97.4
7	54	100	79	53	38	18	5.5	6.1	97.4
7	55	100	77	53	37	18	6.0	6.1	97.9
7	56	100	79	54	37	16	5.5	6.2	97.4
7	57	100	78	53	37	17	5.8	6.2	97.4
7	58	100	78	53	38	17	5.8	6.0	97.9
7	59	100	78	53	36	17	5.9	6.3	97.9
7	60	100	78	53	38	17	6.0	5.9	97.9
7	61	100	78	54	39	18	5.9	6.3	97.9
7	62	100	79	55	39	19	5.4	6.4	97.4
7	63	100	78	54	38	19	6.5	6.0	97.0
7	64	100	78	52	36	18	6.3	6.0	97.0
7	65	100	78	55	39	18	6.3	6.1	96.6
7	66	100	80	56	39	19	6.4	6.3	96.6
7	67	100	77	55	38	19	6.4	5.9	97.4
7	68	100	80	52	37	19	6.5	6.0	97.4
7	69	100	79	53	37	18	6.4	6.0	97.4
7	70	100	81	53	37	17	5.9	6.0	97.0
7	71	100	81	55	39	19	6.1	5.9	97.0
7	72	100	78	54	37	18	5.3	6.0	96.6
7	73	100	80	54	39	19	6.2	6.0	97.4
7	74	100	79	52	38	19	5.9	6.3	97.4
7	75	100	79	52	37	18	6.2	6.0	96.6
7	76	100	82	56	40	19	6.5	6.2	97.2
7	77	100	80	55	36	17	5.9	6.2	97.4
7	78	100	82	54	38	18	5.8	6.0	96.6
7	79	100	80	55	38	17	5.8	6.2	97.0
7	80	100	80	54	38	19	6.0	6.3	97.2
7	81	100	81	55	40	20	6.0	6.2	97.0
7	82	100	79	53	39	19	5.9	6.4	97.0
7	83	100	78	54	38	18	6.4	5.9	97.0
7	84	100	78	52	37	19	6.4	5.8	97.0
7	85	100	81	55	36	17	6.2	6.0	97.4
7	86	100	81	55	39	18	5.9	6.2	97.2
7	87	100	81	53	38	19	6.1	6.1	97.2
7	88	100	78	52	38	19	6.8	6.1	97.2
7	89	100	80	53	38	19	6.4	6.0	97.2
7	90	100	80	54	39	18	6.2	6.5	97.2
7	91	100	77	52	37	18	6.2	6.2	97.2
7	92	100	77	52	37	17	6.2	5.9	97.2
7	93	100	80	53	38	18	6.5	6.4	97.2
7	94	100	80	53	37	18	5.6	5.8	97.2
7	95	100	78	51	36	19	6.0	6.1	97.2
7	96	100	79	54	39	18	6.4	6.0	97.2
7	97	100	79	53	36	17	6.2	6.1	97.2
7	98	100	78	52	37	17	5.5	5.9	97.2
7	99	100	77	52	38	16	6.4	5.8	97.2
7	100	100	81	53	37	17	6.0	5.8	97.2
7	101	100	81	54	39	19	5.9	6.2	97.2
7	102	100	79	52	36	17	5.8	5.8	97.2

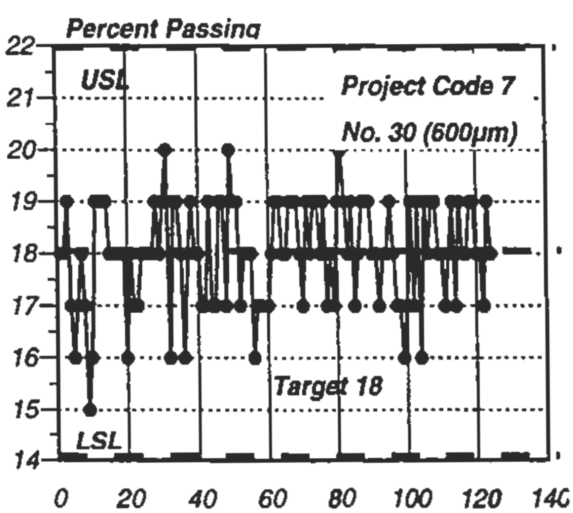
	Code >	7							
	Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
7	103	100	78	52	37	19	6.0	6.4	97.2
7	104	100	78	52	37	16	6.8	6.1	97.2
7	105	100	78	53	38	19	5.8	6.0	97.2
7	106	100	81	53	37	18	5.9	5.9	97.2
7	107	100	78	53	38	19	5.9	6.0	97.2
7	108	100	80	54	39	19	6.5	6.1	97.2
7	109	100	81	54	39	18	6.5	6.0	97.2
7	110	100	80	53	37	18	6.3	6.2	97.2
7	111	100	78	53	36	17	6.4	6.1	97.2
7	112	100	81	55	37	18	6.4	6.0	97.2
7	113	100	80	53	38	19	6.7	6.3	97.2
7	114	100	81	53	36	17	5.9	6.0	97.2
7	115	100	82	53	38	19	6.7	6.3	97.2
7	116	100	81	52	36	18	6.5	5.9	97.2
7	117	100	79	52	37	18	6.4	6.0	97.2
7	118	100	79	53	39	19	6.6	6.2	97.2
7	119	100	78	53	39	19	6.8	6.1	97.2
7	120	100	78	53	38	18	5.9	6.0	97.2
7	121	100	80	53	38	18	6.4	6.0	97.2
7	122	100	80	52	37	17	6.4	6.2	97.2
7	123	100	78	54	38	19	6.3	6.0	97.2
7	124	100	81	53	37	18	6.4	6.5	93.0
	Count	124	124	124	124	124	124	124	124
	Max	100	82	56	40	20	6.9	6.5	98.3
	Min	100	75	51	35	15	5.2	5.8	93.0
	Range	0	7	5	5	5	1.7	0.7	5.3
	Mean	100.00	79.05	53.49	37.89	18.01	6.11	6.11	97.15
	Std. Dev.	0.00	1.51	1.15	1.17	0.99	0.346	0.165	0.540

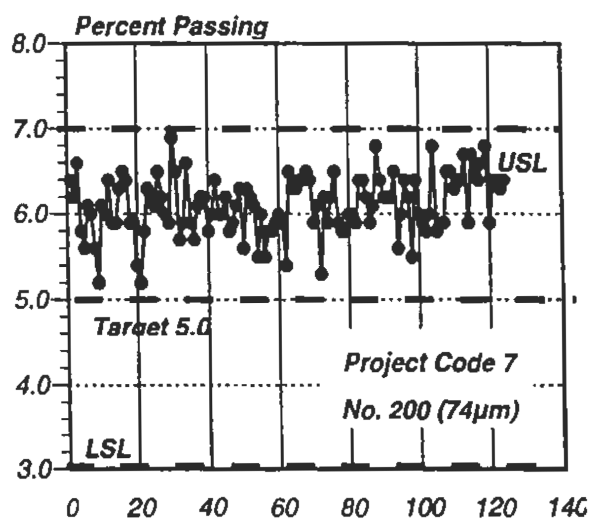

Percent Passing
USL
Target 98
Project Code 7
3/4 (19mm)
LSL
100
99
98
97
96
95
94
93
0 20 40 60 80 100 120 140

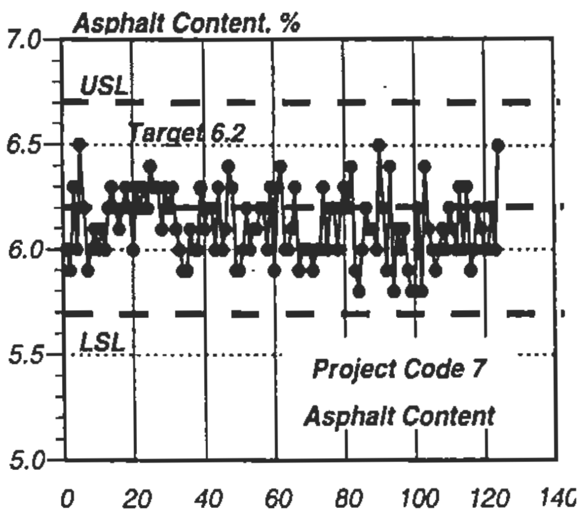

Percent Passing
USL
Project Code 7
3/8 (9.5mm)
Target 80
LSL
86
84
82
80
78
76
74
0 20 40 60 80 100 120 140

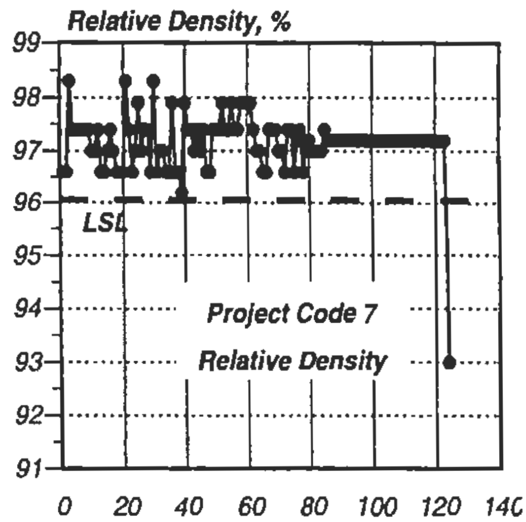

Percent Passing
USL
Project Code 7
No. 4 (4.75mm)
Target 54
LSL
61
59
57
55
53
51
49
47
0 20 40 60 80 100 120 140


Percent Passing
USL
Project Code 7
No. 8 (2.36mm)
Target 38
LSL
43
42
41
40
39
38
37
36
35
34
33
0 20 40 60 80 100 120 140


Percent Passing
USL
Project Code 7
No. 30 (600µm)
Target 18
LSL
22
21
20
19
18
17
16
15
14
0 20 40 60 80 100 120 140

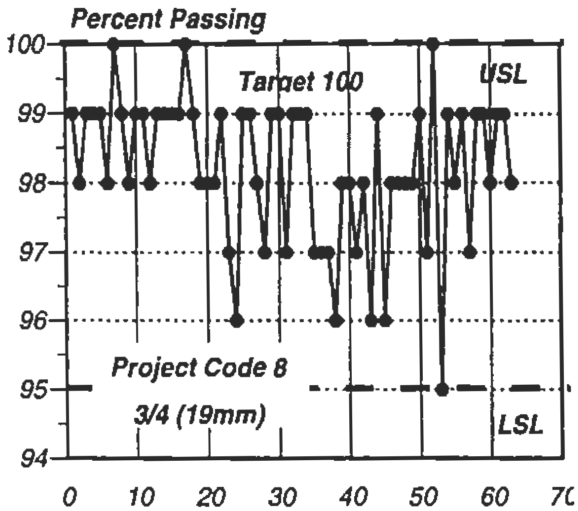

Percent Passing
USL
Target 5.0
Project Code 7
No. 200 (74µm)
LSL
8.0
7.0
6.0
5.0
4.0
3.0
0 20 40 60 80 100 120 140

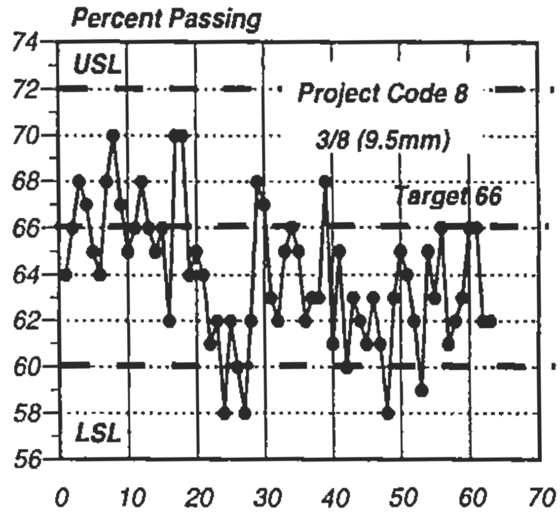

Asphalt Content. %
7.0
6.5
6.0
5.5
5.0
USL
Target 6.2
LSL
Project Code 7
Asphalt Content
0
20
40
60
80
100
120
140

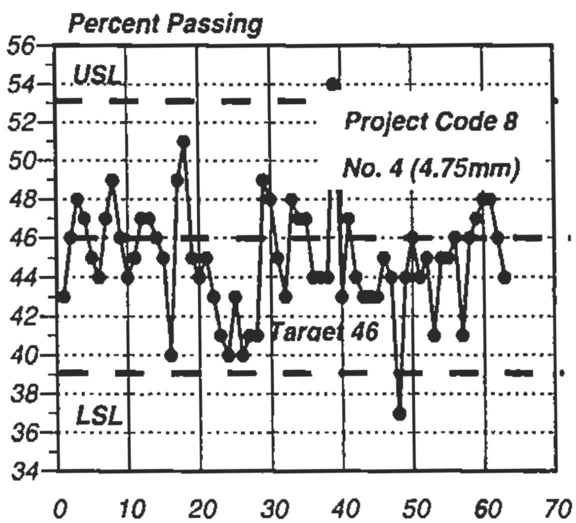

Relative Density, %
99
98
97
96
95
94
93
92
91
LSL
Project Code 7
Relative Density
0
20
40
60
80
100
120
140

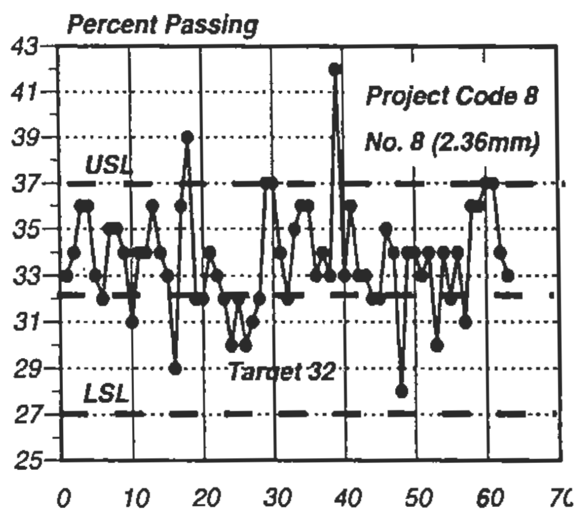
Code > Sub Lot	8 3/4	3/8	4	8	30	200.0	AC	Compact.
1	99	64	43	33	18	6.0	5.2	98.2
2	98	66	46	34	17	5.0	5.2	97.5
3	99	68	48	36	19	7.0	4.8	97.4
4	99	67	47	36	19	7.0	5.4	96.7
5	99	65	45	33	18	6.0	4.9	98.1
6	98	64	44	32	16	6.0	4.7	97.4
7	100	68	47	35	18	6.0	4.9	96.6
8	99	70	49	35	19	7.0	5.1	98.1
9	98	67	46	34	18	6.0	5.4	97.4
10	99	65	44	31	16	6.0	5.2	97.1
11	99	66	45	34	17	6.0	5.2	97.2
12	98	68	47	34	17	6.0	5.4	96.6
13	99	66	47	36	19	6.0	5.3	99.1
14	99	65	46	34	18	7.0	5.4	99.4
15	99	66	45	33	16	5.0	5.0	98.8
16	99	62	40	29	15	5.0	5.0	98.7
17	100	70	49	36	19	7.0	4.8	98.7
18	99	70	51	39	20	7.0	5.4	98.3
19	98	64	45	32	16	6.0	4.7	99.1
20	98	65	44	32	16	5.0	5.4	97.9
21	98	64	45	34	18	6.0	5.1	97.9
22	99	61	43	33	18	6.0	4.8	98.7
23	97	62	41	32	17	6.0	5.2	98.7
24	96	58	40	30	15	6.0	5.1	98.8
25	99	62	43	32	17	6.0	5.2	98.7
26	99	60	40	30	17	6.0	5.4	97.9
27	98	58	41	31	17	6.0	4.8	97.9
28	97	62	41	32	18	6.0	5.6	97.8
29	99	68	49	37	19	7.0	4.6	99.2
30	99	67	48	37	20	7.0	5.5	98.7
31	97	63	45	34	18	7.0	5.2	98.5
32	99	62	43	32	17	6.0	5.5	99.5
33	99	65	48	35	18	7.0	5.0	98.4
34	99	66	47	36	19	7.0	5.5	98.4
35	97	65	47	36	18	7.0	5.3	98.4
36	97	62	44	33	18	7.0	5.2	98.8
37	97	63	44	34	18	7.0	5.5	99.2
38	96	63	44	33	17	6.0	5.3	99.3
39	98	68	54	42	23	8.0	5.2	98.4
40	98	61	43	33	18	7.0	5.4	97.9
41	97	65	47	36	20	7.0	5.1	99.2
42	98	60	44	33	18	7.0	4.9	98.7
43	96	63	43	33	17	7.0	5.1	99.4
44	99	62	43	32	17	7.0	5.4	99.3
45	96	61	43	32	17	7.0	4.7	99.3
46	98	63	45	35	19	8.0	4.8	99.0
47	98	61	44	34	18	7.0	5.6	95.0
48	98	58	37	28	15	6.0	5.2	99.0
49	98	63	44	34	18	8.0	5.3	99.1
50	99	65	46	34	17	7.0	5.1	98.4

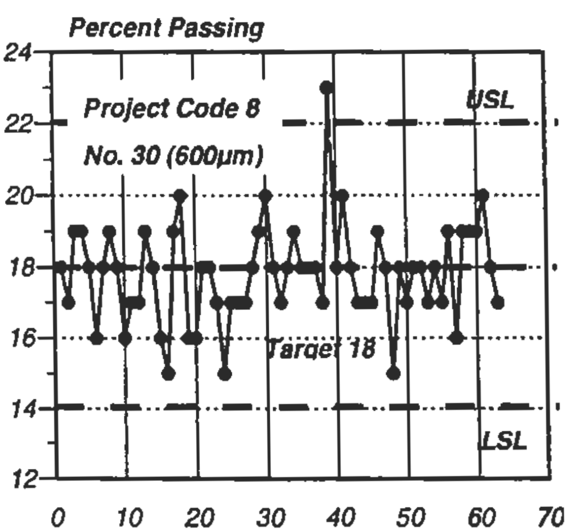
Code >	8							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
51	97	64	44	33	18	8.0	5.5	No Data Available
52	100	62	45	34	18	7.3	5.4	
53	95	59	41	30	17	6.4	5.1	
54	99	65	45	34	18	7.0	4.7	
55	98	63	45	32	17	6.5	4.8	
56	99	66	46	34	19	6.8	4.7	
57	97	61	41	31	16	6.9	5.1	
58	99	62	46	36	19	7.5	5.4	
59	99	63	47	36	19	7.4	5.3	
60	98	66	48	37	19	7.6	5.5	
61	99	66	48	37	20	6.4	5.2	
62	99	62	46	34	18	5.8	4.9	
63	98	62	44	33	17	5.6	5.1	
Count	63	63	63	63	63	63	63	50
Max	100	70	54	42	23	8.0	5.6	99.5
Min	95	58	37	28	15	5.0	4.6	95.0
Range	5	12	17	14	8	3.0	1.0	4.5
Mean	98.2	63.9	44.9	33.7	17.8	6.56	5.15	98.32
Std. Dev.	1.07	2.89	2.87	2.37	1.38	0.741	0.261	0.906

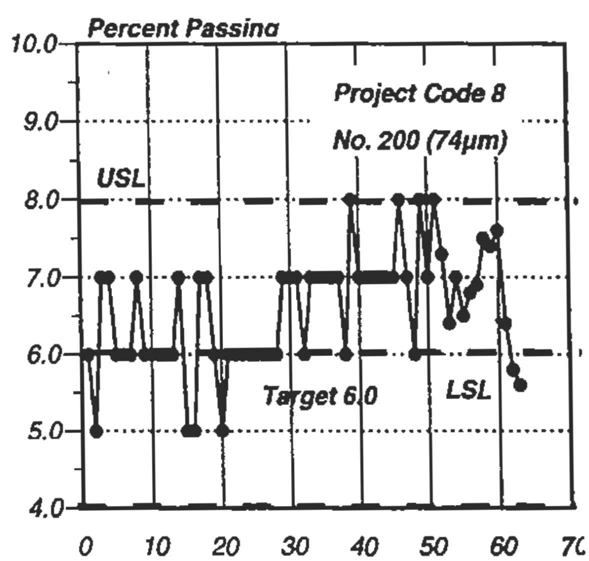

Percent Passing
Target 100
USL
Project Code 8
3/4 (19mm)
LSL
100
99
98
97
96
95
94
0
10
20
30
40
50
60
70

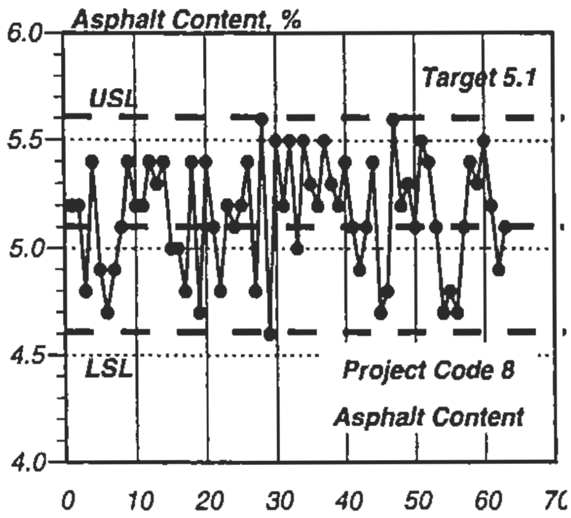

Percent Passing
USL
Project Code 8
3/8 (9.5mm)
Target 66
LSL
74
72
70
68
66
64
62
60
58
56
0
10
20
30
40
50
60
70

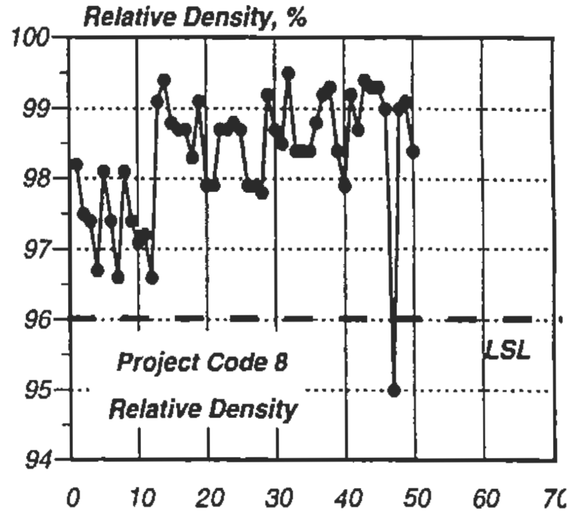

Percent Passing
USL
Project Code 8
No. 4 (4.75mm)
Target 46
LSL
56
54
52
50
48
46
44
42
40
38
36
34
0
10
20
30
40
50
60
70


Percent Passing
Project Code 8
No. 8 (2.36mm)
USL
Target 32
LSL
43
41
39
37
35
33
31
29
27
25
0
10
20
30
40
50
60
70


Percent Passing
Project Code 8
No. 30 (600μm)
USL
Target 18
LSL
24
22
20
18
16
14
12
0
10
20
30
40
50
60
70

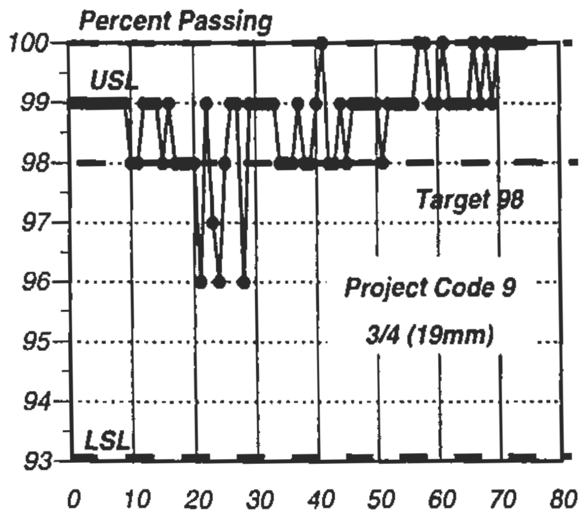

Percent Passing
Project Code 8
No. 200 (74μm)
USL
Target 6.0
LSL
10.0
9.0
8.0
7.0
6.0
5.0
4.0
0
10
20
30
40
50
60
70

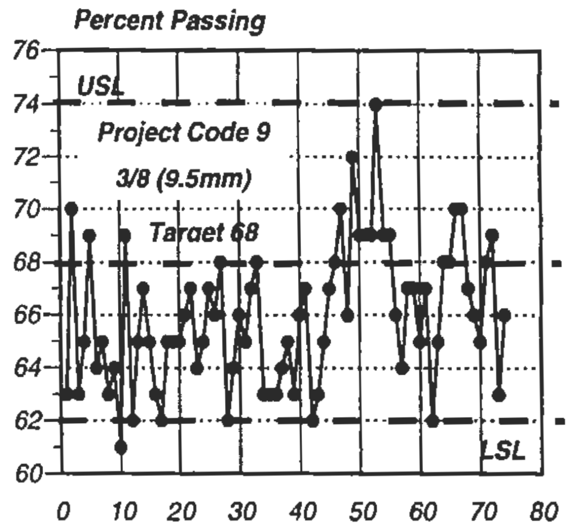

Asphalt Content, %
Target 5.1
USL
LSL
Project Code 8
Asphalt Content
6.0
5.5
5.0
4.5
4.0
0
10
20
30
40
50
60
70

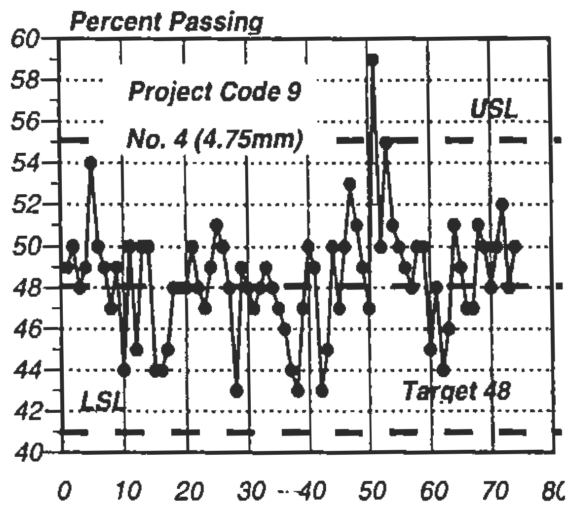

Relative Density, %
LSL
Project Code 8
Relative Density
100
99
98
97
96
95
94
0
10
20
30
40
50
60
70

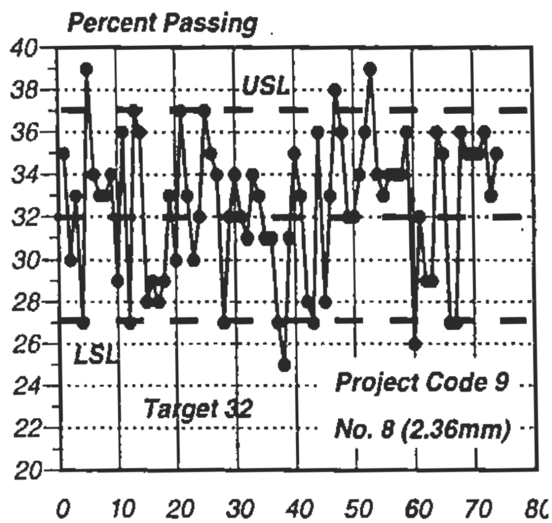
Code > Sub Lot	9 3/4	3/8	4	8	30	200	AC	Compact.
1	99	63	49	35	17	4.0	5.2	97.6
2	99	70	50	30	16	3.0	4.7	98.8
3	99	63	48	33	16	4.0	4.9	98.4
4	99	65	49	27	13	3.0	4.4	96.5
5	99	69	54	39	19	5.0	4.6	98.8
6	99	64	50	34	16	4.0	4.6	98.1
7	99	65	49	33	16	3.8	3.8	94.9
8	99	63	47	33	15	3.3	4.6	97.3
9	99	64	49	34	15	3.9	4.8	97.3
10	98	61	44	29	15	3.1	4.7	95.3
11	98	69	50	36	19	3.5	4.3	95.3
12	99	62	45	27	14	2.7	4.5	100.0
13	99	65	50	37	19	4.0	4.0	96.1
14	99	67	50	36	19	4.0	4.2	95.4
15	98	65	44	28	15	2.6	4.2	96.4
16	99	63	44	29	15	3.1	4.7	97.1
17	98	62	45	28	15	2.7	4.8	99.4
18	98	65	48	29	14	2.9	4.7	97.9
19	98	65	48	33	16	3.3	4.5	98.7
20	98	65	48	30	14	2.8	4.7	98.7
21	96	66	50	37	19	4.0	4.5	98.1
22	99	67	48	33	17	3.8	4.3	98.1
23	97	64	47	30	15	3.3	5.5	97.6
24	96	65	49	32	16	3.4	5.5	99.8
25	98	67	51	37	20	4.7	4.7	100.0
26	99	66	50	35	18	4.4	4.7	97.9
27	99	68	48	34	18	4.2	4.8	97.3
28	96	62	43	27	14	3.3	4.6	99.5
29	99	64	49	32	16	3.4	4.8	100.0
30	99	66	48	34	17	3.8	4.5	97.2
31	99	65	47	32	17	3.8	4.8	98.3
32	99	67	48	31	16	3.4	4.4	97.8
33	99	68	49	34	19	3.9	4.4	99.1
34	98	63	48	33	17	3.8	5.0	96.8
35	98	63	47	31	17	3.8	4.7	98.8
36	98	63	46	31	16	3.7	4.8	98.0
37	99	64	44	27	14	3.5	4.9	97.1
38	98	65	43	25	12	3.0	5.0	96.0
39	98	63	47	31	16	3.8	4.8	96.6
40	99	66	50	35	18	4.0	5.0	97.6
41	100	67	49	33	16	3.9	4.7	96.1

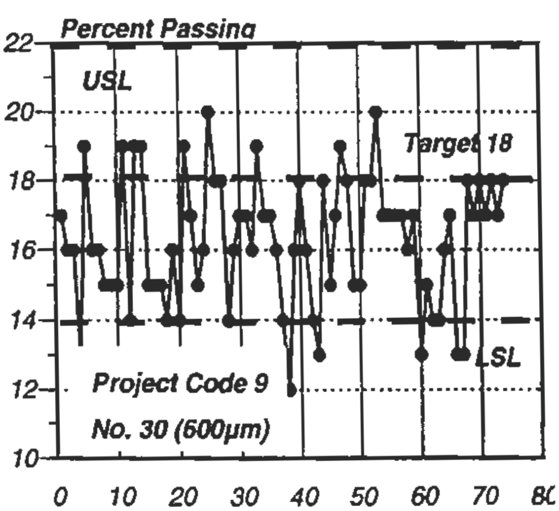
Code >	9							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
42	98	62	43	28	14	3.0	5.1	98.7
43	98	63	45	27	13	2.7	5.2	98.7
44	99	65	50	36	18	4.0	4.4	99.6
45	98	67	47	28	15	3.3	4.9	99.2
46	99	68	50	33	17	4.0	5.3	97.2
47	99	70	53	38	19	4.2	5.3	99.6
48	99	66	51	36	18	4.1	5.2	99.2
49	99	72	49	32	15	3.9	5.0	97.2
50	99	69	47	32	15	3.3	4.4	96.9
51	98	69	59	34	18	3.9	4.6	98.4
52	99	69	50	36	18	4.0	4.3	99.2
53	99	74	55	39	20	3.9	4.3	98.7
54	99	69	51	34	17	3.6	4.4	97.7
55	99	69	50	33	17	4.0	4.1	97.1
56	99	66	49	34	17	3.9	4.2	95.7
57	100	64	48	34	17	3.8	4.4	97.2
58	100	67	50	34	16	3.5	4.4	96.4
59	99	67	50	36	17	3.5	4.3	96.1
60	99	65	45	26	13	3.2	4.4	95.6
61	100	67	48	32	15	3.4	4.5	98.2
62	99	62	44	29	14	3.1	4.5	97.4
63	99	65	46	29	14	3.2	4.9	97.4
64	99	68	51	36	16	4.1	4.4	96.9
65	99	68	49	35	17	3.9	4.2	97.6
66	100	70	47	27	13	2.8	4.6	97.4
67	99	70	47	27	13	2.8	4.5	95.4
68	100	67	51	36	18	3.6	4.3	94.2
69	99	66	50	35	17	3.0	4.3	97.3
70	100	65	48	35	18	3.8	4.3	97.8
71	100	68	50	35	17	4.0	4.6	97.6
72	100	69	52	36	18	4.2	4.3	97.7
73	100	63	48	33	17	3.8	4.1	97.2
74	100	66	50	35	18	4.0	4.7	94.9
Count	74	74	74	74	74	74	74	74
Max	100	74	59	39	20	5.0	5.5	100.0
Min	96	61	43	25	12	2.6	3.8	94.2
Range	4	13	16	14	8	2.4	1.7	5.8
Mean	98.8	65.9	48.4	32.5	16.3	3.61	4.62	97.58
Std. Dev.	0.87	2.62	2.78	3.40	1.86	0.497	0.345	1.348

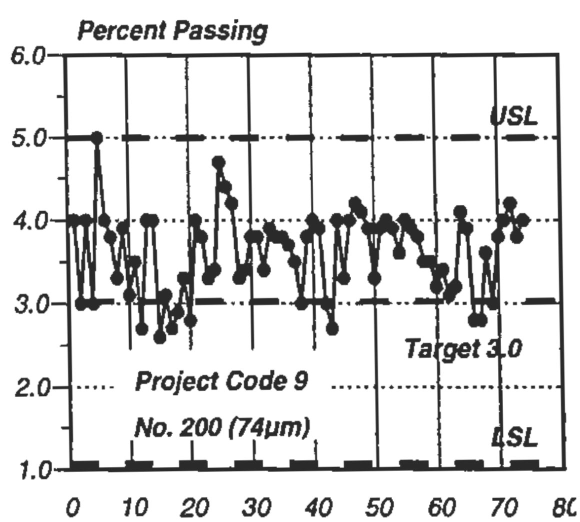

Percent Passing
USL
LSL
Target 98
Project Code 9
3/4 (19mm)

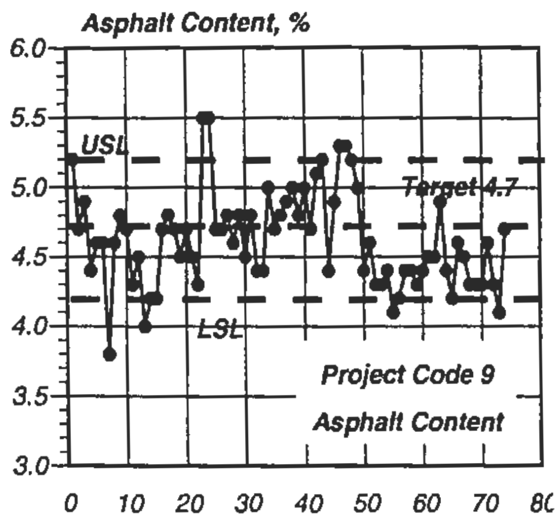

Percent Passing
USL
Project Code 9
3/8 (9.5mm)
Target 68
LSL

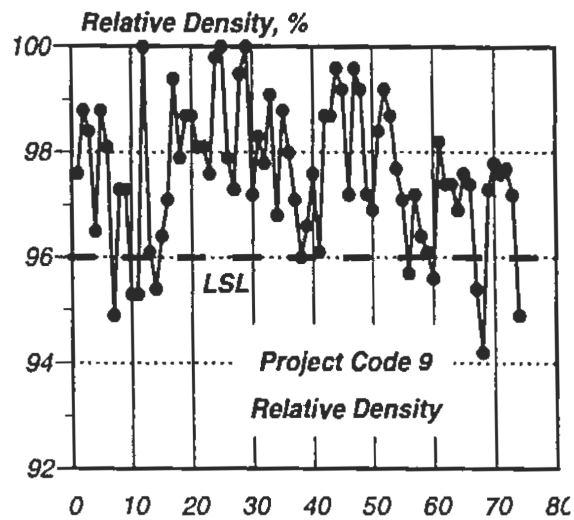

Percent Passing
Project Code 9
No. 4 (4.75mm)
USL
LSL
Target 48


Percent Passing
USL
LSL
Target 32
Project Code 9
No. 8 (2.36mm)

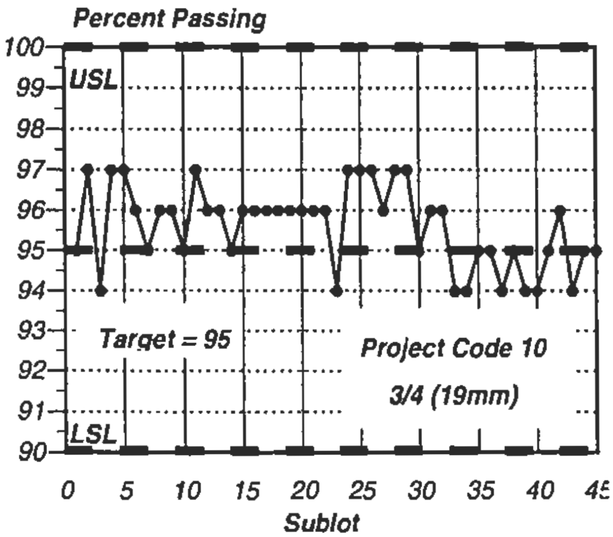

Percent Passing
USL
Target 18
LSL
Project Code 9
No. 30 (600μm)

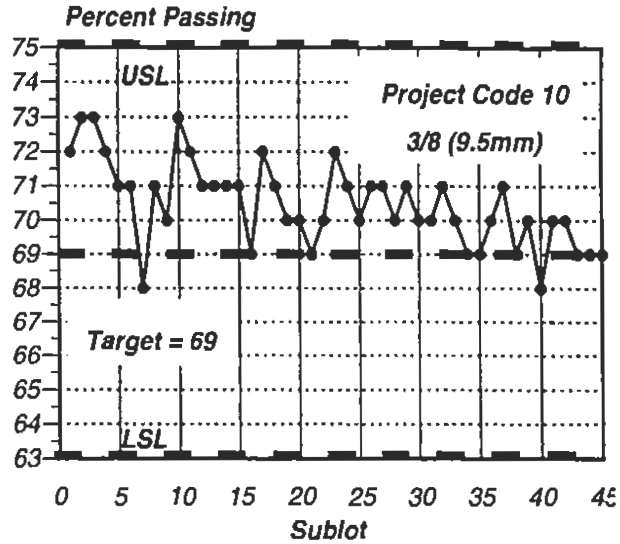

Percent Passing
USL
Target 3.0
Project Code 9
No. 200 (74μm)
LSL

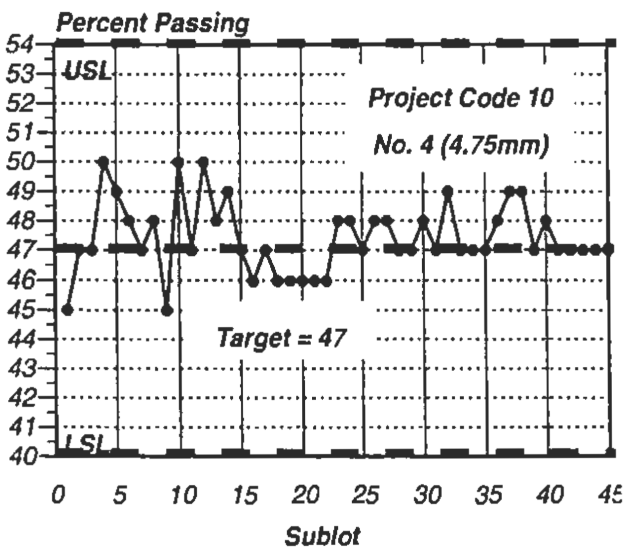

Asphalt Content, %
6.0
5.5
5.0
4.5
4.0
3.5
3.0
USL
Target 4.7
LSL
Project Code 9
Asphalt Content
0
10
20
30
40
50
60
70
80

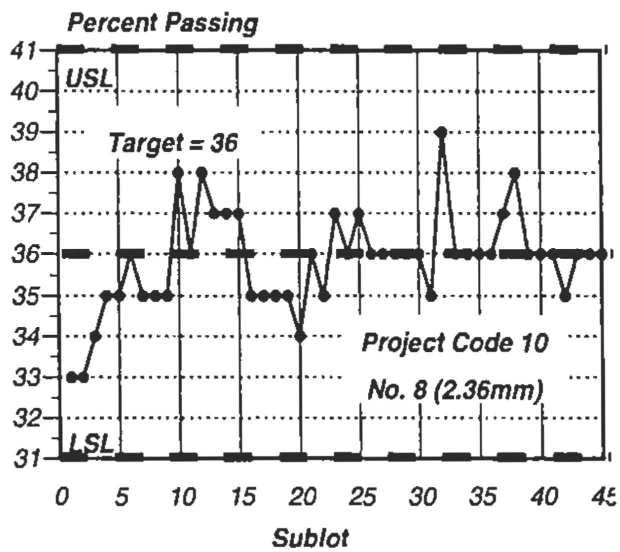

Relative Density, %
100
98
96
94
92
LSL
Project Code 9
Relative Density
0
10
20
30
40
50
60
70
80

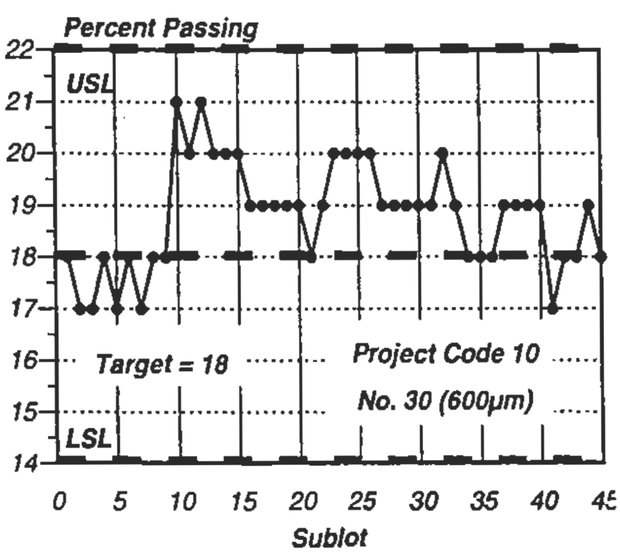
Code >	10							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
1	95	72	45	33	18	4.0	4.6	97.1
2	97	73	47	33	17	4.0	4.6	97.8
3	94	73	47	34	17	4.0	4.6	96.5
4	97	72	50	35	18	4.0	4.5	97.5
5	97	71	49	35	17	4.0	4.5	97.1
6	96	71	48	36	18	4.0	4.7	97.5
7	95	68	47	35	17	5.0	4.7	97.5
8	96	71	48	35	18	4.0	4.5	97.5
9	96	70	45	35	18	5.0	4.5	97.1
10	95	73	50	38	21	5.0	4.7	96.6
11	97	72	47	36	20	4.0	4.4	97.9
12	96	71	50	38	21	5.0	4.6	97.1
13	96	71	48	37	20	4.0	4.5	97.5
14	95	71	49	37	20	4.0	4.7	97.5
15	96	71	47	37	20	5.0	4.6	97.1
16	96	69	46	35	19	5.0	4.6	97.5
17	96	72	47	35	19	5.0	4.8	97.5
18	96	71	46	35	19	5.0	4.6	97.1
19	96	70	46	35	19	5.0	4.8	97.1
20	96	70	46	34	19	5.0	4.6	97.1
21	96	69	46	36	18	4.0	4.6	97.5
22	96	70	46	35	19	5.0	4.6	97.8
23	94	72	48	37	20	4.0	4.6	97.5
24	97	71	48	36	20	5.0	4.6	97.8
25	97	70	47	37	20	5.0	4.7	97.8
26	97	71	48	36	20	4.0	4.7	97.8
27	96	71	48	36	19	5.0	4.7	97.5
28	97	70	47	36	19	4.0	4.7	97.5
29	97	71	47	36	19	5.0	4.8	97.8
30	95	70	48	36	19	4.0	4.6	97.0
31	96	70	47	35	19	5.0	4.7	97.8
32	96	71	49	39	20	4.0	4.7	97.5
33	94	70	47	36	19	4.0	4.5	97.5
34	94	69	47	36	18	4.0	4.4	98.3
35	95	69	47	36	18	4.0	4.6	97.8
36	95	70	48	36	18	4.0	4.5	97.5
37	94	71	49	37	19	4.0	4.6	97.8
38	95	69	49	38	19	5.0	4.8	98.3
39	94	70	47	36	19	5.0	4.7	97.5
40	94	68	48	36	19	4.0	4.6	96.2
41	95	70	47	36	17	4.0	4.5	97.0
42	96	70	47	35	18	5.0	4.7	97.1
43	94	69	47	36	18	4.0	4.6	97.5
44	95	69	47	36	19	5.0	4.5	97.8
45	95	69	47	36	18	4.0	4.6	97.5
Count	45	45	45	45	45	45	45	45
Max	97	73	50	39	21	5.0	4.8	98.3
Min	94	68	45	33	17	4.0	4.4	96.2
Range	3	5	5	6	4	1.0	0.4	2.1
Mean	95.6	70.5	47.4	35.8	18.8	4.44	4.62	97.44
Std. Dev.	1.01	1.24	1.20	1.21	1.04	0.503	0.100	0.416

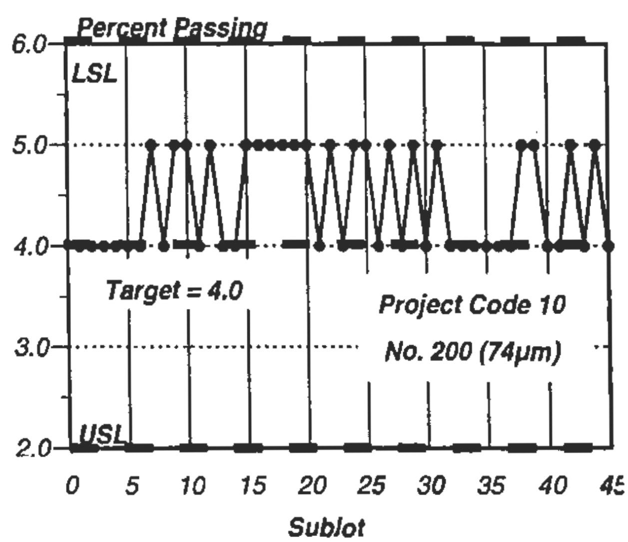

Percent Passing
USL
LSL
Target = 95
Project Code 10
3/4 (19mm)
Sublot

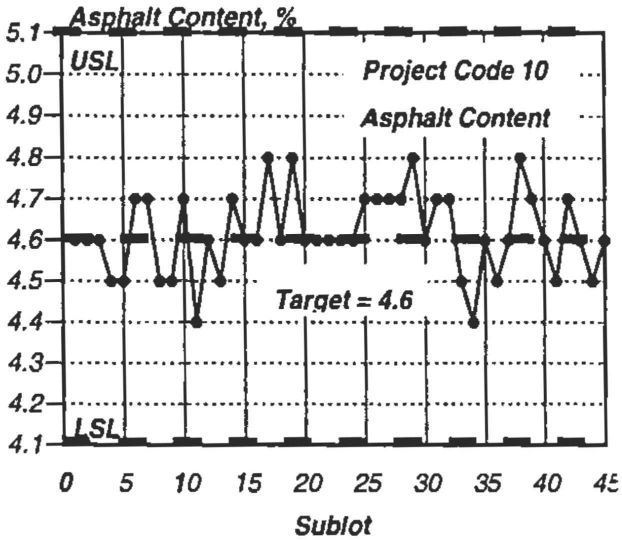

Percent Passing
USL
LSL
Project Code 10
3/8 (9.5mm)
Target = 69
Sublot

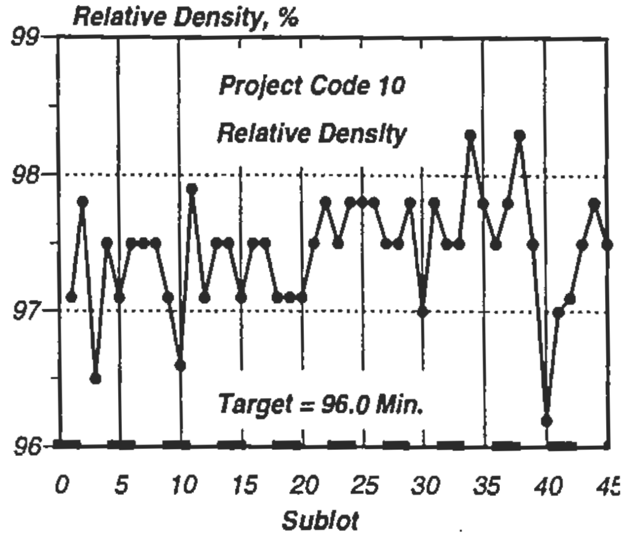

Percent Passing
USL
LSL
Project Code 10
No. 4 (4.75mm)
Target = 47
Sublot


Percent Passing
USL
LSL
Target = 36
Project Code 10
No. 8 (2.36mm)
Sublot


Percent Passing
USL
LSL
Target = 18
Project Code 10
No. 30 (600μm)
Sublot


Percent Passing
LSL
USL
Target = 4.0
Project Code 10
No. 200 (74μm)
Sublot


Asphalt Content, %
USL
LSL
Project Code 10
Asphalt Content
Target = 4.6
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
0 5 10 15 20 25 30 35 40 45
Sublot

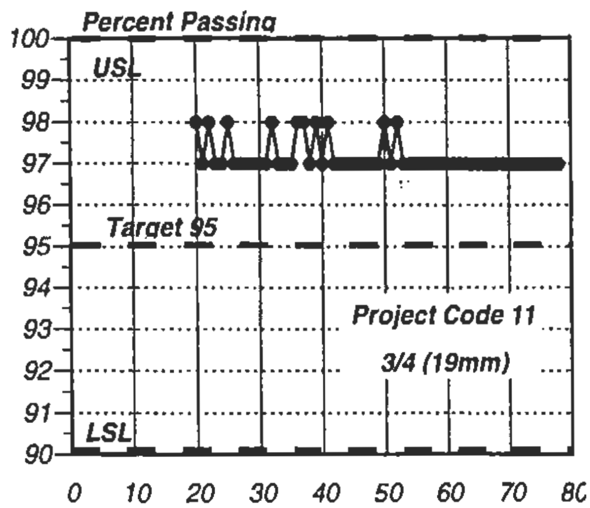

Relative Density, %
Project Code 10
Relative Density
Target = 96.0 Min.
99
98
97
96
0 5 10 15 20 25 30 35 40 45
Sublot

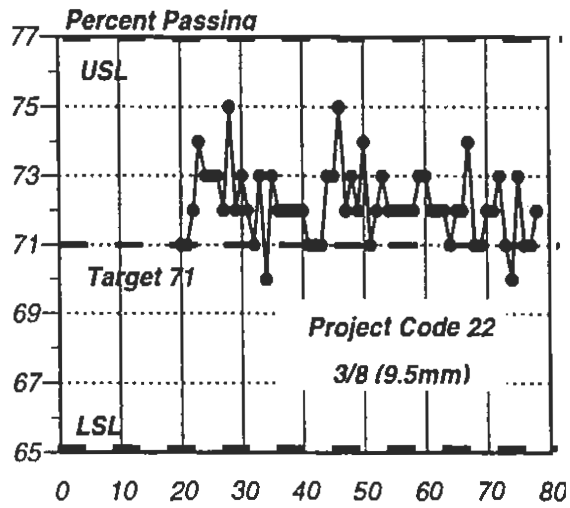
Coda >	11								
Sub Lot	3/4	3/8	4	8	30	200	AC	Moist.	Compact.
19	98	.71	51	39	20	6	5.6	0.04	97.2
20	98	71	52	39	19	5	5.4	0.03	97.4
21	97	71	52	39	18	4	5.3	0.03	97.1
22	98	72	54	41	20	4	5.5	0.03	97.1
23	97	74	54	43	22	4	5.3	0.03	96.9
24	97	73	54	40	19	4	5.2	0.04	97.0
25	98	73	54	41	19	4	5.1	0.03	97.2
26	97	73	51	40	19	4	5.4	0.03	97.1
27	97	72	51	39	18	4	5.5	0.04	96.1
28	97	75	52	41	22	5	5.0	0.03	97.1
29	97	72	53	40	20	5	5.4	0.04	96.8
30	97	73	52	40	19	5	5.4	0.04	97.4
31	97	72	49	39	20	5	5.5	0.04	96.2
32	98	71	49	38	18	4	5.4	0.04	96.6
33	97	73	57	43	20	5	5.4	0.04	97.1
34	97	70	53	40	19	5	5.3	0.03	96.2
35	97	73	51	40	19	5	5.2	0.04	96.6
36	98	72	52	39	17	5	5.3	0.03	97.1
37	98	72	51	39	18	5	5.0	0.04	97.9
38	97	72	48	39	18	5	5.2	0.04	97.0
39	98	72	50	38	18	5	5.2	0.04	97.0
40	97	72	51	38	18	6	5.3	0.04	96.6
41	98	71	51	39	17	5	5.1	0.03	96.6
42	97	71	50	40	17	4	5.3	0.04	96.6
43	97	71	49	39	18	4	5.1	0.04	
44	97	73	51	36	16	6	5.2	0.03	
45	97	73	51	37	16	6	5.3	0.03	
46	97	75	54	42	21	5	5.1	0.04	
47	97	72	52	39	19	5	5.3	0.04	
48	97	73	51	40	21	5	5.6	0.04	
49	97	72	53	41	20	6	5.4	0.04	
50	98	74	54	45	24	5	5.3	0.04	
51	97	71	52	39	18	4	5.0	0.04	
52	98	72	53	40	19	4	5.1	0.03	
53	97	73	53	40	19	5	5.1	0.04	
54	97	72	53	39	20	6	5.3	0.04	
55	97	72	53	41	21	5	5.0	0.03	
56	97	72	53	38	17	5	5.3	0.03	
57	97	72	53	38	19	7	5.5	0.04	
58	97	72	55	40	20	6	5.5	0.04	
59	97	73	57	42	19	5	5.1	0.04	
60	97	73	55	43	20	4	5.4	0.04	
61	97	72	52	39	17	4	5.5	0.04	
62	97	72	52	41	19	4	5.3	0.04	
63	97	72	52	40	20	5	4.7	0.03	
64	97	71	54	37	18	7	5.2	0.03	
65	97	72	52	38	17	4	5.5	0.04	

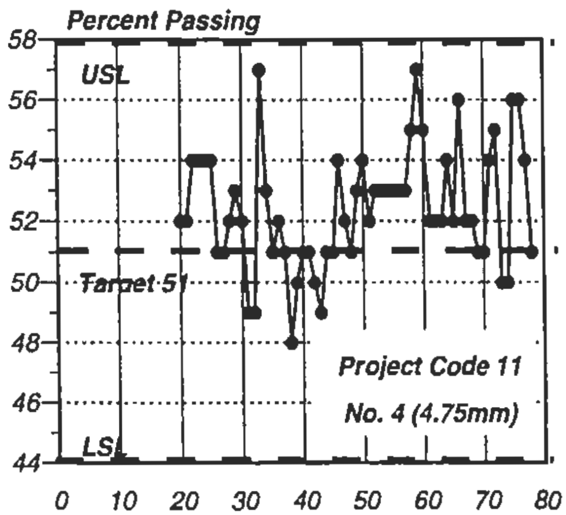
Code >	11, Cont'd.								
Sub Lot	3/4	3/8	4	8	30	200	AC	Moist.	Compact.
66	97	72	56	43	21	5	5.3	0.03	
67	97	74	52	38	18	5	5.3	0.04	
68	97	71	52	39	19	5	4.8	0.03	
69	97	71	51	39	18	6	5.3	0.03	
70	97	72	51	39	18	4	5.1	0.03	
71	97	72	54	41	20	5	5.2	0.04	
72	97	73	55	40	21	5	5.0	0.04	
73	97	71	50	38	19	5	4.9	0.04	
74	97	70	50	36	18	7	5.2	0.03	
75	97	73	56	41	19	6	5.5	0.03	
76	97	71	56	43	21	6	5.3	0.04	
77	97	71	54	41	21	5	5.2	0.04	
78	97	72	51	38	18	5	5.3	0.04	
Count	60	60	60	60	60	60	60	60	24
Max	98.0	75.0	57.0	45.0	24.0	7.0	5.6	0.0	97.9
Min	97.0	70.0	48.0	36.0	16.0	4.0	4.7	0.0	96.1
Range	1.0	5.0	9.0	9.0	8.0	3.0	0.9	0.0	1.8
Mean	97.2	72.1	52.4	39.7	19.1	4.98	5.26	0.04	96.91
Std. Dev.	0.39	1.05	1.98	1.77	1.53	0.813	0.189	0.005	0.418

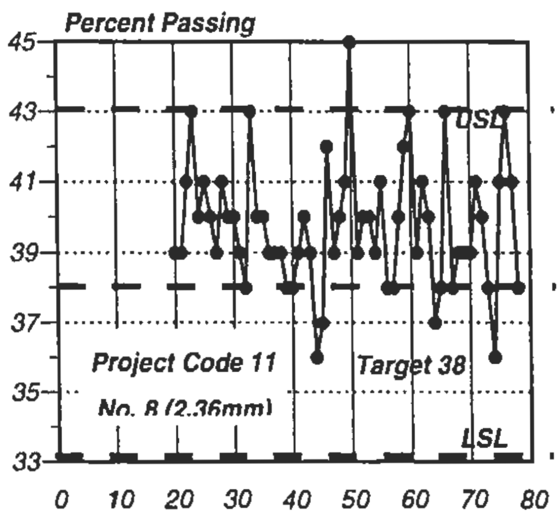
The following sublots were not input into ACPay by Caltrans for calculating Pay Factor. Therefore, they should be removed from the analysis

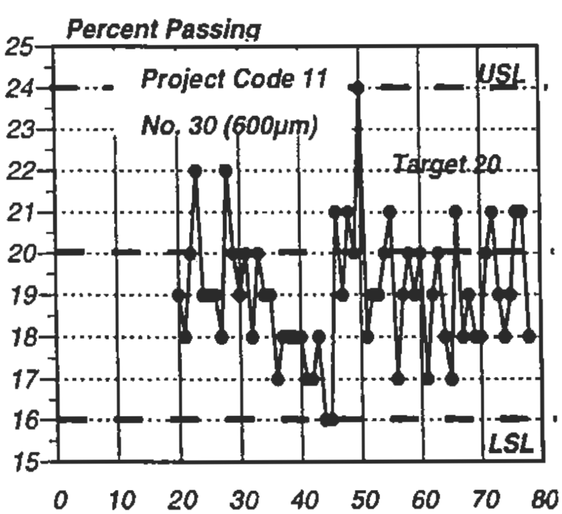
1	98	70	53	41	20	4	5.6	0.04	96.2
2	97	72	53	38	19	7	5.0	0.03	96.6
3	98	72	51	39	20	5	5.4	0.03	98.0
4	97	71	50	39	18	4	5.3	0.04	92.4
5	98	70	51	39	18	4	5.3	0.03	97.9
6	97	70	51	39	20	5			97.0
7	97	72	51	38	18	4	5.1	0.03	97.0
8	98	71	50	37	19	5	4.9	0.03	
9	97	71	48	39	19	5	5.4	0.04	
10	97	74	52	41	21	5	5.1	0.04	
11	98	72	53	40	19	6	5.3	0.03	
12	98	70	49	39	20	4	5.2	0.03	
13	98	70	52	40	19	5	5.4	0.04	
14	97	70	49	38	19	5	5.2	0.03	
15	97	71	50	38	21	7	5.4	0.04	
16	98	71	51	38	19	5	5.3	0.04	
17	97	69	48	40	20	5	5.3	0.04	
18	98	69	46	36	17	5	5.3	0.03	

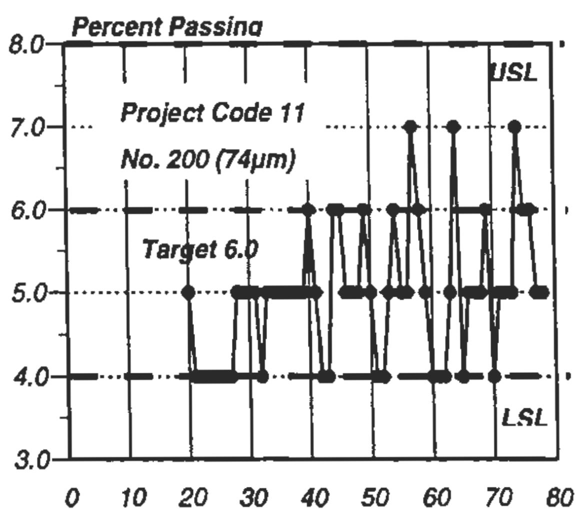

Percent Passing
USL
Target 95
Project Code 11
3/4 (19mm)
LSL


Percent Passing
USL
Target 71
Project Code 22
3/8 (9.5mm)
LSL


Percent Passing
USL
Target 51
Project Code 11
No. 4 (4.75mm)
LSL


Percent Passing
USL
Project Code 11
Target 38
LSL

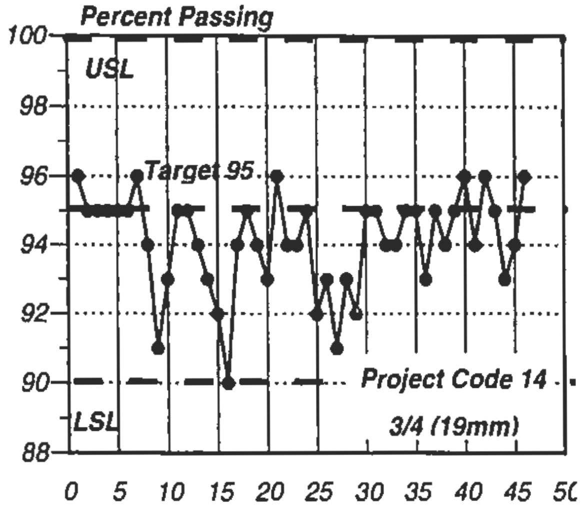

Percent Passing
Project Code 11
No. 30 (600µm)
USL
Target 20
LSL

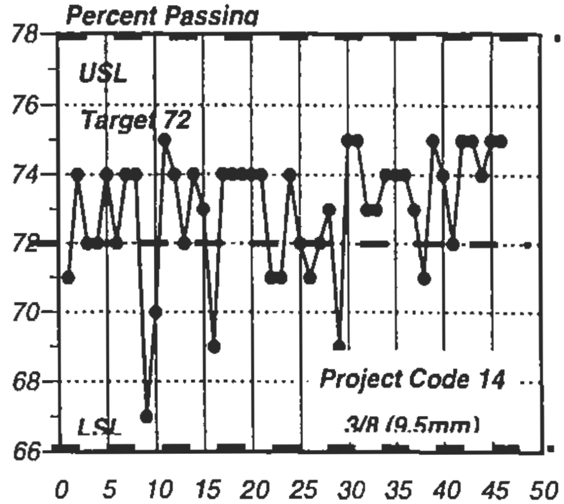

Percent Passing
USL
Project Code 11
No. 200 (74µm)
Target 6.0
LSL

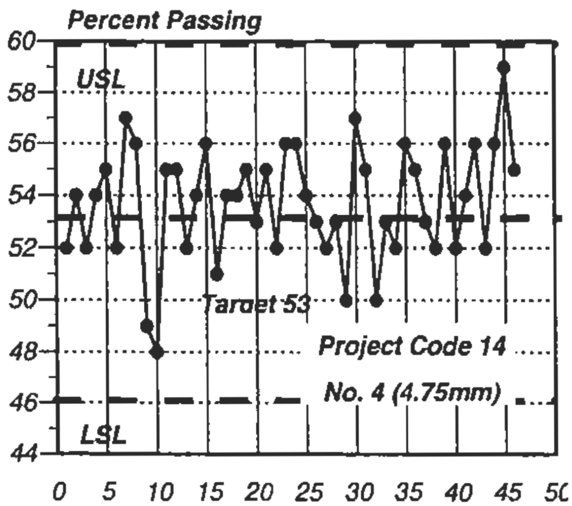
Code >	12							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
1	100	71	48	35	17	2.9	4.9	99.5
2	100	71	49	36	18	3.4	4.6	99.5
3	100	72	48	37	18	3.5	4.9	98.5
4	100	72	49	37	18	3.4	4.9	98.5
5	100	70	47	34	17	3.3	5.3	100.0
6	100	73	48	34	16	2.9	5.3	99.6
7	100	71	48	35	17	2.9	5.0	99.3
8	100	72	49	34	16	2.9	4.9	99.3
9	100	74	50	36	18	3.5	5.2	98.8
10	100	73	48	36	18	2.9	4.7	98.8
11	100	74	50	36	17	2.5	5.4	99.3
12	100	72	49	36	18	3.4	5.2	99.4
13	100	73	48	36	16	2.9	5.4	99.3
14	100	74	50	39	21	4.0	5.1	99.1
15	100	73	50	39	21	3.5	5.4	99.1
16	100	71	49	36	18	2.9	5.3	99.5
17	100	74	51	36	18	3.6	5.3	99.4
18	100	73	49	35	18	2.9	5.1	99.5
19	100	72	48	37	20	3.1	5.0	99.5
20	100	70	48	36	19	3.4	5.1	99.7
21	100	71	48	36	19	2.9	5.1	99.8
22	100	70	47	38	21	3.6	5.0	99.2
23	100	70	47	33	14	2.4	4.9	98.9
24	100	74	51	36	19	3.1	4.8	99.8
25	100	71	50	36	20	3.5	4.9	99.7
26	100	71	49	36	19	3.4	5.0	100.0
27	100	70	49	36	19	3.4	4.7	99.1
28	100	71	50	39	21	2.5	4.8	98.6
29	100	72	48	35	18	3.4	4.9	98.2
30	100	74	50	37	18	3.1	5.0	98.5
31	100	70	51	37	18	3.6	5.1	98.2
32	100	72	50	37	19	3.5	5.1	99.7
33	100	72	49	36	18	3.4	4.8	98.8
34	99	73	51	37	18	3.6	5.2	99.3
35	100	72	50	36	19	4	5.1	99.1
36	100	73	51	37	20	4.1	5.2	98.5
37	99	70	49	35	16	2.9	5.2	99.0
38	100	71	50	36	18	3.5	5	98.4
39	100	72	51	37	17	3.6	4.8	98.9
40	99	71	51	35	15	3.1	5.1	98.9
41	100	72	50	37	19	4	4.8	98.6
42	100	72	49	34	18	3.3	5.2	98.8
43	100	74	50	35	19	3.5	4.8	98.3
44	100	74	51	36	20	3.9	5.2	98.2
45	100	71	49	34	17	3.2	4.8	98.0
46	100	72	49	35	18	3.4	5.1	98.5
47	100	72	50	37	19	3.5	4.7	97.7
48	100	73	50	36	18	3.5	5.1	97.8
49	100	73	49	37	17	2.9	5.2	96.9
50	100	71	47	36	18	3.3	5.1	97.6
51	100	73	49	35	18	3.4	5.1	97.0
52	100	72	48	36	16	3.4	5.2	97.9

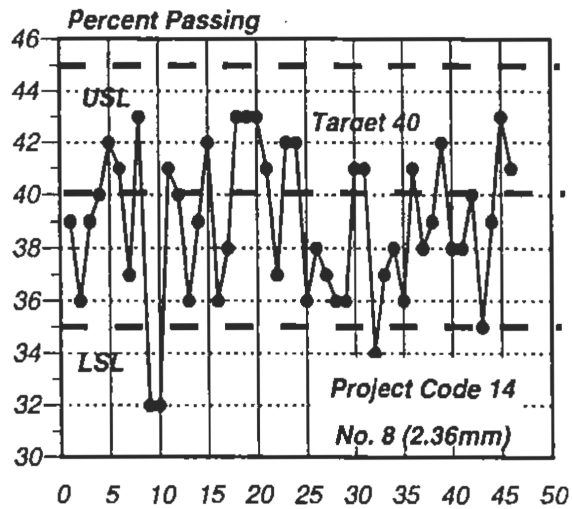
Count	52	52	52	52	52	52	52	52
Max	100	74	51	39	21	4.1	5.4	100.0
Min	99	70	47	33	14	2.4	4.6	96.9
Range	1	4	4	6	7	1.7	0.8	3.1
Mean	99.9	72.0	49.2	36.0	18.1	3.30	5.04	98.88
Std. Dev.	0.24	1.27	1.18	1.26	1.49	0.38	0.20	0.723

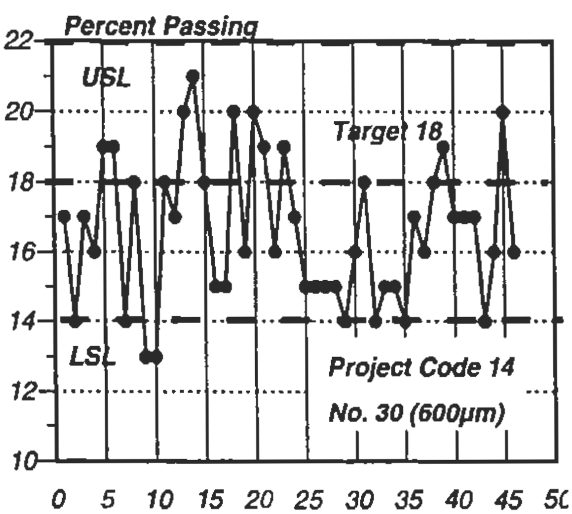
Code >	14							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
1	96	71	52	39	17	3.0	5.9	
2	95	74	54	36	14	2.0	5.5	
3	95	72	52	39	17	3.0	6.5	
4	95	72	54	40	16	2.0	5.8	
5	95	74	55	42	19	4.0	6.3	
6	95	72	52	41	19	5.0	5.3	
7	96	74	57	37	14	2.0	7.3	
8	94	74	56	43	18	2.0	6.5	
9	91	67	49	32	13	2.0	6.29	
10	93	70	48	32	13	2.0	6.15	
11	95	75	55	41	18	3.0	6.56	
12	95	74	55	40	17	4.0	6.04	
13	94	72	52	36	20	5.0	6.56	
14	93	74	54	39	21	4.0	6.80	
15	92	73	56	42	18	3.0	6.57	
16	90	69	51	36	15	3.0	6.29	
17	94	74	54	38	15	3.0	6.48	
18	95	74	54	43	20	4.0	6.70	
19	94	74	55	43	16	4.0	6.60	
20	93	74	53	43	20	4.0	6.75	
21	96	74	55	41	19	4.0	6.11	
22	94	71	52	37	16	3.0	6.50	
23	94	71	56	42	19	3.0	6.60	
24	95	74	56	42	17	3.0	6.48	
25	92	72	54	36	15	3.0	6.47	
26	93	71	53	38	15	3.0	6.43	
27	91	72	52	37	15	3.0	6.70	
28	93	73	53	36	15	3.0	6.50	
29	92	69	50	36	14	3.0	6.10	
30	95	75	57	41	16	4.0	6.50	
31	95	75	55	41	18	4.0	6.40	
32	94	73	50	34	14	3.0	6.00	
33	94	73	53	37	15	3.0	6.50	
34	95	74	52	38	15	4.0	6.50	
35	95	74	56	36	14	3.0	6.40	
36	93	74	55	41	17	3.0	6.20	
37	95	73	53	38	16	3.0	6.20	
38	94	71	52	39	18	4.0	6.40	
39	95	75	56	42	19	5.0	6.60	
40	96	74	52	38	17	4.0	6.50	
41	94	72	54	38	17	4.0	6.10	
42	96	75	56	40	17	4.0	6.50	
43	95	75	52	35	14	3.0	6.60	
44	93	74	56	39	16	2.0	6.50	
45	94	75	59	43	20	4.0	6.40	
46	96	75	55	41	16	3.0	6.60	
Count	46	46	46	46	46	46	46	
Max	96	75	59	43	21	5.0	7.3	
Min	90	67	48	32	13	2.0	5.3	
Range	6	8	11	11	8	3.0	2.0	
Mean	94.1	73.0	53.7	38.9	16.6	3.30	6.38	
Std. Dev.	1.43	1.84	2.25	2.90	2.08	0.813	0.334	

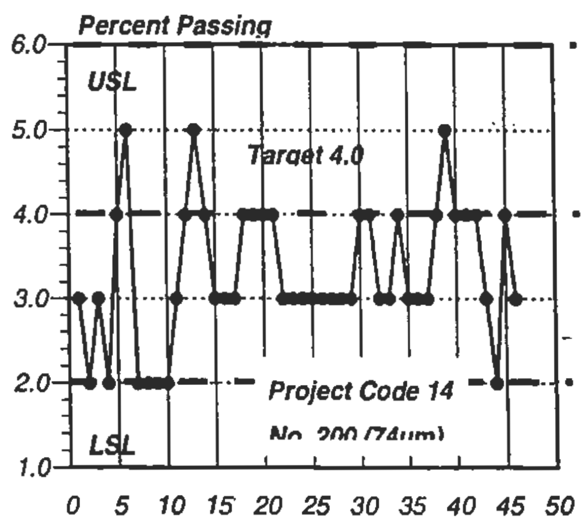

Percent Passing
USL
Target 95
LSL
Project Code 14
3/4 (19mm)
100
98
96
94
92
90
88
0 5 10 15 20 25 30 35 40 45

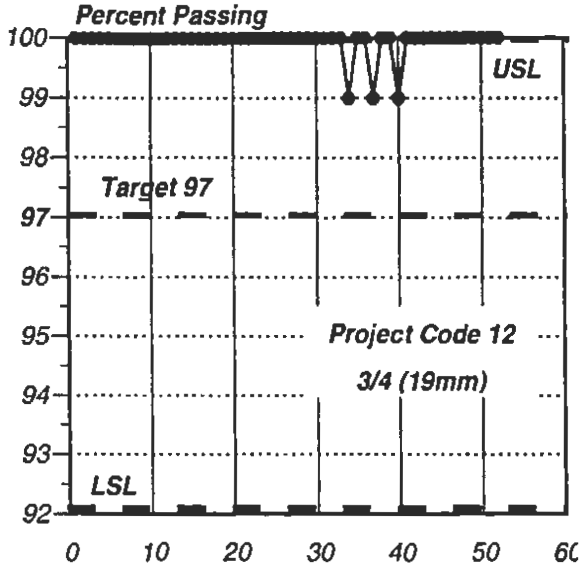

Percent Passing
USL
Target 72
LSL
Project Code 14
3/8 (9.5mm)
78
76
74
72
70
68
66
0 5 10 15 20 25 30 35 40 45 50

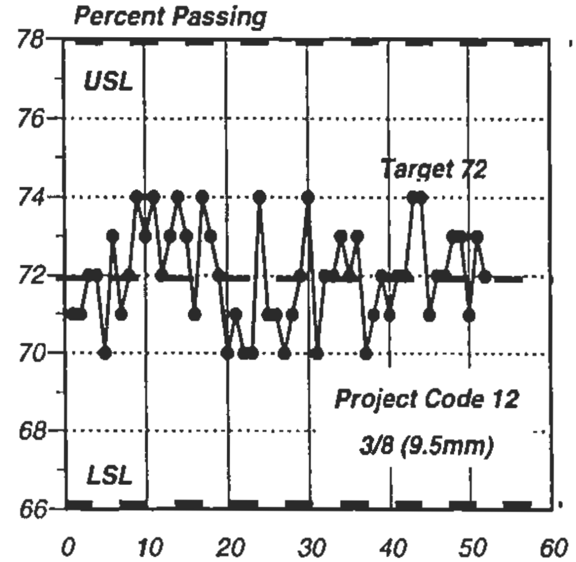

Percent Passing
USL
Target 53
LSL
Project Code 14
No. 4 (4.75mm)
60
58
56
54
52
50
48
46
44
0 5 10 15 20 25 30 35 40 45

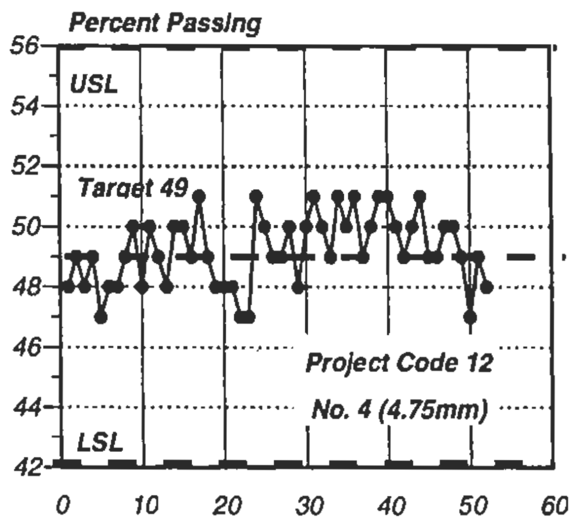

Percent Passing
USL
Target 40
LSL
Project Code 14
No. 8 (2.36mm)
46
44
42
40
38
36
34
32
30
0 5 10 15 20 25 30 35 40 45 50

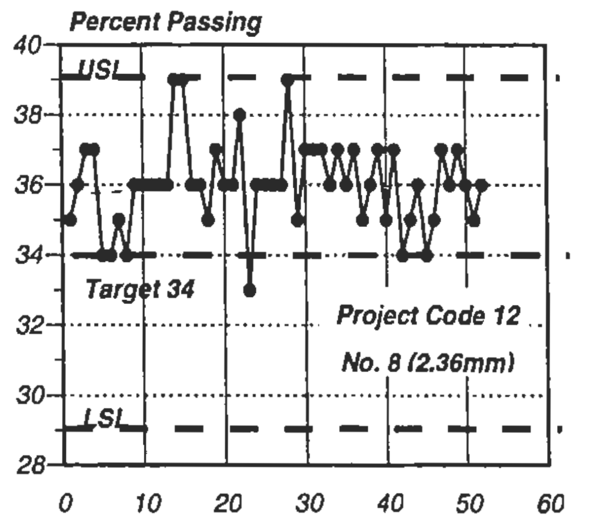

Percent Passing
USL
Target 18
LSL
Project Code 14
No. 30 (600µm)
22
20
18
16
14
12
10
0 5 10 15 20 25 30 35 40 45

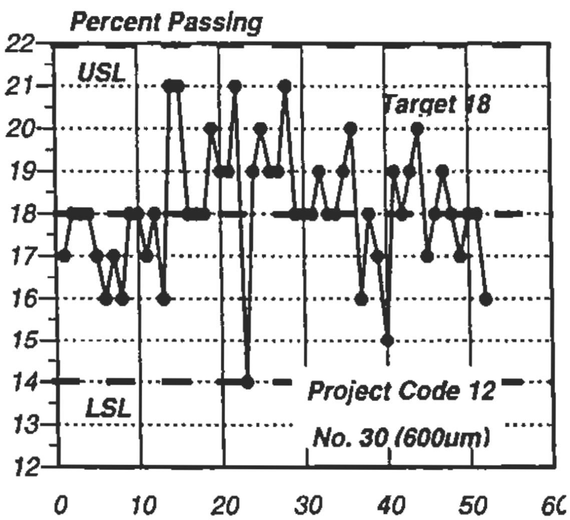

Percent Passing
USL
Target 4.0
LSL
Project Code 14
6.0
5.0
4.0
3.0
2.0
1.0
0 5 10 15 20 25 30 35 40 45 50

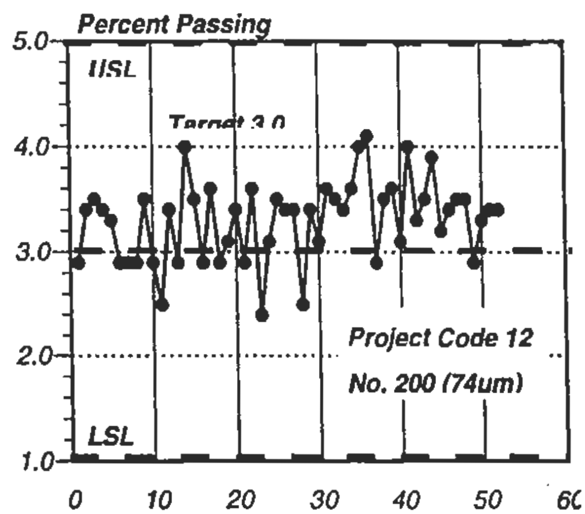

Percent Passing
100
99
98
97
96
95
94
93
92
USL
Target 97
Project Code 12
3/4 (19mm)
LSL
0
10
20
30
40
50
60

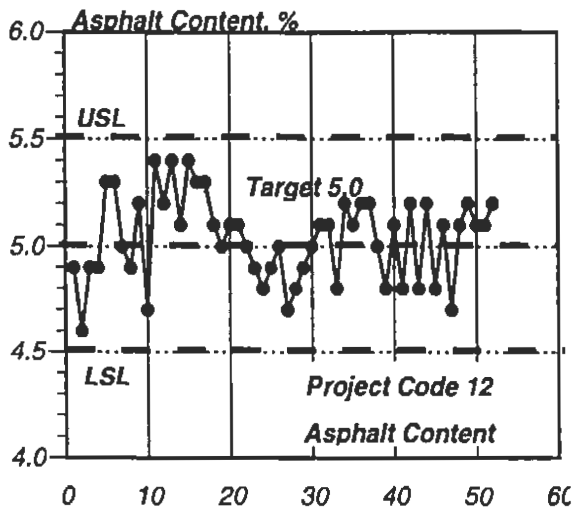

Percent Passing
78
76
74
72
70
68
66
USL
Target 72
Project Code 12
3/8 (9.5mm)
LSL
0
10
20
30
40
50
60

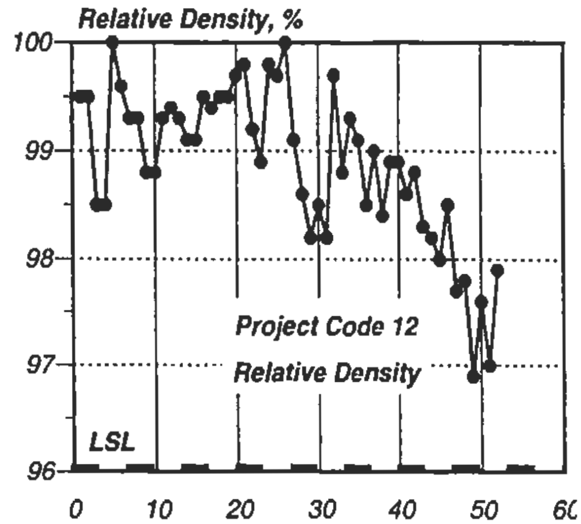

Percent Passing
56
54
52
50
48
46
44
42
USL
Target 49
Project Code 12
No. 4 (4.75mm)
LSL
0
10
20
30
40
50
60


Percent Passing
40
38
36
34
32
30
28
USL
Target 34
Project Code 12
No. 8 (2.36mm)
LSL
0
10
20
30
40
50
60

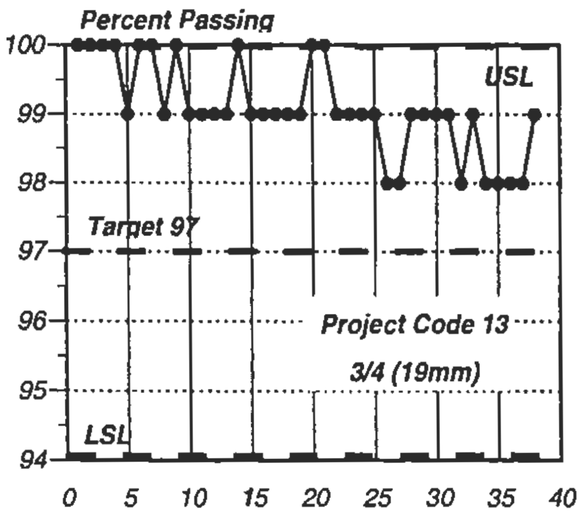

Percent Passing
22
21
20
19
18
17
16
15
14
13
12
USL
Target 18
Project Code 12
No. 30 (600um)
LSL
0
10
20
30
40
50
60

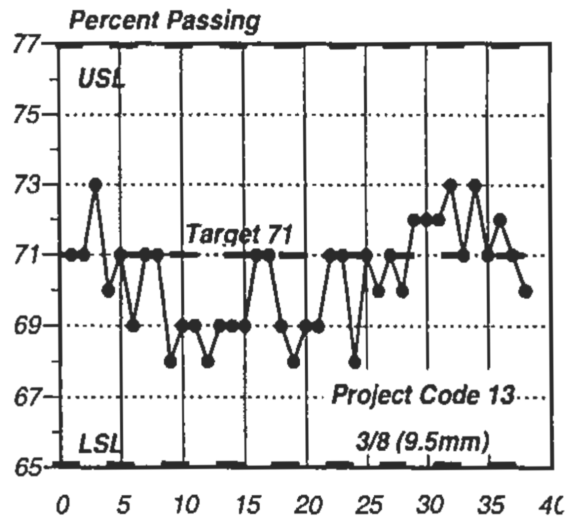

Percent Passing
5.0
4.0
3.0
2.0
1.0
USL
Project Code 12
No. 200 (74um)
LSL
0
10
20
30
40
50
60

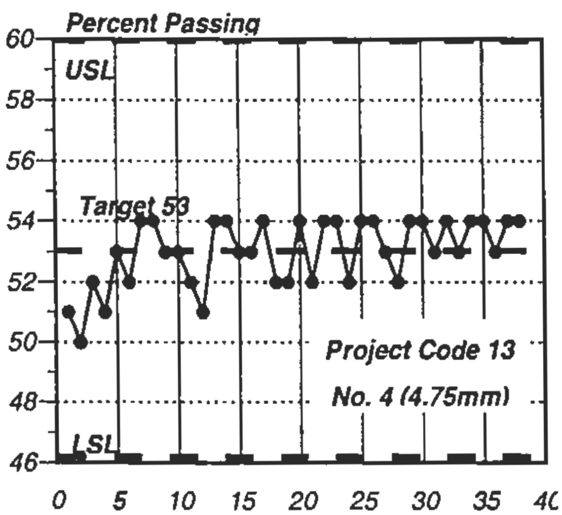

Asphalt Content, %
6.0
5.5
5.0
4.5
4.0
USL
Target 5.0
LSL
Project Code 12
Asphalt Content
0
10
20
30
40
50
60

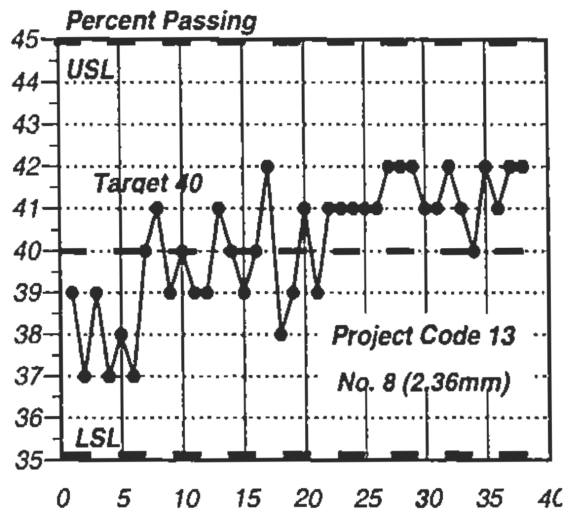

Relative Density, %
100
99
98
97
96
Project Code 12
Relative Density
LSL
0
10
20
30
40
50
60

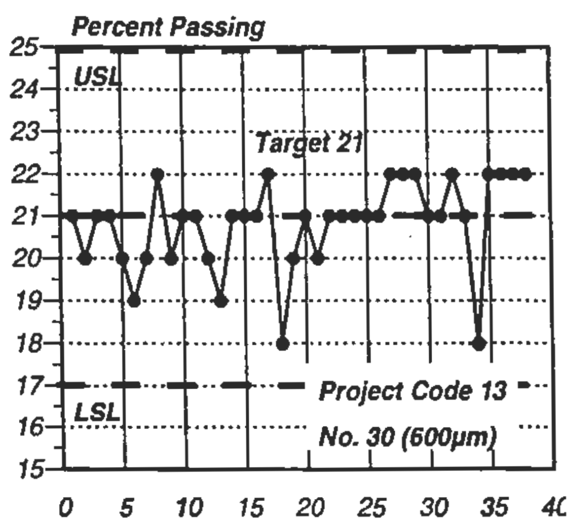
Code >	13							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
1	100	71	51	39	21	5.0	4.9	97.1
2	100	71	50	37	20	5.0	4.8	97.1
3	100	73	52	39	21	6.0	5.2	98.3
4	100	70	51	37	21	5.1	5.1	97.9
5	99	71	53	38	20	4.8	4.8	97.1
6	100	69	52	37	19	4.7	5.0	97.1
7	100	71	54	40	20	5.0	4.9	97.1
8	99	71	54	41	22	5.0	4.9	97.5
9	100	68	53	39	20	5.0	5.1	97.5
10	99	69	53	40	21	5.0	5.3	97.5
11	99	69	52	39	21	6.0	5.1	97.5
12	99	68	51	39	20	5.0	4.6	97.9
13	99	69	54	41	19	5.0	4.9	97.5
14	100	69	54	40	21	5.0	4.9	97.7
15	99	69	53	39	21	5.0	5.2	97.7
16	99	71	53	40	21	5.0	5.2	97.9
17	99	71	54	42	22	5.0	5.0	97.9
18	99	69	52	38	18	5.2	5.0	97.5
19	99	68	52	39	20	5.2	4.9	97.9
20	100	69	54	41	21	5.2	4.8	97.1
21	100	69	52	39	20	5.7	5.0	97.9
22	99	71	54	41	21	5.4	5.3	97.5
23	99	71	54	41	21	5.4	5.0	97.5
24	99	68	52	41	21	5.7	4.9	95.5
25	99	71	54	41	21	5.9	4.7	97.9
26	98	70	54	41	21	5.9	4.9	97.5
27	98	71	53	42	22	5.3	4.7	97.5
28	99	70	52	42	22	5.7	5.0	97.5
29	99	72	54	42	22	5.9	4.9	97.5
30	99	72	54	41	21	5.4	5.2	97.1
31	99	72	53	41	21	5.8	4.9	97.5
32	98	73	54	42	22	5.9	5.0	97.5
33	99	71	53	41	21	5.8	5.0	97.5
34	98	73	54	40	18	4.9	4.9	97.1
35	98	71	54	42	22	5.9	4.9	97.1
36	98	72	53	41	22	5.8	4.7	97.9
37	98	71	54	42	22	5.9	5.2	97.0
38	99	70	54	42	22	5.9	4.8	97.5
Count	38	38	38	38	38	38	38	38
Max	100	73	54	42	22	6.0	5.3	98.3
Min	98	68	50	37	18	4.7	4.6	95.5
Range	2	5	4	5	4	1.3	0.7	2.8
Mean	99.1	70.4	53.0	40.2	20.8	5.38	4.96	97.46
Std. Dev.	0.67	1.44	1.12	1.52	1.06	0.42	0.17	0.454

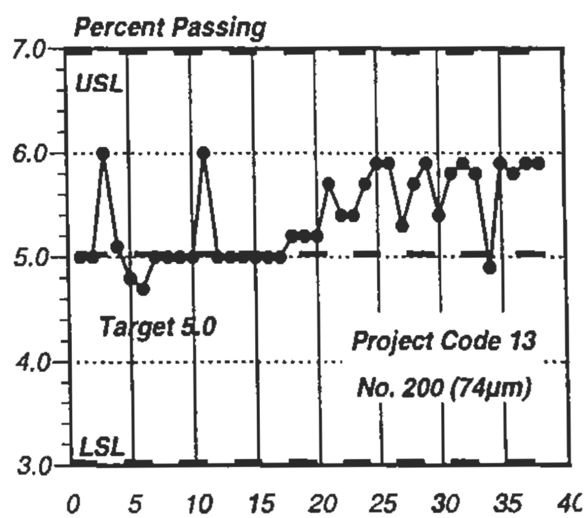

Percent Passing
USL
Target 97
Project Code 13
3/4 (19mm)
LSL

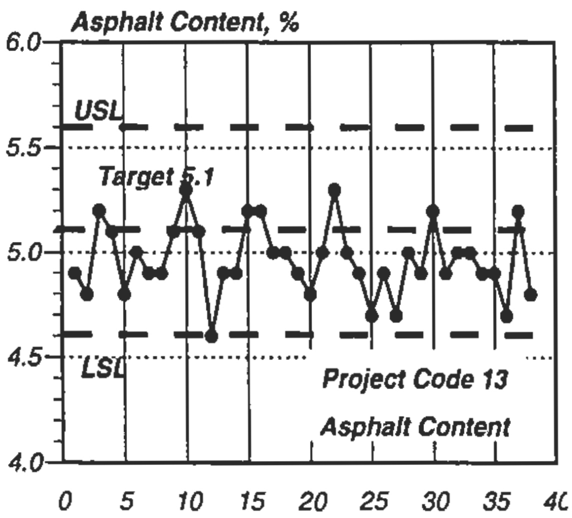

Percent Passing
USL
Target 71
Project Code 13
3/8 (9.5mm)
LSL

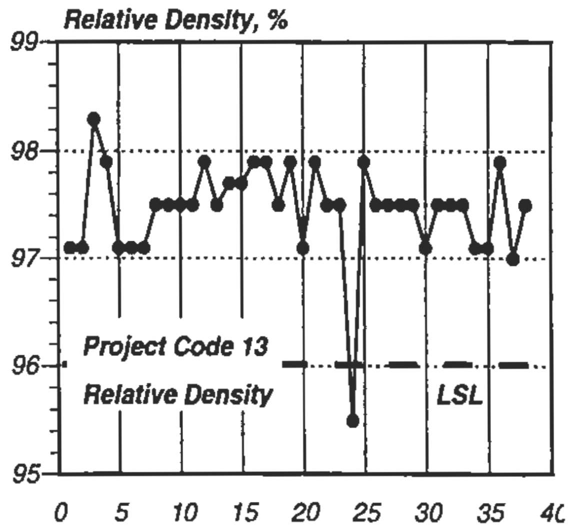

Percent Passing
USL
Target 53
Project Code 13
No. 4 (4.75mm)
LSL

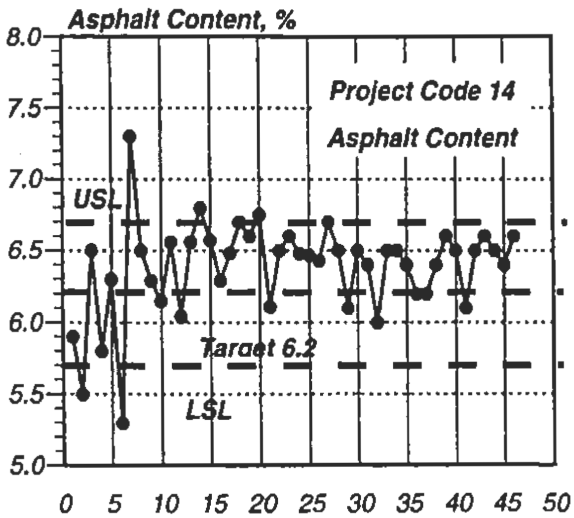

Percent Passing
USL
Target 40
Project Code 13
No. 8 (2.36mm)
LSL


Percent Passing
USL
Target 21
Project Code 13
No. 30 (600µm)
LSL


Percent Passing
USL
Target 5.0
Project Code 13
No. 200 (74µm)
LSL


Asphalt Content, %
6.0
5.5
5.0
4.5
4.0
USL
Target 5.1
LSL
Project Code 13
Asphalt Content
0
5
10
15
20
25
30
35
40


Relative Density, %
99
98
97
96
95
Project Code 13
Relative Density
LSL
0
5
10
15
20
25
30
35
40

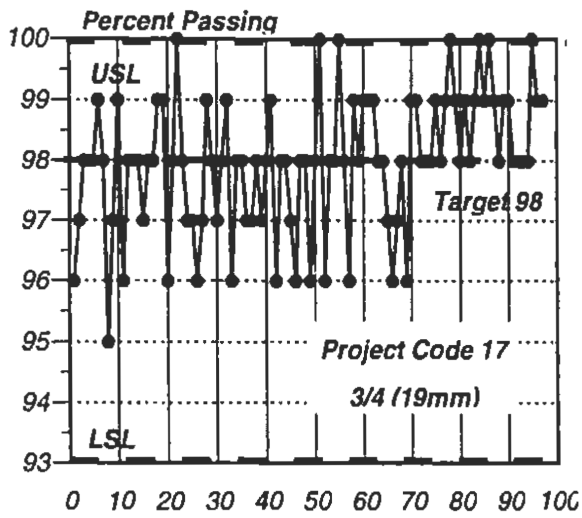

Asphalt Content, %
8.0
7.5
7.0
6.5
6.0
5.5
5.0
0
5
10
15
20
25
30
35
40
45
50
Project Code 14
Asphalt Content
USL
Target 6.2
LSL

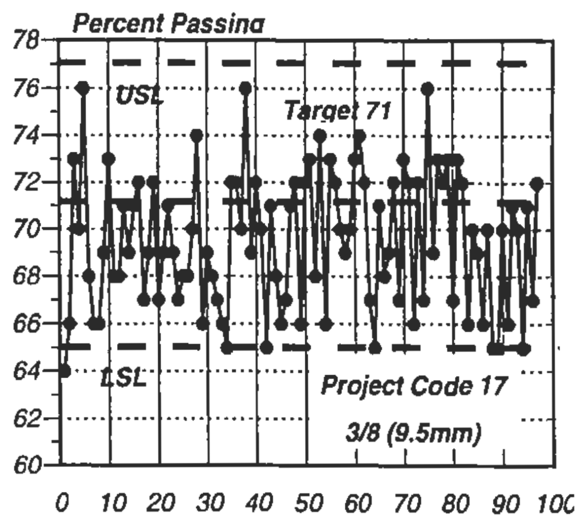
	Code >	16							
	Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
Lot 1	1	94	70	48	35	19	3.4	5.6	97.9
Lot 1	2	94	65	47	34	18	3.3	5.4	97.5
Lot 1	3	94	66	48	37	20	4.1	4.5	98.9
Lot 1	4	95	63	46	37	20	3.0	5.3	97.9
Lot 1	5	95	68	46	34	18	3.0	5.2	97.1
Lot 1	6	94	63	46	35	18	3.0	5.4	97.8
Lot 1	Count	6	6	6	6	6	6	6	6
Lot 1	Max	95	70	48	37	20	4	6	99
Lot 1	Min	94	63	46	34	18	3	5	97
Lot 1	Range	1	7	2	3	2	1	1	2
Lot 1	Mean	94.3	65.8	46.8	35.3	18.8	3.30	5.23	97.85
Lot 1	Std. Dev.	0.52	2.79	0.98	1.37	0.98	0.429	0.383	0.599

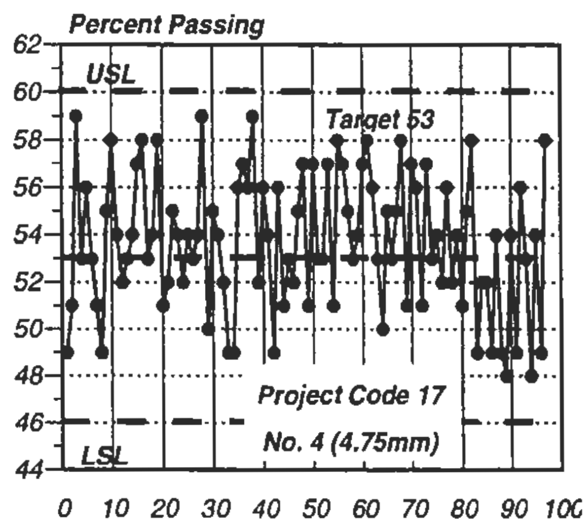
	Code >	16							
	Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.
Lot 2	1	94	69	49	37	20	4.5	5.0	97.1
Lot 2	2	94	69	50	36	19	4.1	4.2	96.7
Lot 2	3	92	67	47	35	19	2.5	4.3	95.8
Lot 2	4	95	71	51	37	20	4.8	4.6	95.8
Lot 2	5	94	70	49	36	19	4.0	4.4	96.7
Lot 2	6	93	71	49	36	19	4.1	4.9	95.8
Lot 2	7	95	70	49	36	20	3.6	4.3	97.1
Lot 2	8	96	71	51	38	20	4.2	4.6	97.1
Lot 2	9	94	70	51	37	19	3.7	4.4	97.1
Lot 2	10	93	67	48	37	20	4.2	4.8	97.1
Lot 2	11	94	71	50	37	20	3.4	4.5	97.1
Lot 2	Count	11	11	11	11	11	11	11	11
Lot 2	Max	96	71	51	38	20	5	5	97
Lot 2	Min	92	67	47	35	19	3	4	96
Lot 2	Range	4	4	4	3	1	2	1	1
Lot 2	Mean	94.0	69.6	49.5	36.5	19.5	3.9	4.5	96.7
Lot 2	Std. Dev.	1.10	1.50	1.29	0.82	0.52	0.61	0.26	0.58

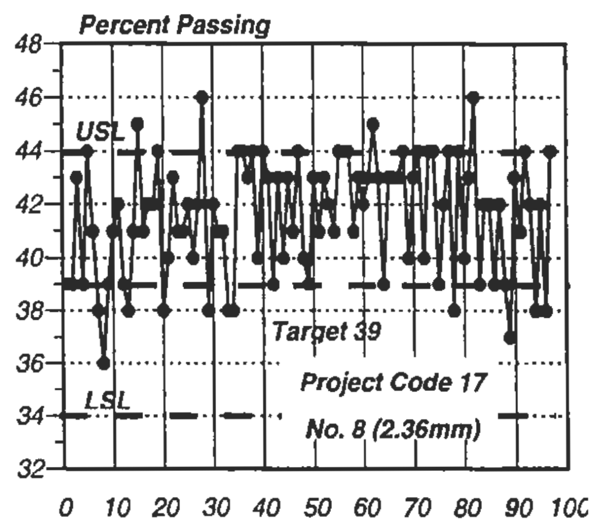
Code >	16							
Sub Lot	3/4	3/8	4	8	30	200	AC	Compact.

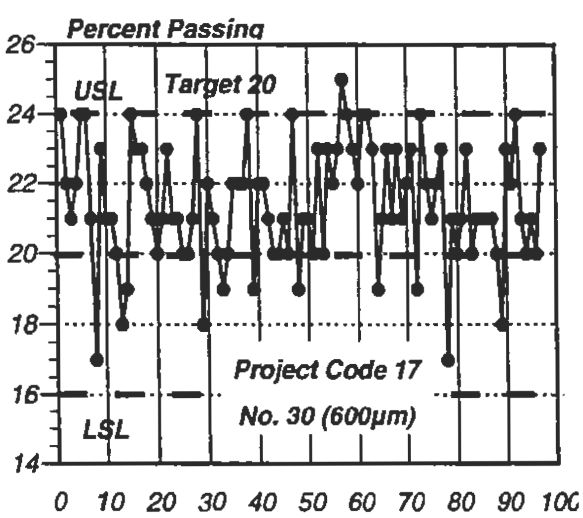
Code >	17							
Sub Lot	3/4	3/8	4	8	30	200.0	AC	Compact.
50	98	72	57	43	21	4.0	4.6	96.6
51	100	73	53	41	20	4.0	4.5	96.5
52	96	68	53	43	23	5.0	4.5	96.4
53	98	74	57	42	20	4.0	4.7	96.2
54	98	66	51	41	23	4.0	4.7	95.9
55	100	73	58	44	22	4.0	4.8	96.2
56	98	72	57	44	23	5.0	4.5	96.9
57	96	70	55	44	25	4.0	4.6	96.9
58	99	69	53	41	24	4.0	4.7	96.9
59	98	70	54	43	23	4.0	4.6	96.8
60	99	73	57	42	22	6.0	4.7	96.2
61	99	74	58	43	24	5.0	4.5	96.2
62	99	72	56	45	24	4.0	4.6	97.1
63	98	67	53	43	23	4.0	4.6	96.8
64	98	65	50	39	19	3.0	4.7	97.1
65	97	71	55	43	21	4.0	4.7	97.3
66	96	68	53	43	23	5.0	4.9	97.1
67	97	69	55	43	21	4.0	4.6	97.5
68	98	72	58	44	23	4.0	4.5	97.0
69	96	67	51	40	21	4.0	4.5	96.6
70	99	73	57	43	22	4.0	4.5	96.4
71	99	72	56	44	23	4.0	4.8	96.9
72	98	66	51	40	19	4.0	4.7	97.1
73	98	72	57	44	24	4.0	4.6	97.0
74	98	67	53	44	22	3.0	4.9	96.8
75	99	76	54	39	21	4.0	4.5	97.0
76	98	69	52	42	22	4.0	4.6	97.0
77	99	73	56	44	23	4.0	4.5	96.7
78	100	72	52	38	17	4.0	4.5	96.9
79	99	73	54	44	21	4.0	4.5	97.2
80	98	67	51	40	20	4.0	4.9	97.6
81	99	73	55	43	21	4.0	4.7	97.4
82	98	72	58	46	23	4.0	4.4	97.8
83	99	66	49	39	20	4.0	4.4	97.8
84	100	70	52	42	21	4.0	4.6	97.8
85	99	69	52	42	21	4.0	4.8	97.4
86	100	66	49	39	21	3.0	4.6	97.1
87	99	70	54	42	21	4.0	4.6	97.5
88	98	65	49	39	20	3.0	4.6	97.8
89	99	65	48	37	18	4.0	4.8	97.4
90	99	70	54	43	23	4.0	4.8	97.7
91	98	66	49	41	22	3.0	4.8	98.2
92	98	71	56	44	24	4.0	4.8	97.6
93	98	70	53	42	21	4.0	4.6	96.9
94	98	65	48	38	20	4.0	4.7	97.6
95	100	71	54	42	21	4.0	4.7	97.3
96	99	67	49	38	20	3.0	4.8	97.2
97	99	72	58	44	23	5.0	4.6	97.2
Count	97	97	97	97	97	97	97	97
Max	100.0	76.0	59.0	46.0	25.0	6.0	5.2	98.2
Min	95.0	64.0	48.0	36.0	17.0	3.0	4.3	95.6
Range	5	12	11	10	8	3.0	0.9	2.6
Mean	98.0	69.5	53.7	41.5	21.4	4.01	4.67	96.87
Std. Dev.	1.13	2.88	2.90	2.23	1.72	0.685	0.166	0.505

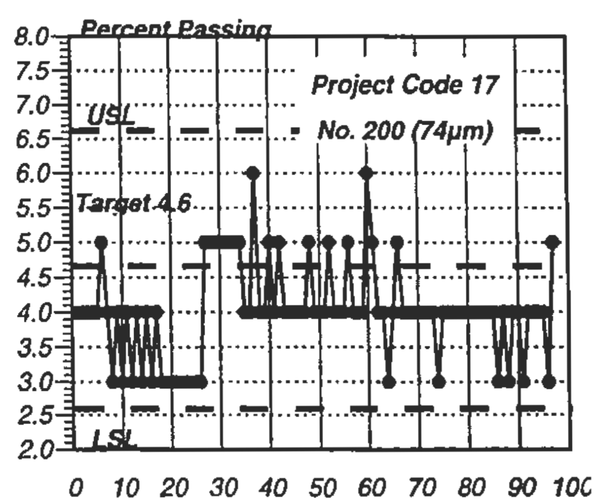

Percent Passing
USL
Target 98
Project Code 17
3/4 (19mm)
LSL
100
99
98
97
96
95
94
93
0 10 20 30 40 50 60 70 80 90 100

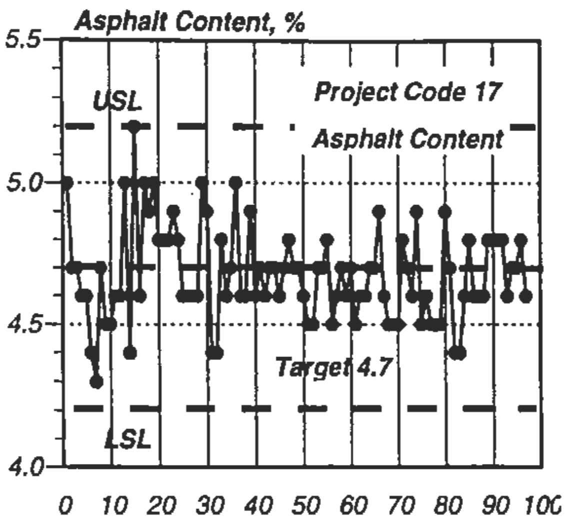

Percent Passing
USL
Target 71
LSL
Project Code 17
3/8 (9.5mm)
78
76
74
72
70
68
66
64
62
60
0 10 20 30 40 50 60 70 80 90 100

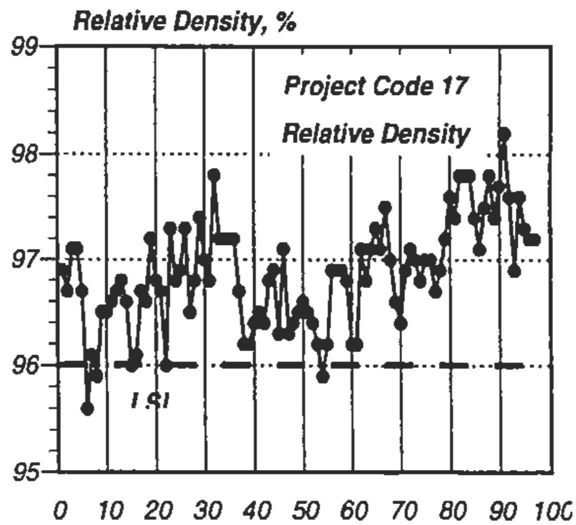

Percent Passing
USL
Target 53
Project Code 17
No. 4 (4.75mm)
LSL
62
60
58
56
54
52
50
48
46
44
0 10 20 30 40 50 60 70 80 90 100


Percent Passing
USL
Target 39
Project Code 17
LSL
No. 8 (2.36mm)
48
46
44
42
40
38
36
34
32
0 10 20 30 40 50 60 70 80 90 100

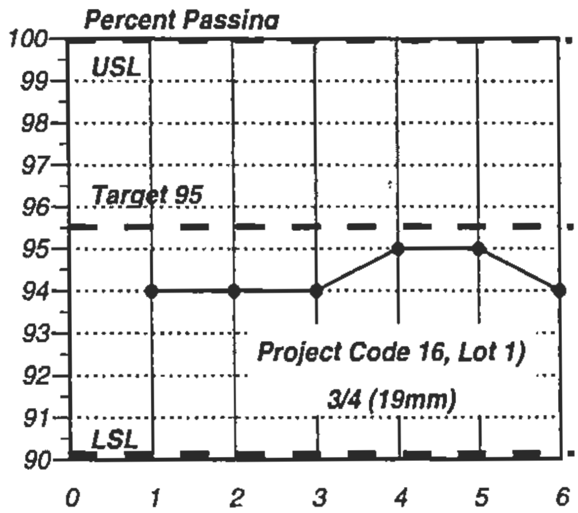

Percent Passing
USL
Target 20
Project Code 17
No. 30 (600µm)
LSL
26
24
22
20
18
16
14
0 10 20 30 40 50 60 70 80 90 100

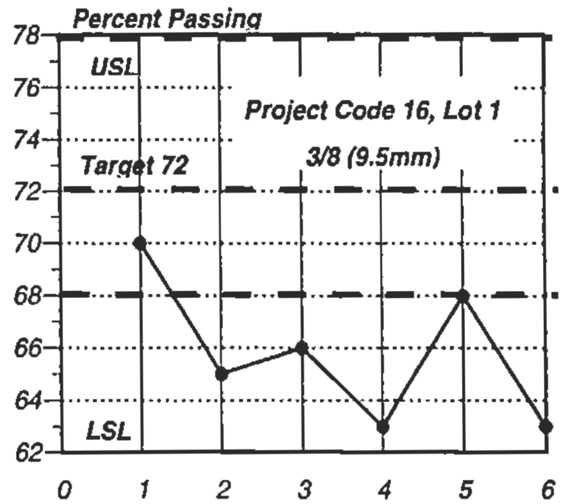

Percent Passing
Project Code 17
USL
No. 200 (74µm)
Target 4.6
LSL
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
0 10 20 30 40 50 60 70 80 90 100

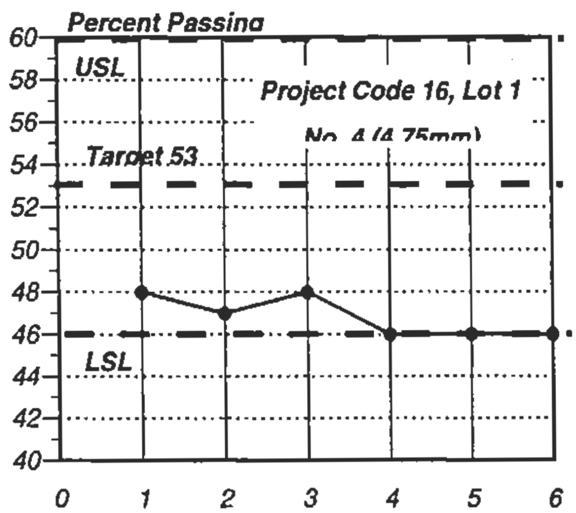

Asphalt Content, %
5.5
5.0
4.5
4.0
USL
Project Code 17
Asphalt Content
Target 4.7
LSL
0 10 20 30 40 50 60 70 80 90 100

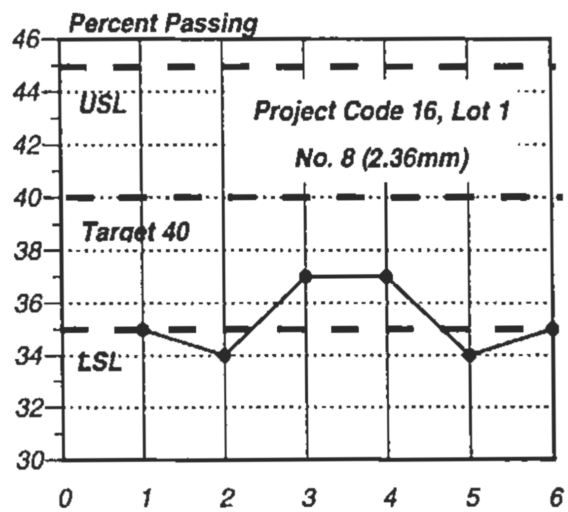

Relative Density, %
99
98
97
96
95
Project Code 17
Relative Density
0 10 20 30 40 50 60 70 80 90 100

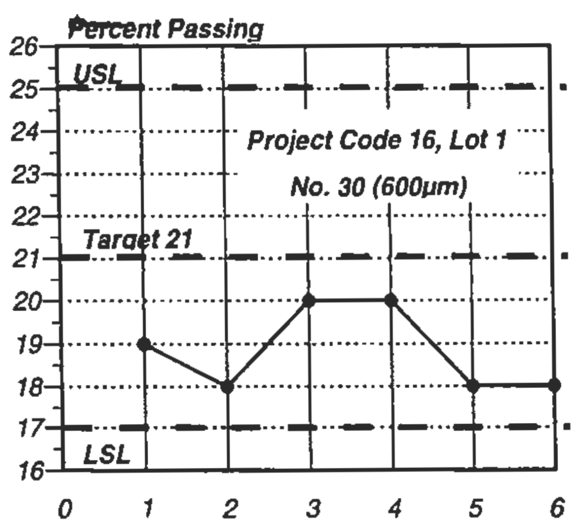
Lot 3	12	94	73	52	40	22	3.9	4.6	96.7
Lot 3	13	95	74	52	38	21	3.8	4.7	96.7
Lot 3	14	95	72	50	37	20	3.8	4.8	97.5
Lot 3	15	96	70	50	38	21	3.9	4.3	97.5
Lot 3	16	96	74	55	41	22	3.9	4.8	97.1
Lot 3	17	96	72	53	39	21	4.1	4.6	96.7
Lot 3	18	95	71	51	38	22	3.6	4.3	97.1
Lot 3	19	96	75	55	39	21	3.6	4.5	99.2
Lot 3	20	96	75	54	42	23	3.8	4.6	97.1
Lot 3	21	95	72	54	42	24	4.2	4.6	97.5
Lot 3	22	95	72	52	40	20	3.9	4.6	97.1
Lot 3	23	95	75	55	44	24	3.9	4.4	97.7
Lot 3	24	97	75	56	43	22	4.0	4.8	97.9
Lot 3	25	98	74	53	36	19	4.0	4.6	97.9
Lot 3	26	97	75	55	37	22	4.3	4.4	97.1
Lot 3	27	95	70	50	38	22	4.0	4.5	97.1
Lot 3	28	96	71	52	38	20	4.1	4.4	97.5
Lot 3	29	94	70	53	37	20	3.9	4.6	98.3
Lot 3	30	94	71	53	40	23	4.6	4.5	97.1
Lot 3	31	95	69	52	40	22	4.6	4.8	96.7
Lot 3	32	94	72	52	40	22	4.6	4.6	97.5
Lot 3	**Count**	21	21	21	21	21	21	21	21
Lot 3	**Max**	98	75	56	44	24	5	5	99
Lot 3	**Min**	94	69	50	36	19	4	4	97
Lot 3	**Range**	4	6	6	8	5	1	1	3
Lot 3	**Mean**	95.4	72.5	52.8	39.4	21.6	4.0	4.6	97.4
Lot 3	**Std. Dev.**	1.08	1.97	1.78	2.13	1.33	0.29	0.16	0.60

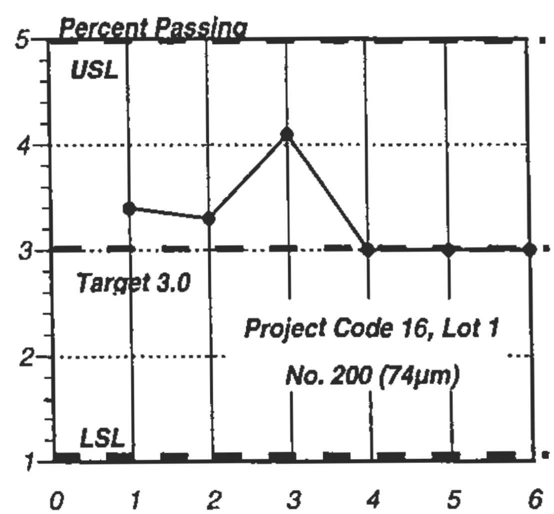

Percent Passing
USL
Target 95
LSL
Project Code 16, Lot 1)
3/4 (19mm)

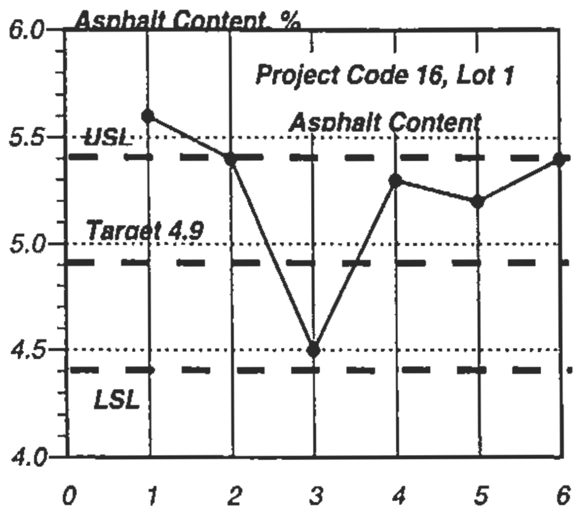

Percent Passing
USL
Target 72
LSL
Project Code 16, Lot 1
3/8 (9.5mm)

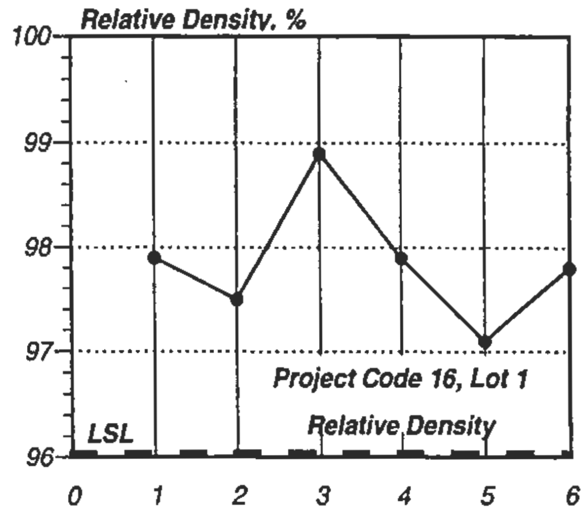

Percent Passing
USL
Target 53
LSL
Project Code 16, Lot 1

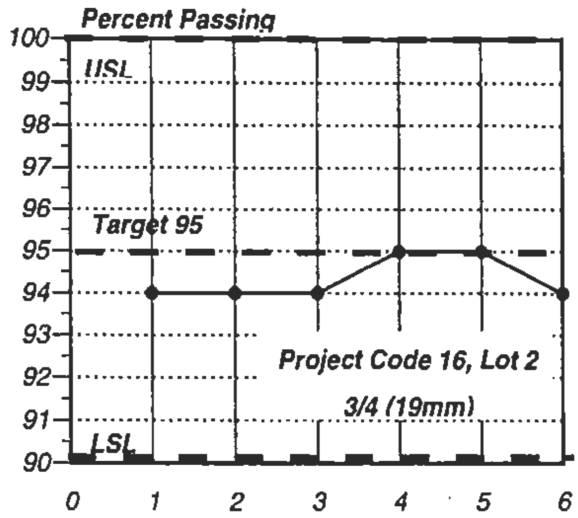

Percent Passing
USL
Target 40
LSL
Project Code 16, Lot 1
No. 8 (2.36mm)

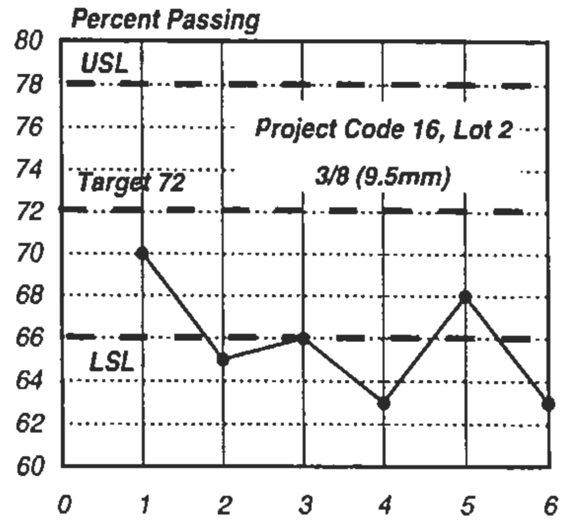

Percent Passing
USL
Target 21
LSL
Project Code 16, Lot 1
No. 30 (600μm)

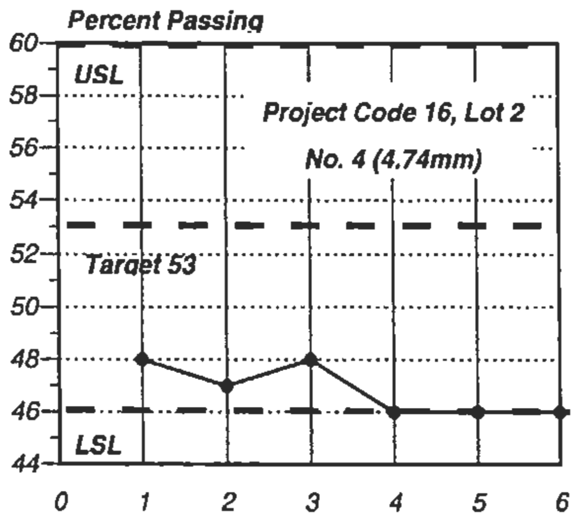

Percent Passing
USL
Target 3.0
LSL
Project Code 16, Lot 1
No. 200 (74μm)

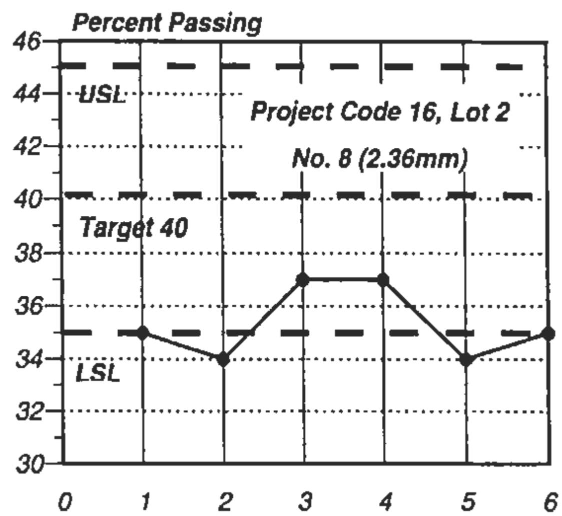

Asphalt Content, %
Project Code 16, Lot 1
Asphalt Content
USL
Target 4.9
LSL
6.0
5.5
5.0
4.5
4.0
0
1
2
3
4
5
6

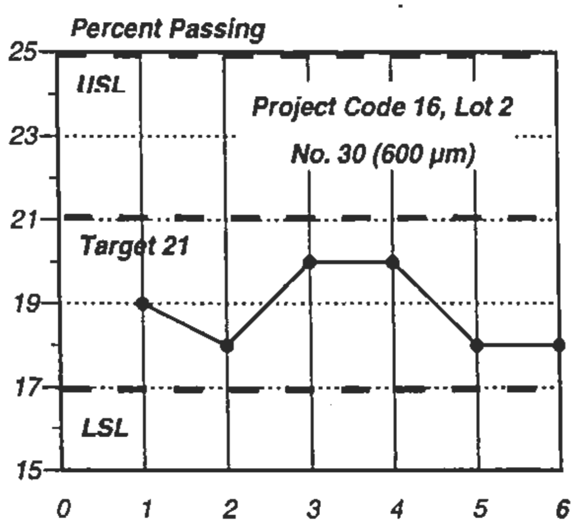

Relative Density, %
Project Code 16, Lot 1
Relative Density
LSL
100
99
98
97
96
0
1
2
3
4
5
6

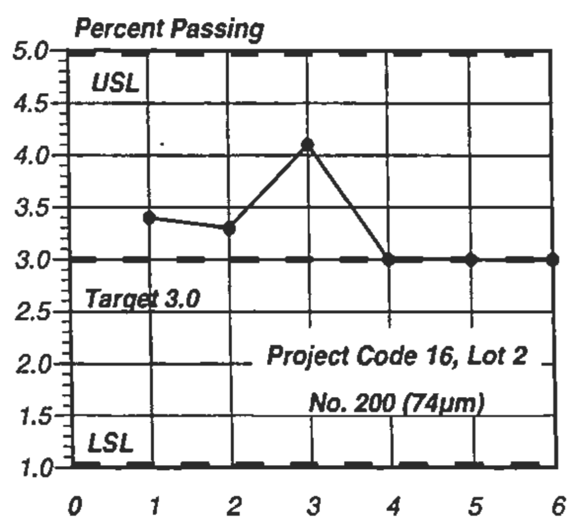

Percent Passing
USL
Target 95
LSL
Project Code 16, Lot 2
3/4 (19mm)

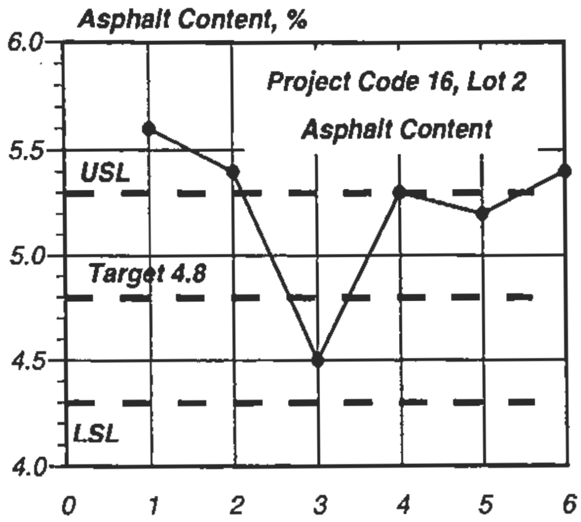

Percent Passing
USL
Project Code 16, Lot 2
3/8 (9.5mm)
Target 72
LSL

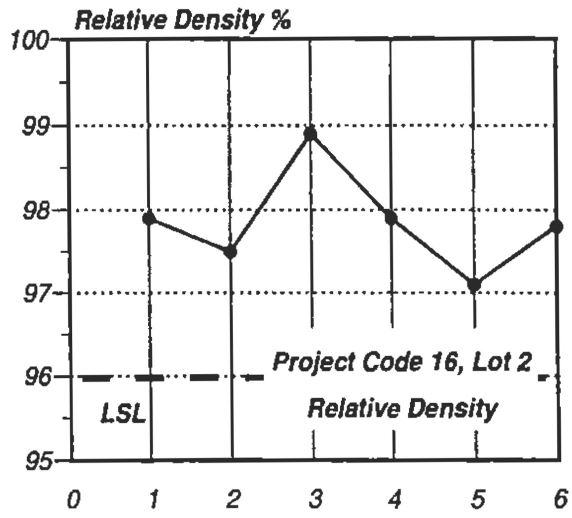

Percent Passing
USL
Project Code 16, Lot 2
No. 4 (4.74mm)
Target 53
LSL

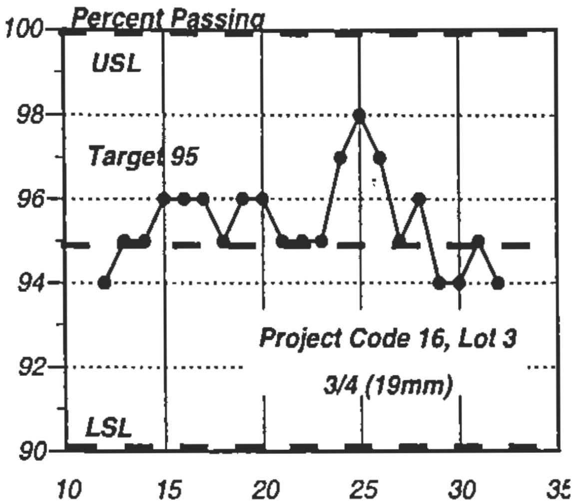

Percent Passing
USL
Project Code 16, Lot 2
No. 8 (2.36mm)
Target 40
LSL

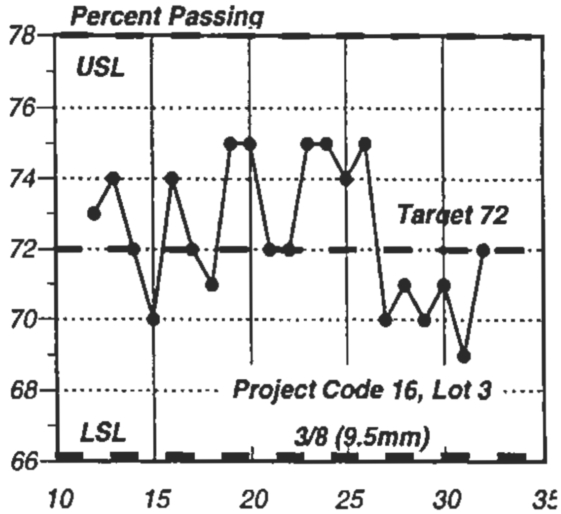

Percent Passing
USL
Project Code 16, Lot 2
No. 30 (600 µm)
Target 21
LSL

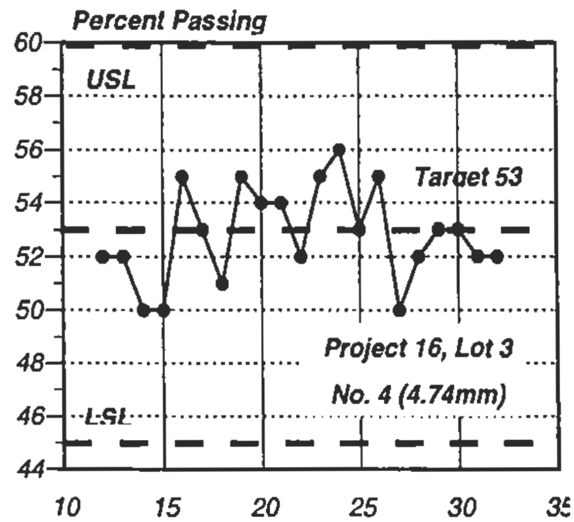

Percent Passing
USL
Target 3.0
Project Code 16, Lot 2
No. 200 (74µm)
LSL

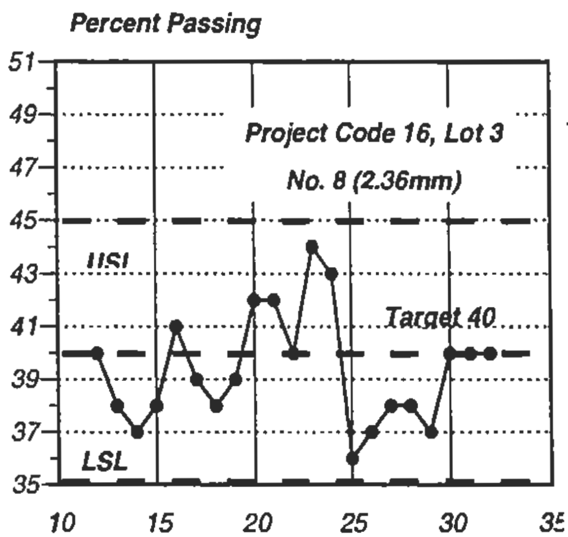

Asphalt Content, %
Project Code 16, Lot 2
Asphalt Content
USL
Target 4.8
LSL
6.0
5.5
5.0
4.5
4.0
0
1
2
3
4
5
6

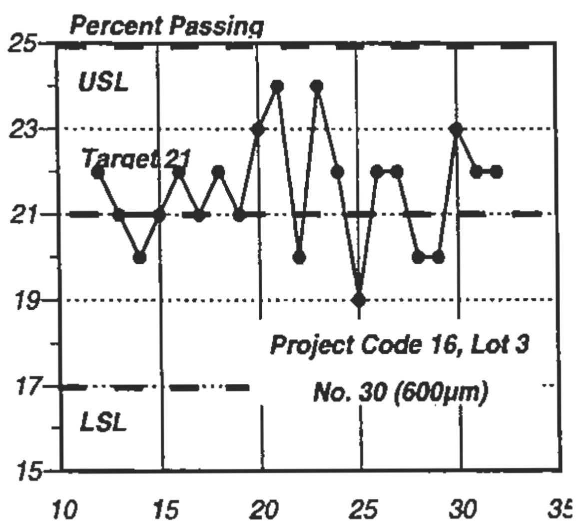

Relative Density %
Project Code 16, Lot 2
Relative Density
LSL
100
99
98
97
96
95
0
1
2
3
4
5
6

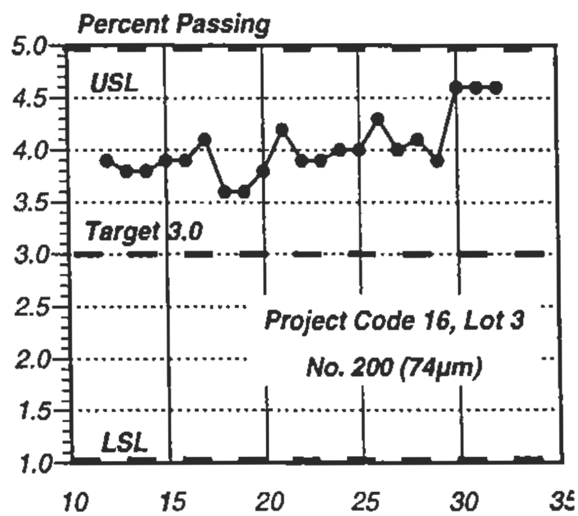

Percent Passing
USL
Target 95
Project Code 16, Lot 3
3/4 (19mm)
LSL
100
98
96
94
92
90
10
15
20
25
30
35

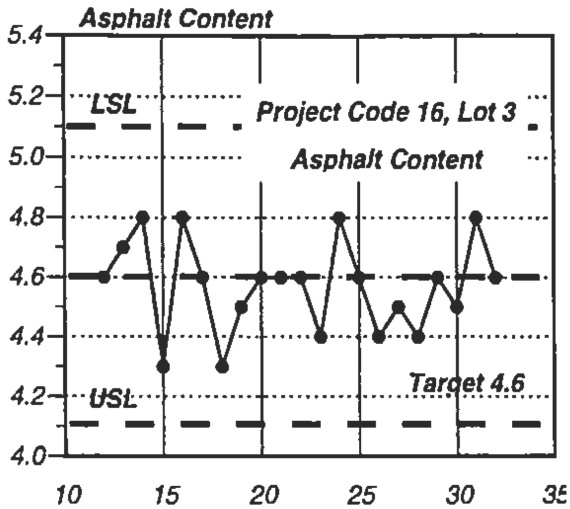

Percent Passing
USL
Target 72
Project Code 16, Lot 3
3/8 (9.5mm)
LSL
78
76
74
72
70
68
66
10
15
20
25
30
35

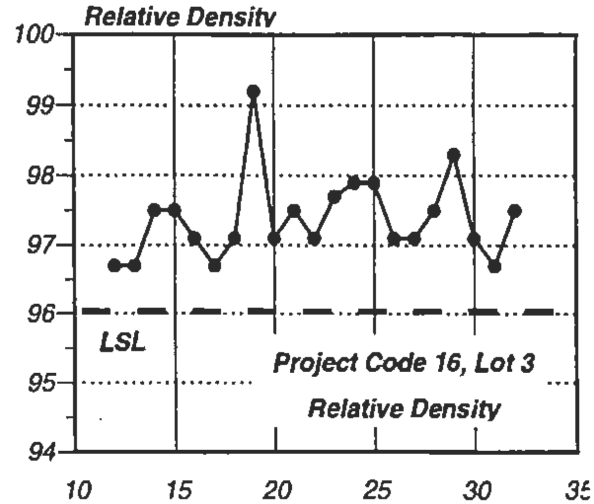

Percent Passing
USL
Target 53
Project 16, Lot 3
No. 4 (4.74mm)
LSL
60
58
56
54
52
50
48
46
44
10
15
20
25
30
35


Percent Passing
Project Code 16, Lot 3
No. 8 (2.36mm)
USL
Target 40
LSL
51
49
47
45
43
41
39
37
35
10
15
20
25
30
35


Percent Passing
USL
Target 21
Project Code 16, Lot 3
No. 30 (600µm)
LSL
25
23
21
19
17
15
10
15
20
25
30
35


Percent Passing
USL
Target 3.0
Project Code 16, Lot 3
No. 200 (74µm)
LSL
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
10
15
20
25
30
35


Asphalt Content
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
LSL
USL
Project Code 16, Lot 3
Asphalt Content
Target 4.6
10
15
20
25
30


Relative Density
100
99
98
97
96
95
94
LSL
Project Code 16, Lot 3
Relative Density
10
15
20
25
30

Code > Sub Lot	17 3/4	3/8	4	8	30	200.0	AC	Compact.
1	96	64	49	39	24	4.0	5.0	96.9
2	97	66	51	39	22	4.0	4.7	96.7
3	98	73	59	43	21	4.0	4.7	97.1
4	98	70	53	39	22	4.0	4.6	97.1
5	98	76	56	44	24	4.0	4.6	96.7
6	99	68	53	41	24	5.0	4.4	95.6
7	98	66	51	38	21	4.0	4.3	96.1
8	95	66	49	36	17	3.0	4.7	95.9
9	97	69	55	39	23	4.0	4.5	96.5
10	99	73	58	41	21	3.0	4.5	96.5
11	96	68	54	42	21	4.0	4.6	96.6
12	98	68	52	39	20	3.0	4.6	96.7
13	98	71	53	38	18	4.0	5.0	96.8
14	98	69	54	41	19	3.0	4.4	96.6
15	97	71	57	45	24	4.0	5.2	96.0
16	98	72	58	41	23	3.0	4.6	96.1
17	98	67	53	42	23	4.0	5.0	96.7
18	99	69	54	42	22	3.0	4.9	96.6
19	99	72	58	44	21	3.0	5.0	97.2
20	96	67	51	38	20	3.0	4.8	96.8
21	98	69	52	40	21	3.0	4.8	96.7
22	100	71	55	43	23	3.0	4.8	96.0
23	98	69	54	41	21	3.0	4.9	97.3
24	97	67	52	41	21	3.0	4.8	96.8
25	97	68	54	42	20	3.0	4.6	96.9
26	96	68	53	40	20	3.0	4.6	97.3
27	97	70	54	42	21	5.0	4.6	96.5
28	99	74	59	46	24	5.0	4.6	96.8
29	98	66	50	38	18	5.0	5.0	97.4
30	97	69	55	42	22	5.0	4.9	97.0
31	98	68	54	41	21	5.0	4.4	96.8
32	99	67	52	41	20	5.0	4.4	97.8
33	96	66	49	38	19	5.0	4.8	97.2
34	98	65	49	38	20	5.0	4.6	97.2
35	98	72	56	44	22	4.0	4.7	97.2
36	97	72	57	44	22	4.0	5.0	97.2
37	97	70	56	43	22	6.0	4.6	96.7
38	98	76	59	44	24	4.0	4.6	96.2
39	97	69	52	40	19	4.0	4.9	96.2
40	98	72	56	44	22	5.0	4.6	96.4
41	99	70	54	43	22	4.0	4.7	96.5
42	96	65	49	39	21	5.0	4.6	96.4
43	98	71	56	43	20	4.0	4.7	96.8
44	98	68	51	40	20	4.0	4.7	96.9
45	97	66	53	43	21	4.0	4.6	96.3
46	96	67	52	41	20	4.0	4.7	97.1
47	98	71	55	44	24	4.0	4.8	96.3
48	98	72	57	40	19	5.0	4.7	96.4
49	96	66	51	39	21	4.0	4.7	96.5

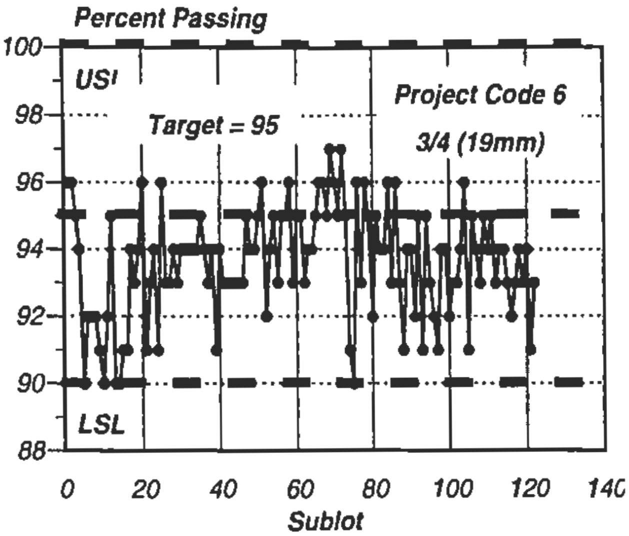
Appendix B

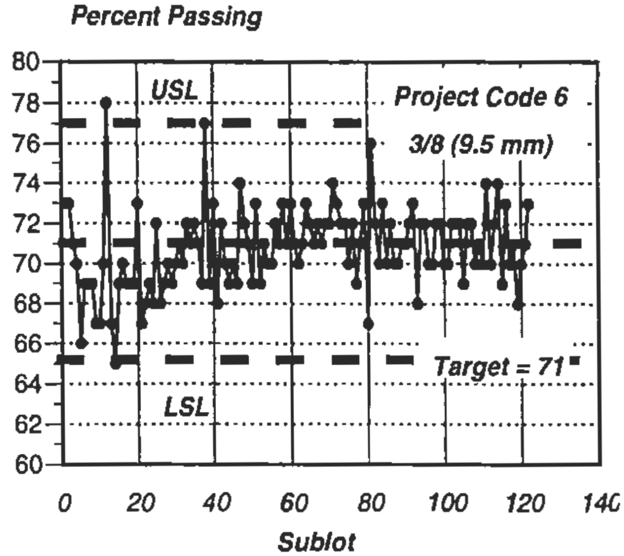
Typical Statistical Analyses

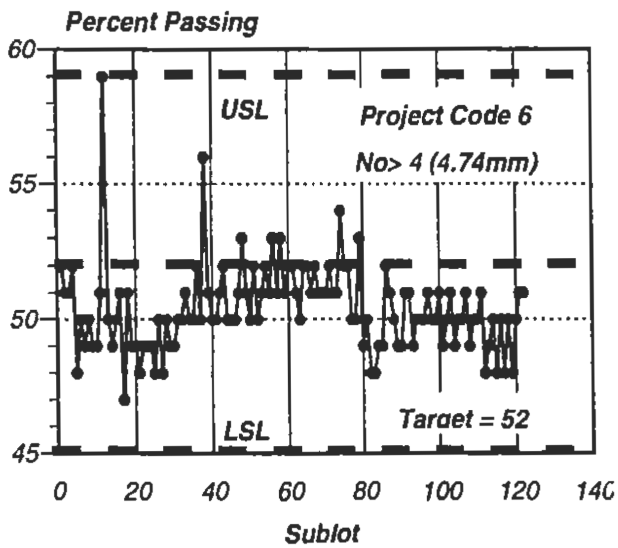
Item	***Page***

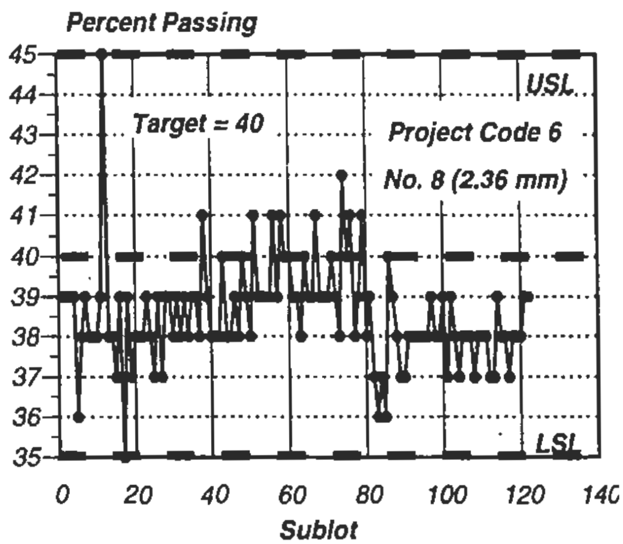
Project Code 6

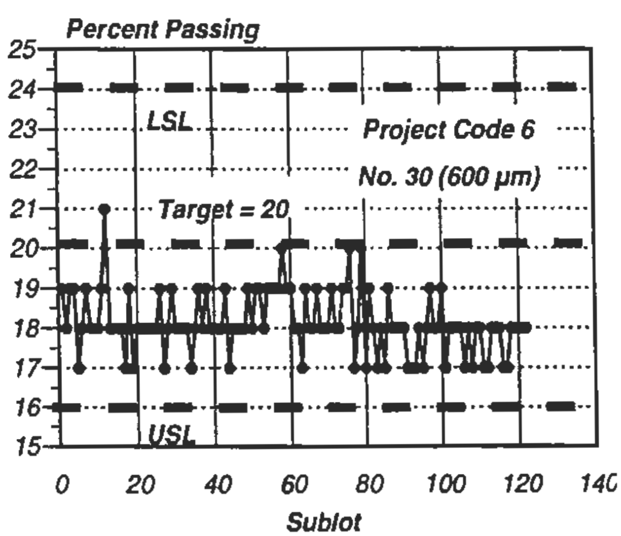
Data Plots

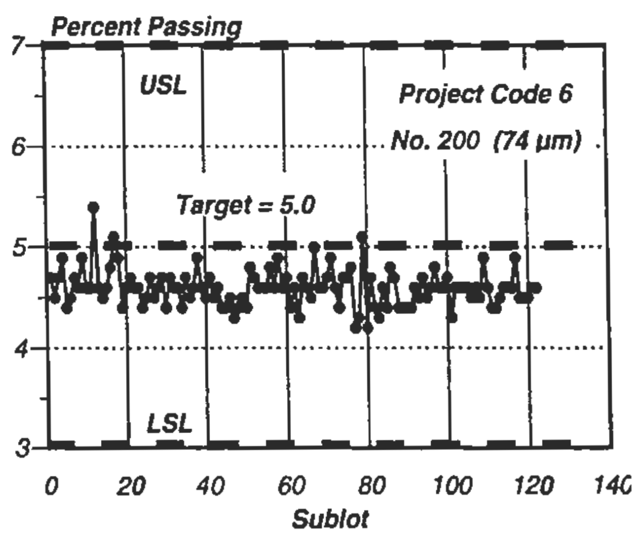

Percent Passing
USL
Target = 95
Project Code 6
3/4 (19mm)
LSL
100
98
96
94
92
90
88
0 20 40 60 80 100 120 140
Sublot

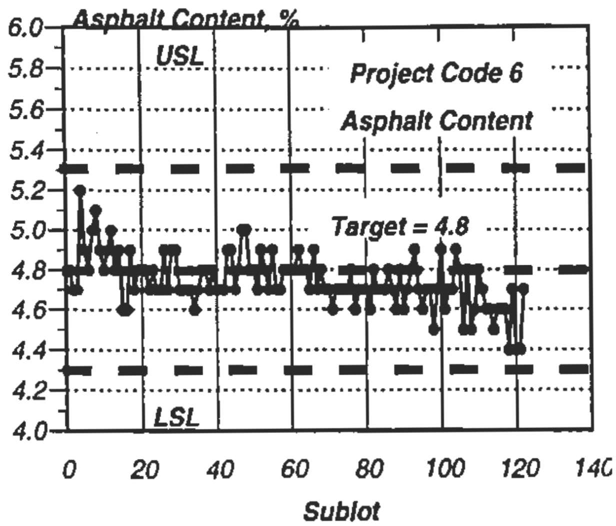

Percent Passing
USL
Project Code 6
3/8 (9.5 mm)
Target = 71
LSL
80
78
76
74
72
70
68
66
64
62
60
0 20 40 60 80 100 120 140
Sublot

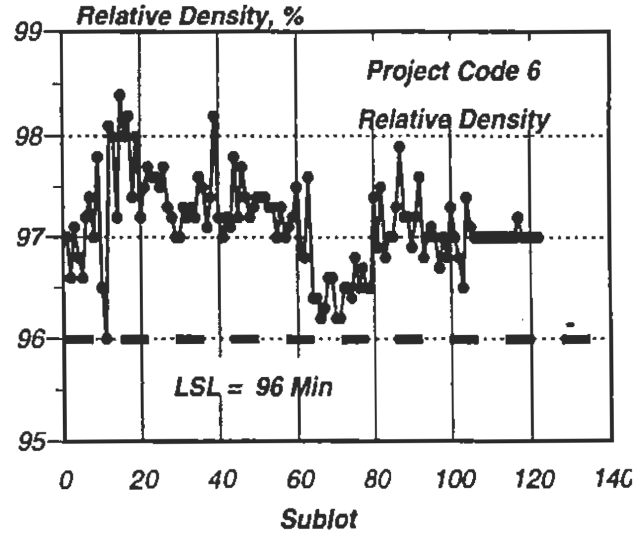

Percent Passing
USL
Project Code 6
No> 4 (4.74mm)
LSL
Target = 52
60
55
50
45
0 20 40 60 80 100 120 140
Sublot


Percent Passing
USL
Target = 40
Project Code 6
No. 8 (2.36 mm)
LSL
45
44
43
42
41
40
39
38
37
36
35
0 20 40 60 80 100 120 140
Sublot


Percent Passing
LSL
Project Code 6
No. 30 (600 µm)
Target = 20
USL
25
24
23
22
21
20
19
18
17
16
15
0 20 40 60 80 100 120 140
Sublot


Percent Passing
USL
Project Code 6
No. 200 (74 µm)
Target = 5.0
LSL
7
6
5
4
3
0 20 40 60 80 100 120 140
Sublot

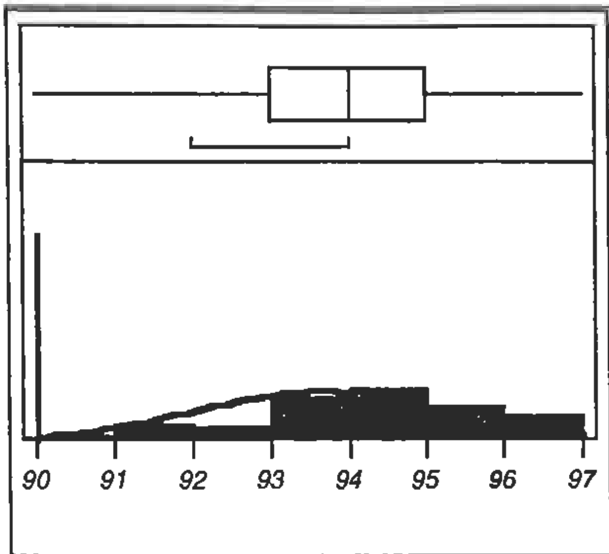

Asphalt Content, %
USL
Project Code 6
Asphalt Content
Target = 4.8
LSL
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
0 20 40 60 80 100 120 140
Sublot


Relative Density, %
Project Code 6
Relative Density
LSL = 96 Min
99
98
97
96
95
0 20 40 60 80 100 120 140
Sublot

Project Code 6

Statistical Data

3/4 Descriptive Statistics



Quantiles

Moments

Mean	93.6066
Std Dev	1.6542
Std Err Mean	0.1498
upper 95% Mean	93.9031
lower 95% Mean	93.3101
N	122.0000
Sum Wgts	122.0000

3/4 Normality and Quality Control Capability Analysis (Min 1.3 Req'd.)

Test for Normality

Shapiro-Wilk W Test

W	Prob<W
0.932805	0.0000

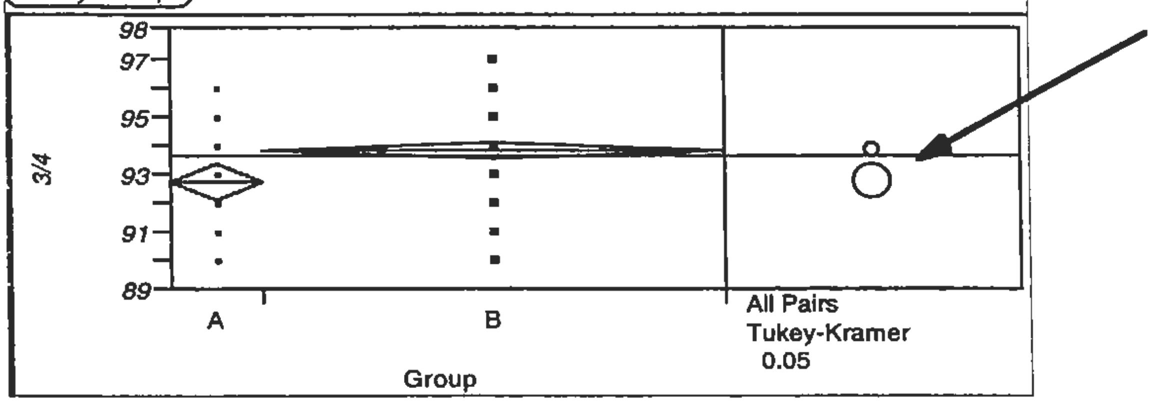
Capability Analysis

Specification	Value	Percent	Actual	Normal
Lower Spec Limit	90	%Below LSL	0.000	1.462
Upper Spec Limit	100	%Above USL	0.000	0.006
Spec Target	95			

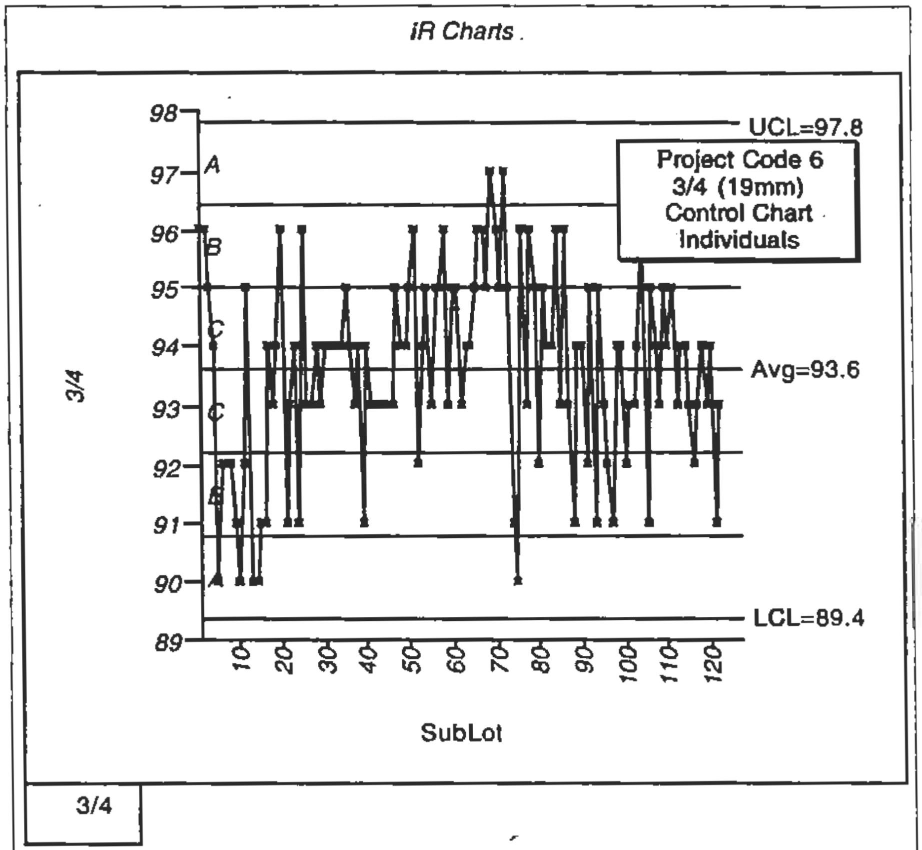
Capability	Index
CPL	0.727
CPU	1.288
CPK	0.727
CP	1.008
CPM	0.771

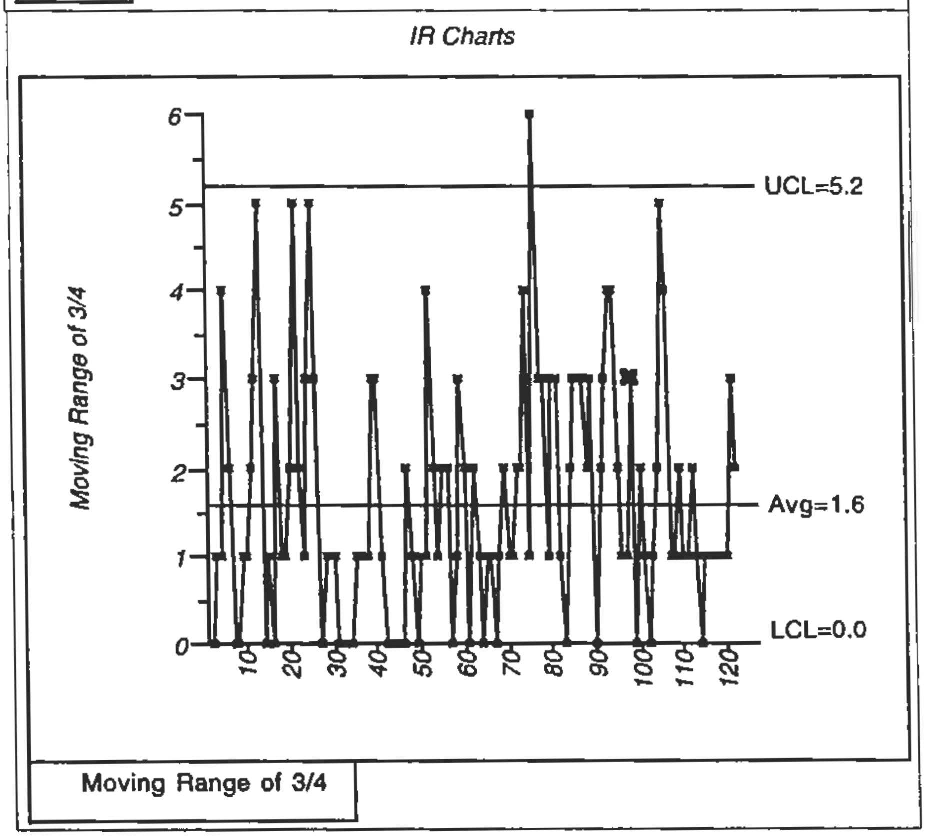
Group Sublots 1-20 v. 21-120. Groups are different - probably different populations.

3/4 By Group

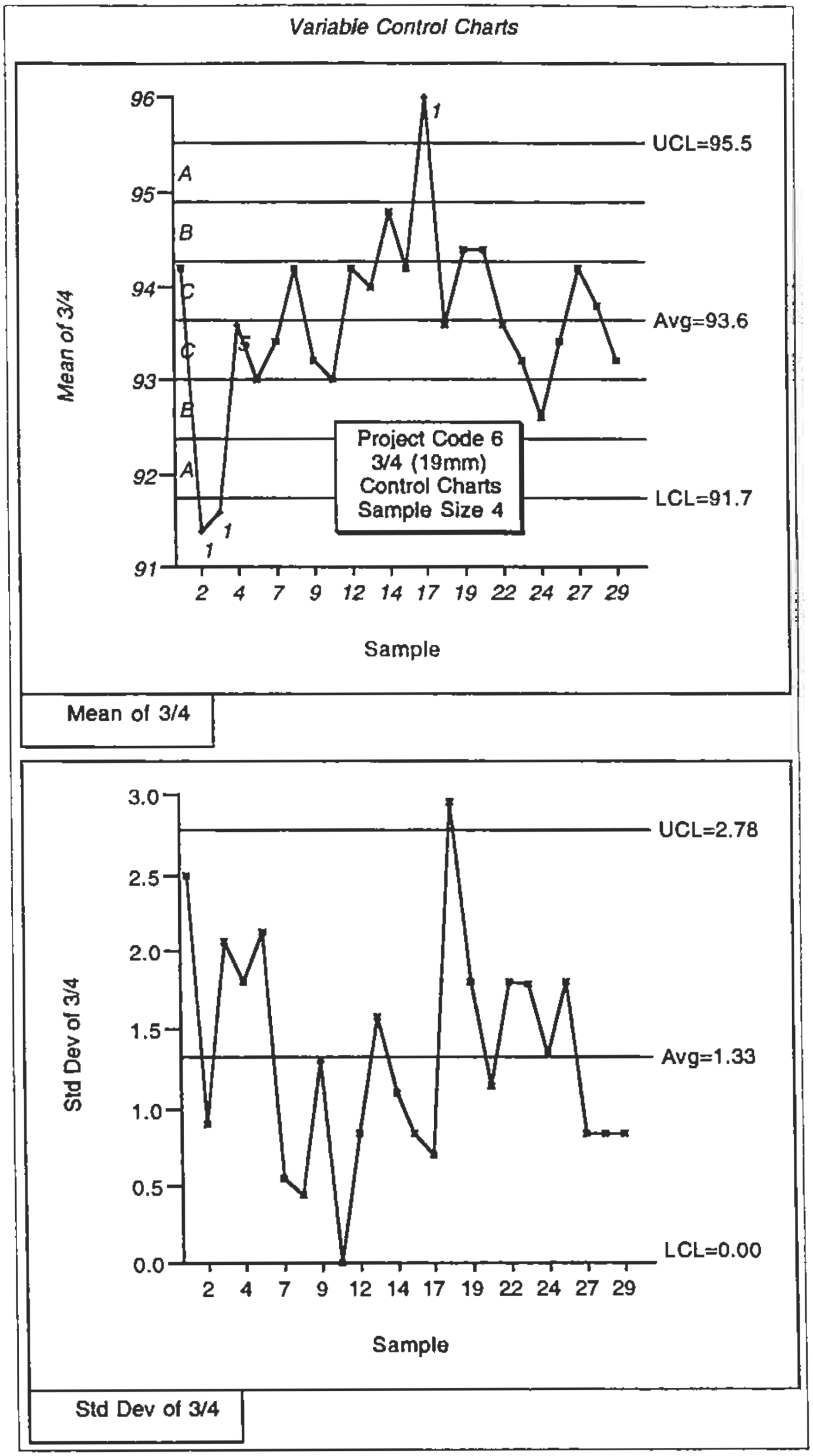


3/4 Control Chart, Individuals



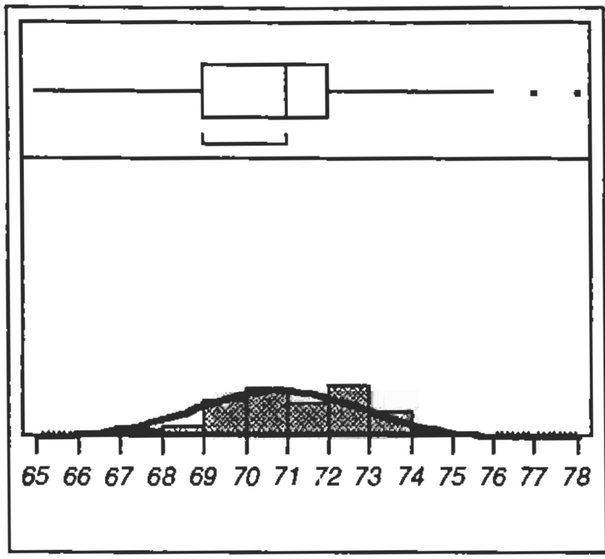


3/4 Control Chart, Sample Size 4



3/8 Descriptive Statistics

3/8



Quantiles

Moments

Mean	70.7705
Std Dev	2.0682
Std Err Mean	0.1872
upper 95% Mean	71.1412
lower 95% Mean	70.3998
N	122.0000
Sum Wgts	122.0000

Project Code 6
3/8 (9.5mm)
Descriptive Statistics

Test for Normality

Shapiro-Wilk W Test

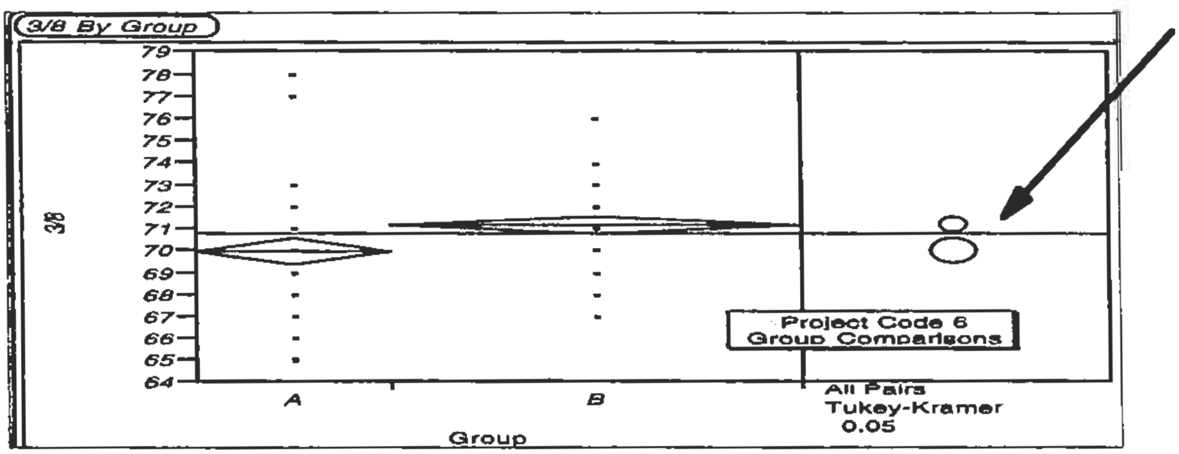
W	Prob<W
0.963784	0.0233

Capability Analysis

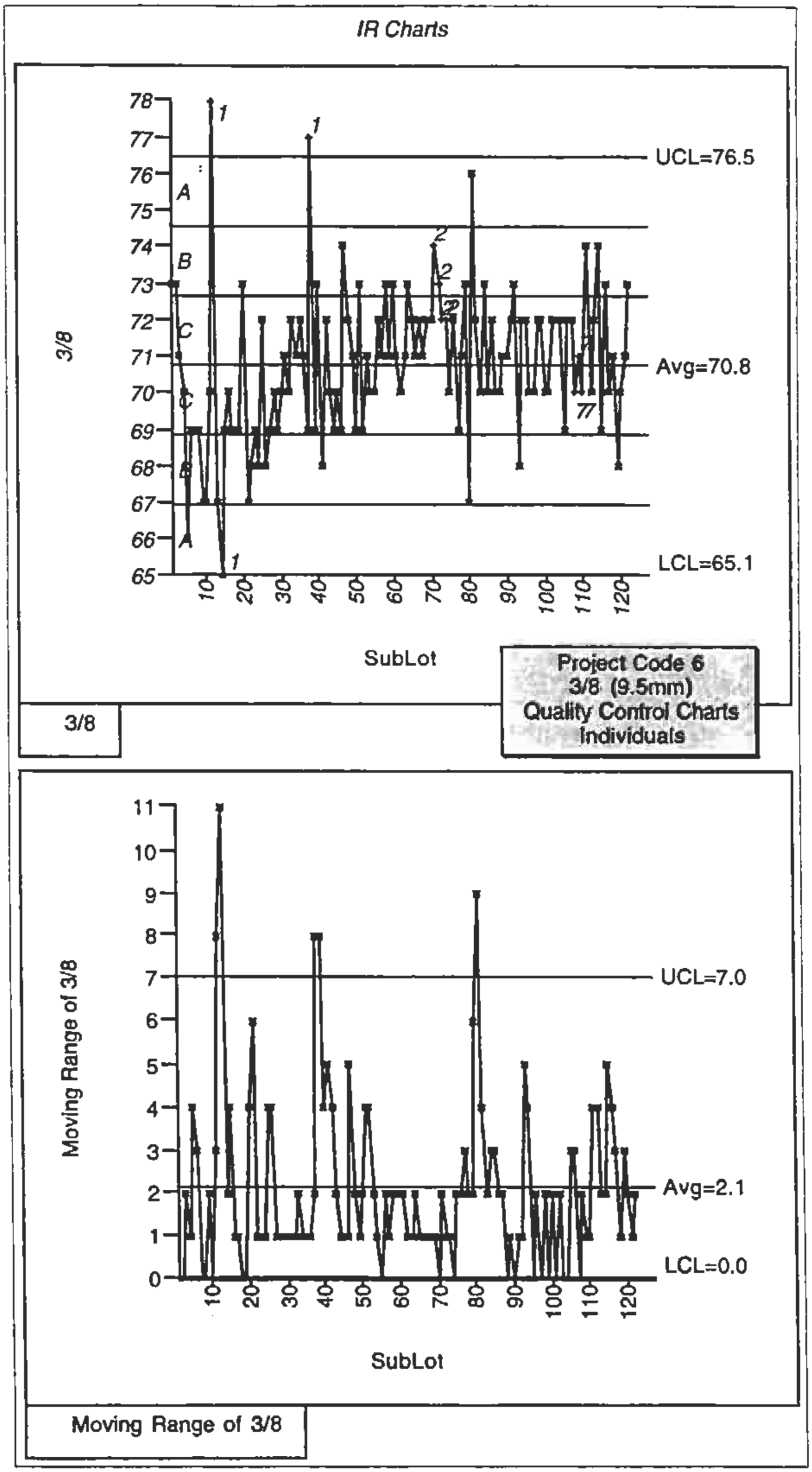
Specification	Value	Percent	Actual	Normal
Lower Spec Limit	65	%Below LSL	0.000	0.263
Upper Spec Limit	77	%Above USL	0.820	0.130
Spec Target	71			

Capability	Index
CPL	0.930
CPU	1.004
CPK	0.930
CP	0.967
CPM	0.961

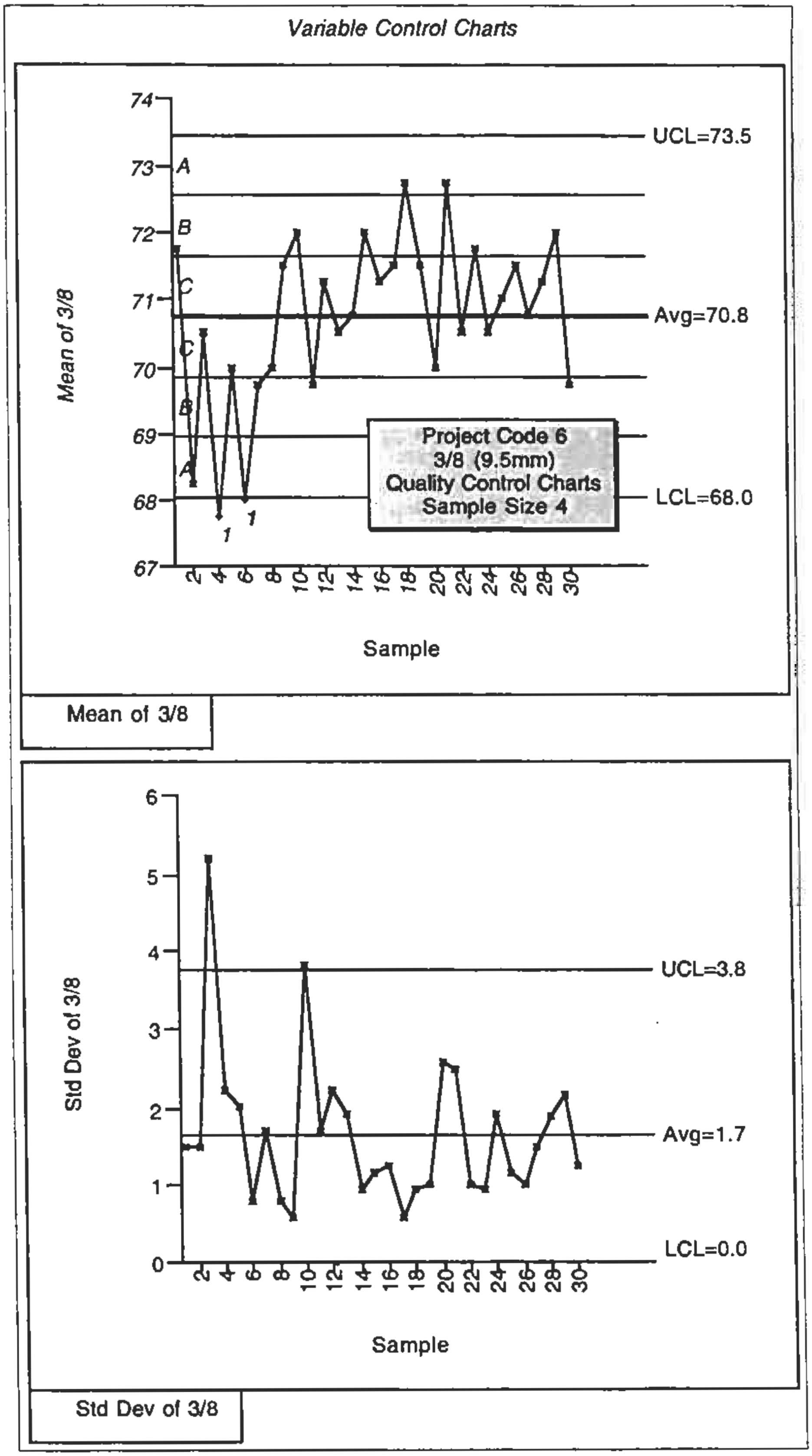
3/8 Group A (Sublots 1-40) v. Group B (Sublots 40-122). Groups are different.



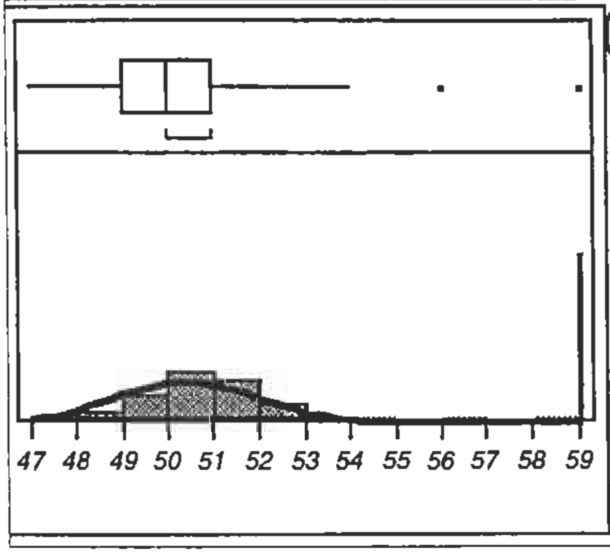
3/8 Control Charts, Individuals



3/8 Quality Control Charts, SampleSize 4



No. 4 Descriptive Statistics



Quantiles

Moments

Mean	50.3934
Std Dev	1.6035
Std Err Mean	0.1452
upper 95% Mean	50.6809
lower 95% Mean	50.1060
N	122.0000
Sum Wgts	122.0000

No. 4 Normality and Capability Analysis

Test for Normality

Shapiro-Wilk W Test

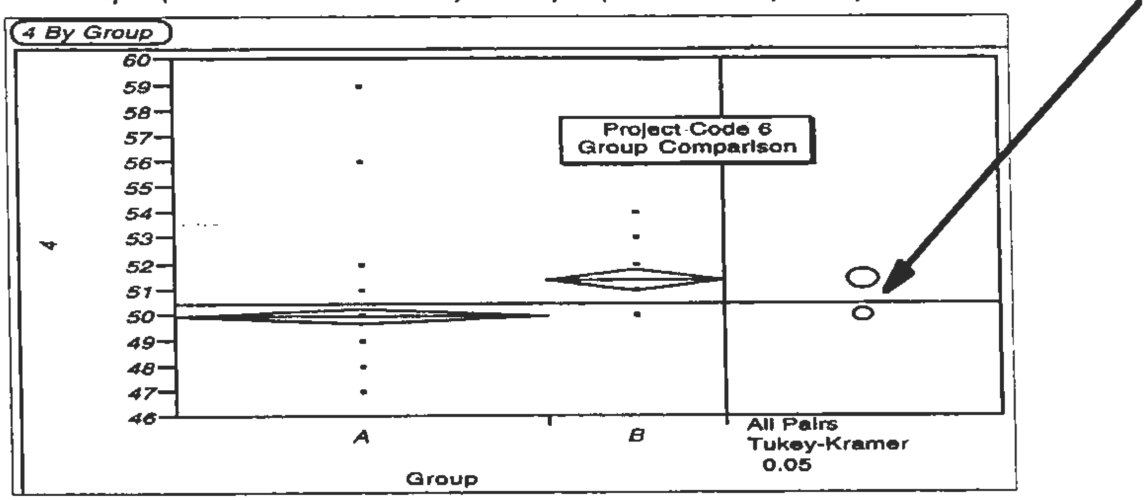
W	Prob<W
0.889528	0.0000

Capability Analysis

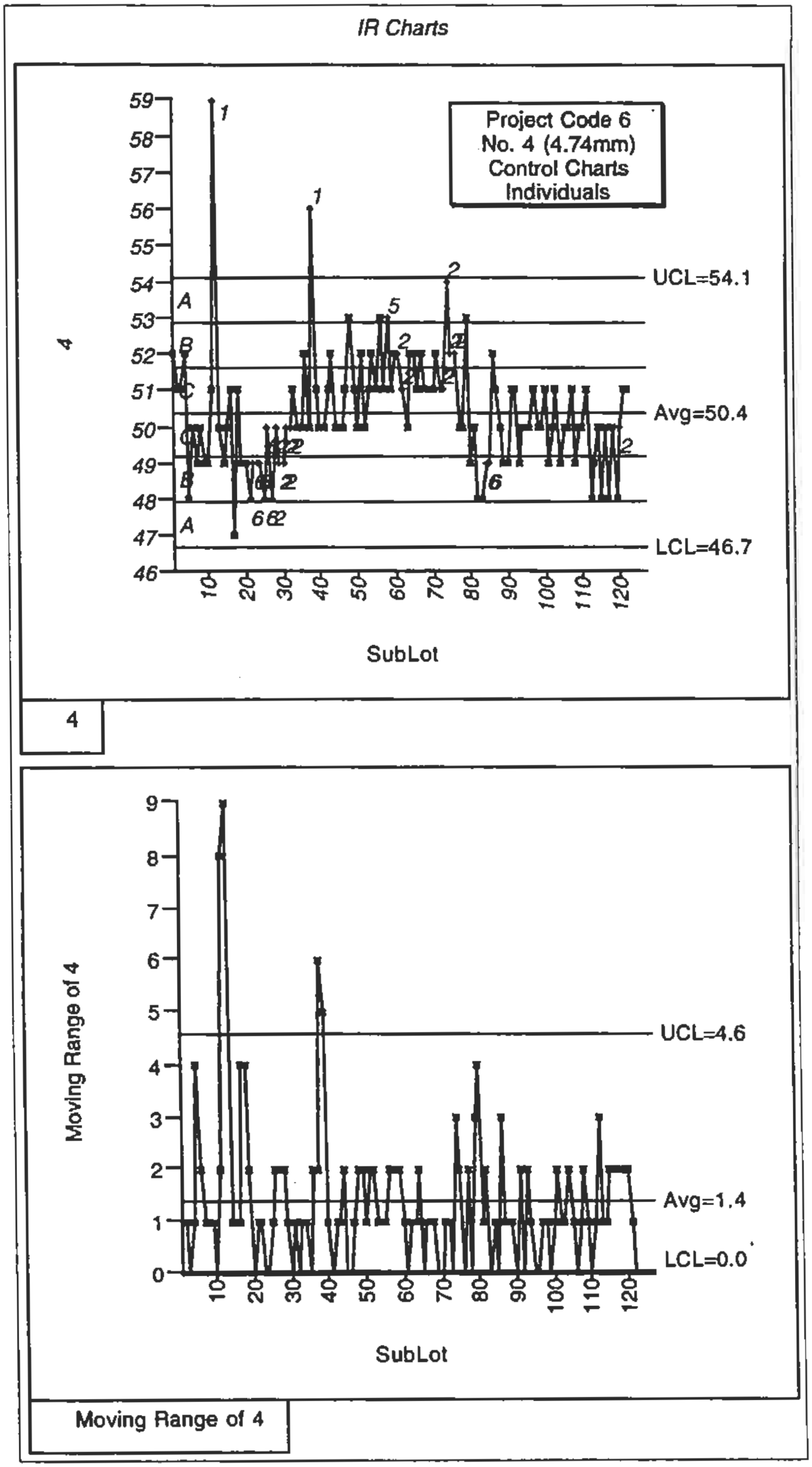
Specification	Value	Percent	Actual	Normal
Lower Spec Limit	45	%Below LSL	0.000	0.038
Upper Spec Limit	59	%Above USL	0.000	0.000
Spec Target	52			

Capability	Index
CPL	1.121
CPU	1.789
CPK	1.121
CP	1.455
CPM	1.028

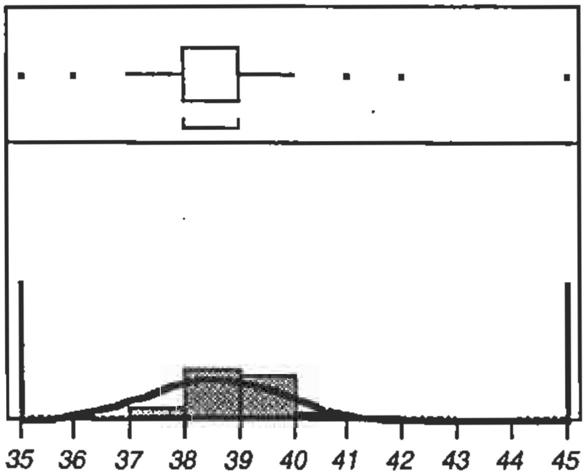
Compare Group A (Sublots 1-40 and 80-120) v Group B (Sublots 41-79). Groups are different..



No. 4 Control Charts, Individuals



No. 8 Descriptive Statistics



Quantiles

Moments

Mean	38.5410
Std Dev	1.2866
Std Err Mean	0.1165
upper 95% Mean	38.7716
lower 95% Mean	38.3104
N	122.0000
Sum Wgts	122.0000

Project Code 6
No 8 (2.36mm)
Descriptive Statistics

No. 8 Normality and Control Capability Analysis

Test for Normality

Shapiro-Wilk W Test

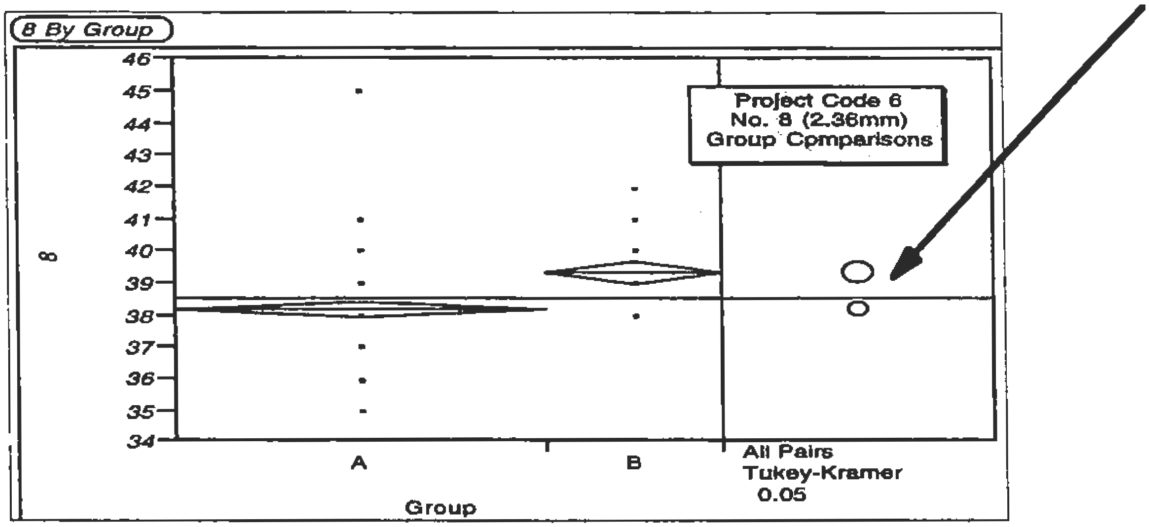
W	Prob<W
0.892011	0.0000

Capability Analysis

Specification	Value	Percent	Actual	Normal
Lower Spec Limit	35	%Below LSL	0.000	0.296
Upper Spec Limit	45	%Above USL	0.000	0.000
Spec Target	40			

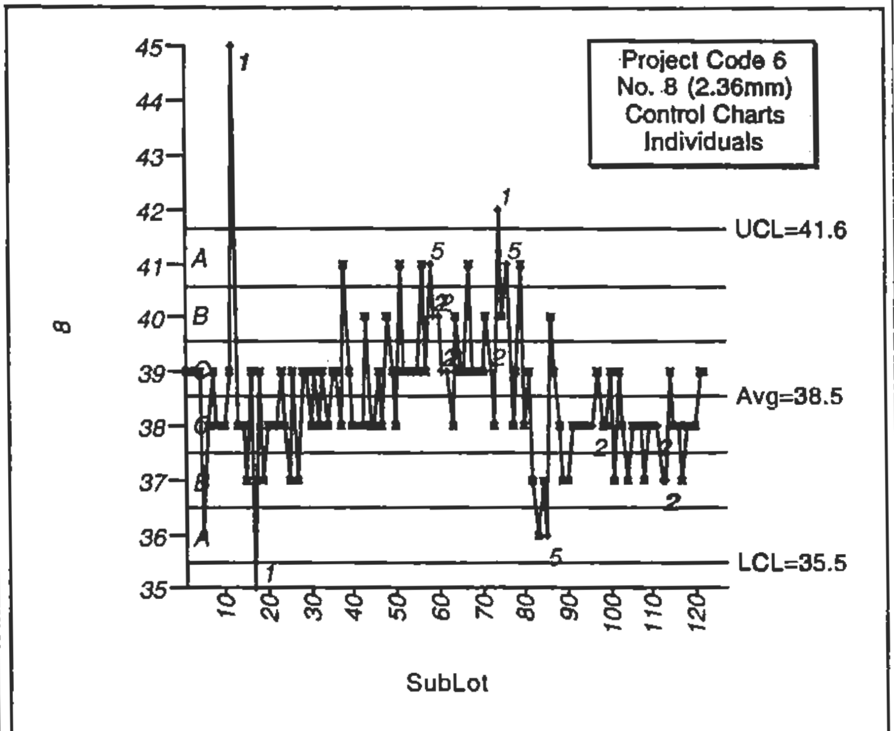
Capability	Index
CPL	0.917
CPU	1.673
CPK	0.917
CP	1.295
CPM	0.857

Group Cpmparisons (Same Grouping as for No. 4). Groups are different.

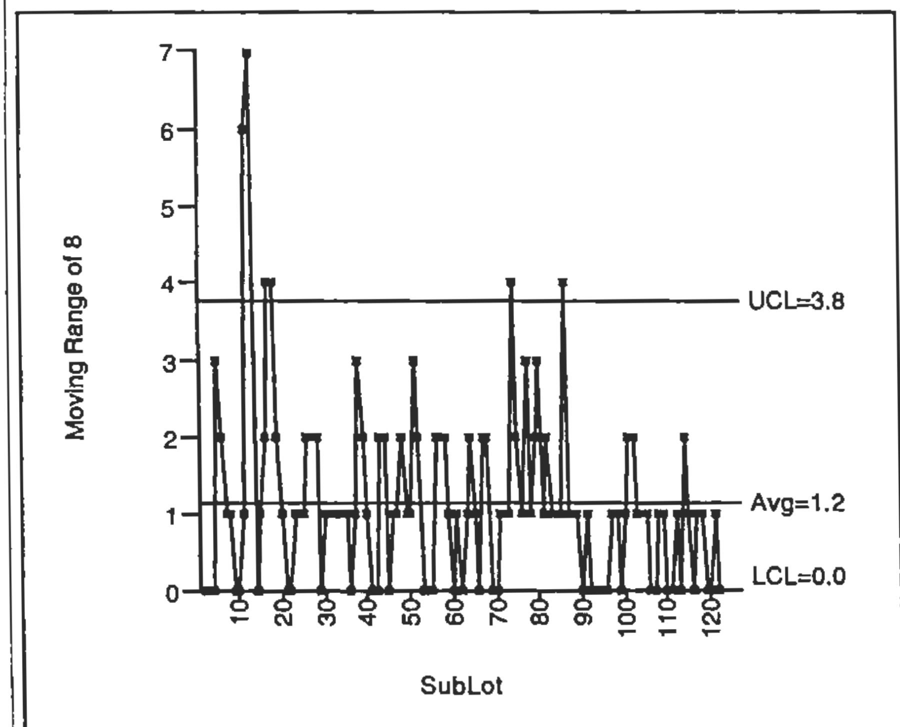


No. 8 Control Charts, Individuals.

IR Charts

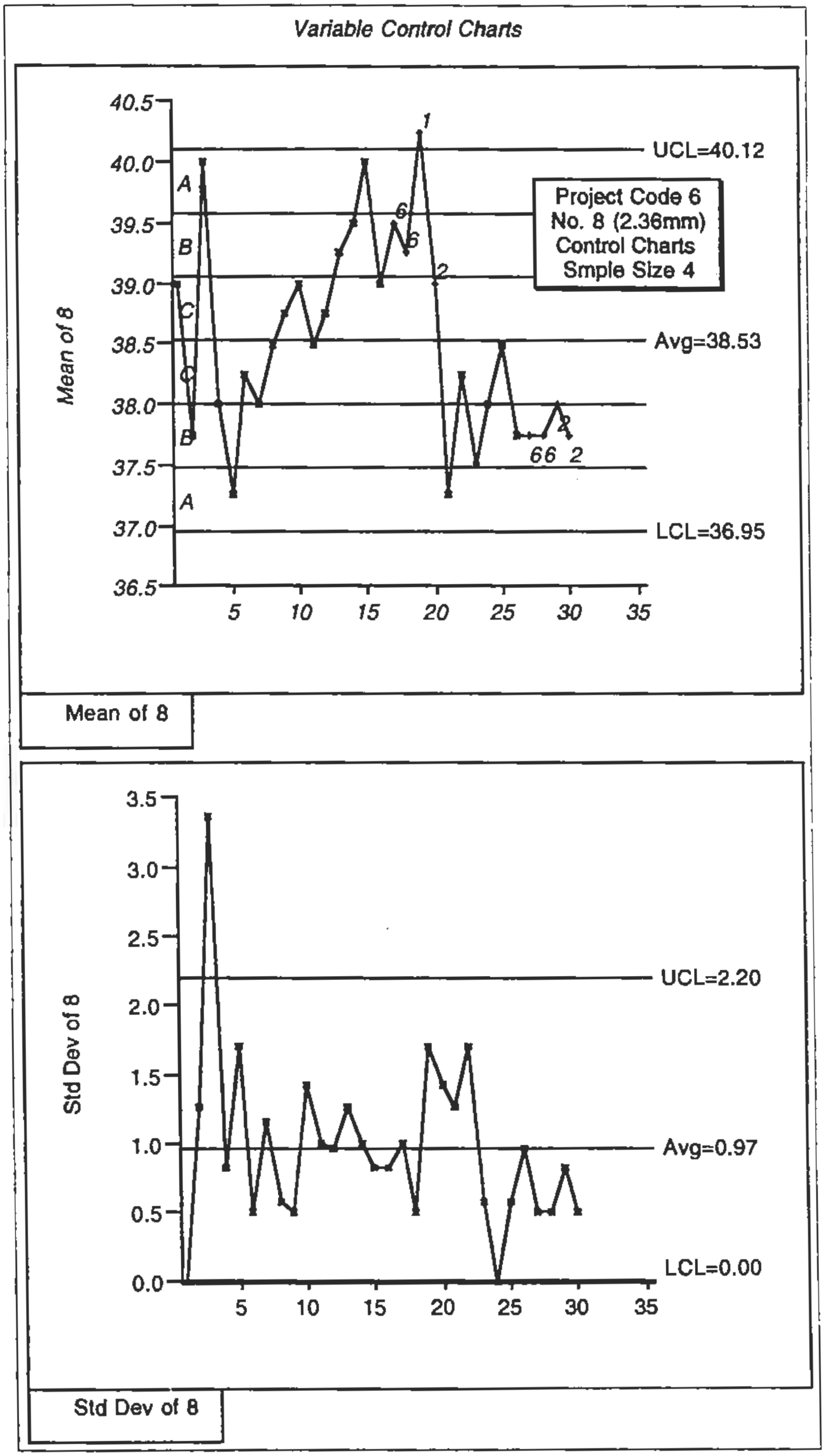


8

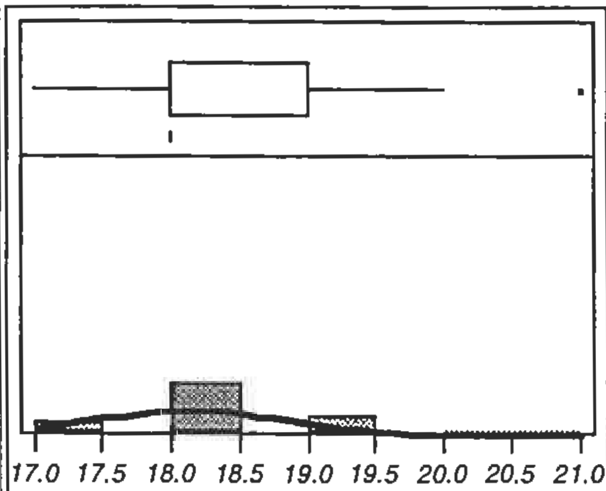


Moving Range of 8

No. 8 Control Charts, Sqample Size 4.



No. 30 Descriptive Statistics



Quantiles

Moments

Mean	18.1311
Std Dev	0.7601
Std Err Mean	0.0688
upper 95% Mean	18.2674
lower 95% Mean	17.9949
N	122.0000
Sum Wgts	122.0000

No. 30 Normality and Control Capability Analysis

Test for Normality

Shapiro-Wilk W Test

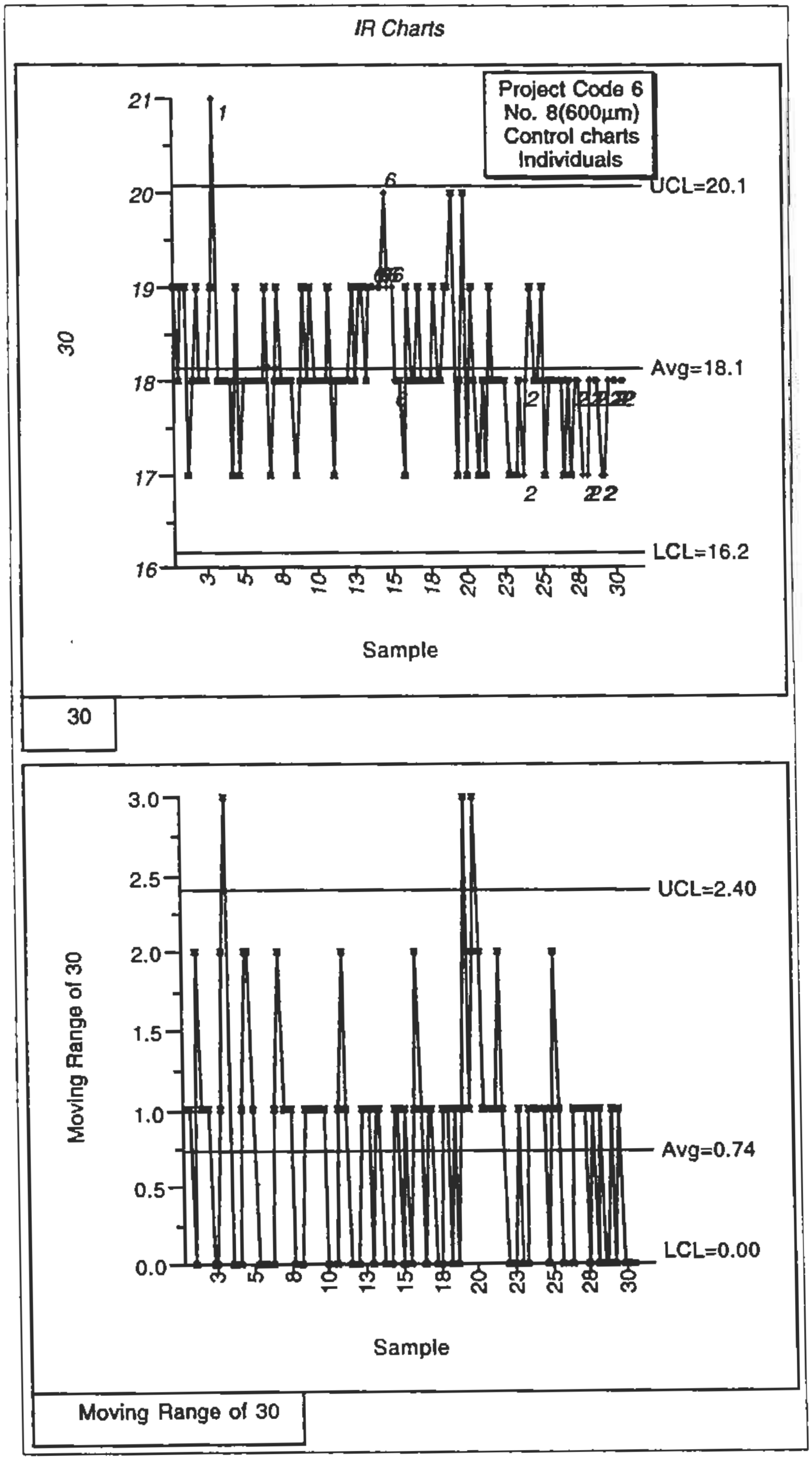
W	Prob<W
0.828166	0.0000

Capability Analysis

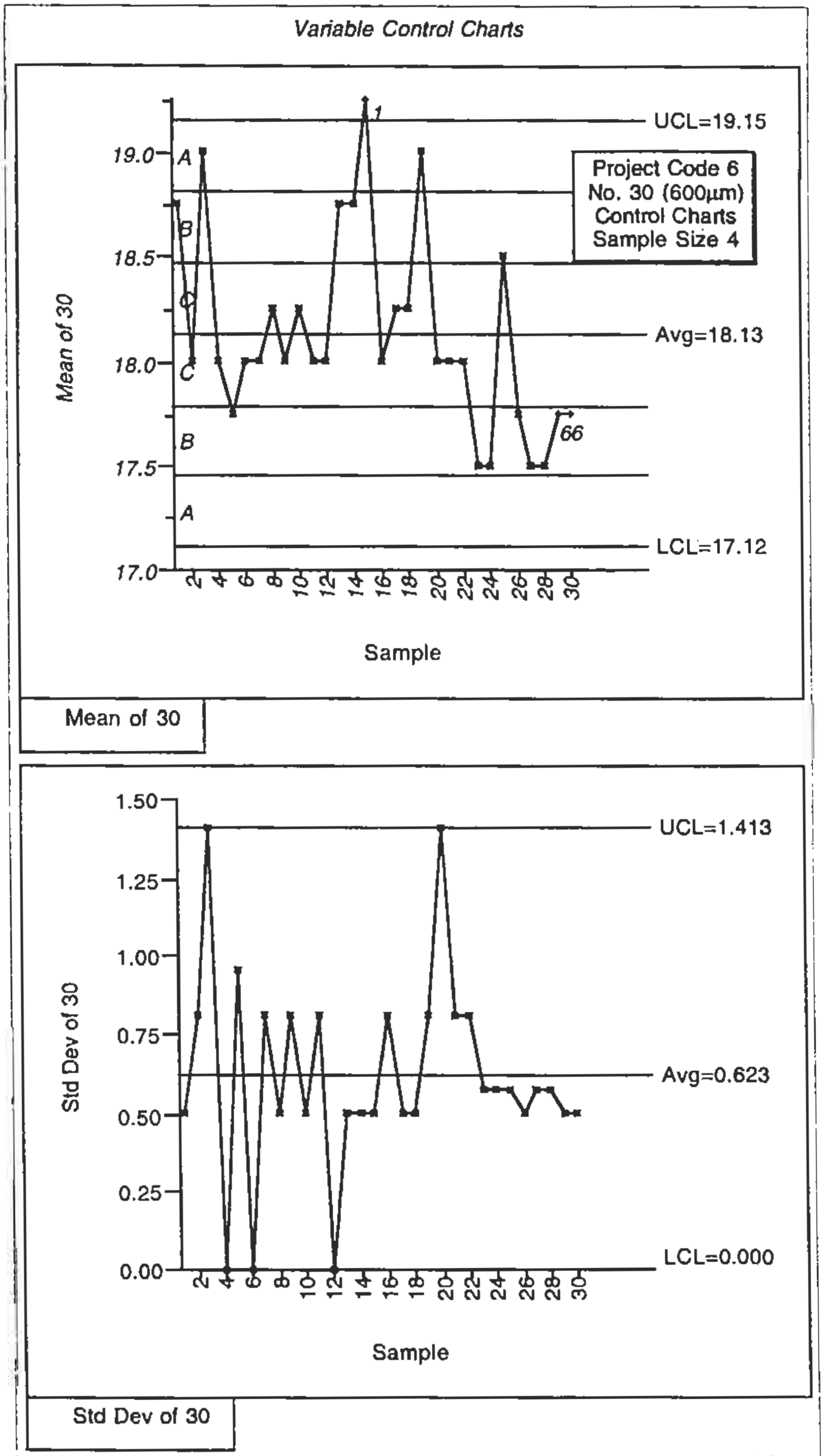
Specification	Value	Percent	Actual	Normal
Lower Spec Limit	16	%Below LSL	0.000	0.252
Upper Spec Limit	24	%Above USL	0.000	0.000
Spec Target	20			

Capability	Index
CPL	0.935
CPU	2.574
CPK	0.935
CP	1.754
CPM	0.661

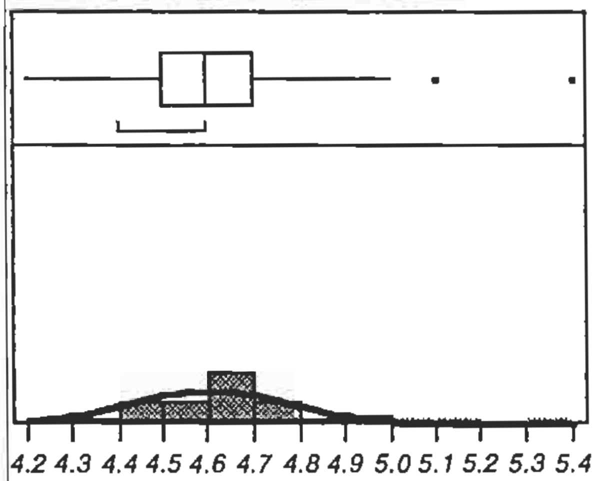
No. 30 Conrtol Charts, Individuals



No. 30 Control Charts, Sample Size 4



No. 200 Descriptive Statistics



Quantiles

Moments

Mean	4.5975
Std Dev	0.1856
Std Err Mean	0.0168
upper 95% Mean	4.6308
lower 95% Mean	4.5643
N	122.0000
Sum Wgts	122.0000

Project Code 6
No 200(74μm)
Descriptive Statistics

No. 200 Normality and Control Capability Analysis

Test for Normality

Shapiro-Wilk W Test

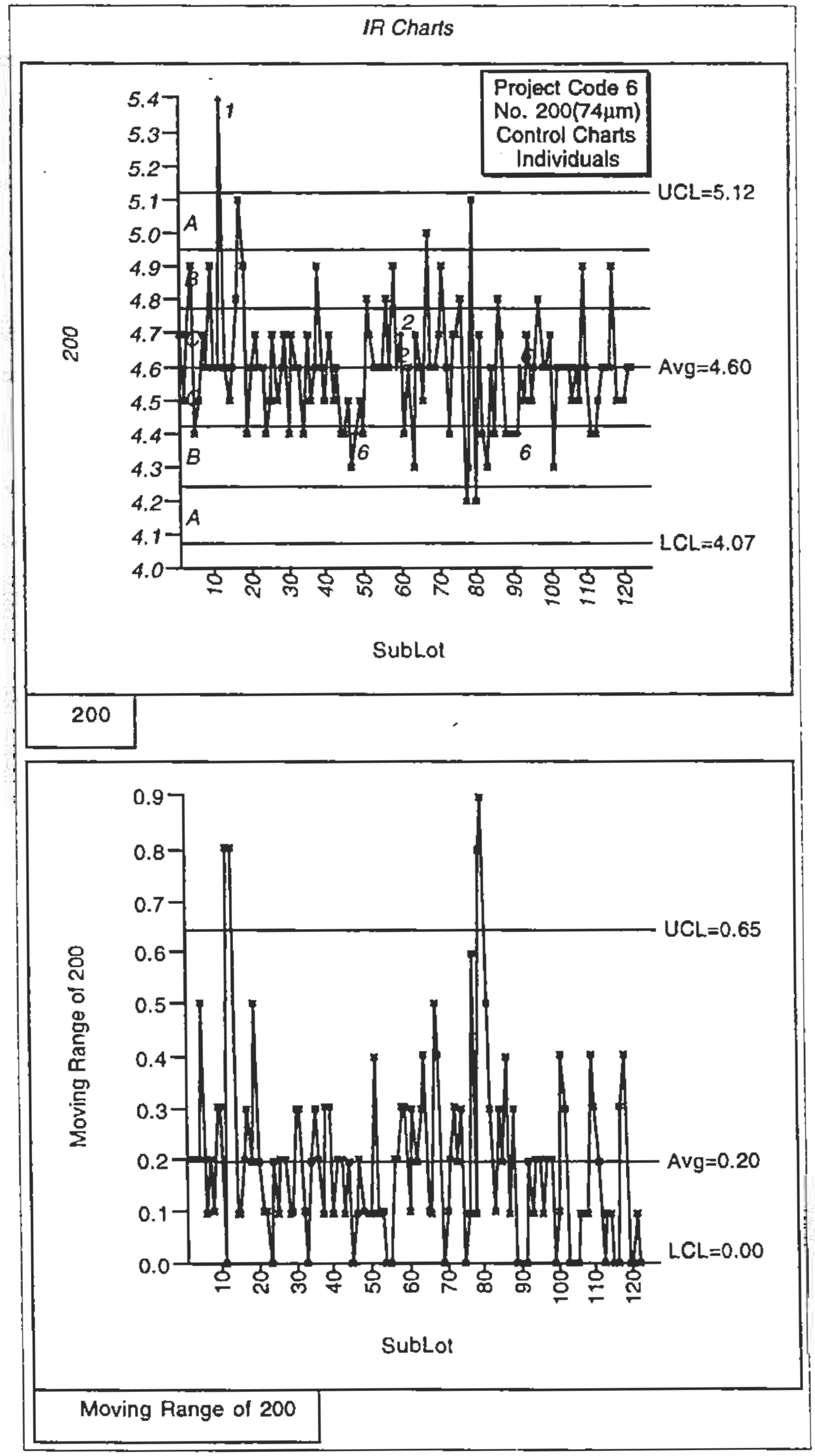
W	Prob<W
0.930507	0.0000

Capability Analysis

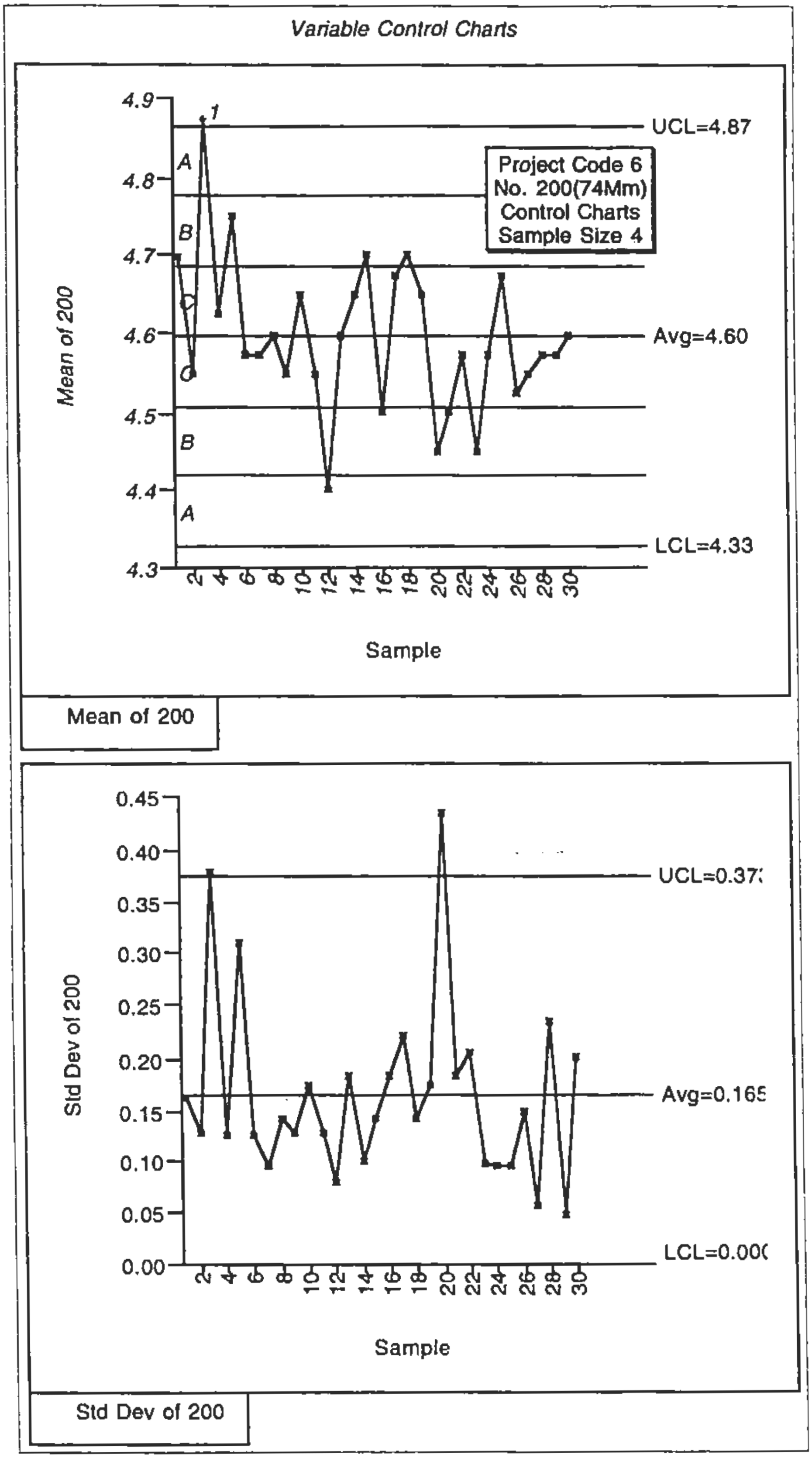
Specification	Value	Percent	Actual	Normal
Lower Spec Limit	3	%Below LSL	0.000	0.000
Upper Spec Limit	7	%Above USL	0.000	0.000
Spec Target	5			

Capability	Index
CPL	2.869
CPU	4.314
CPK	2.869
CP	3.591
CPM	1.504

No. 200 Control Charts, Individuals

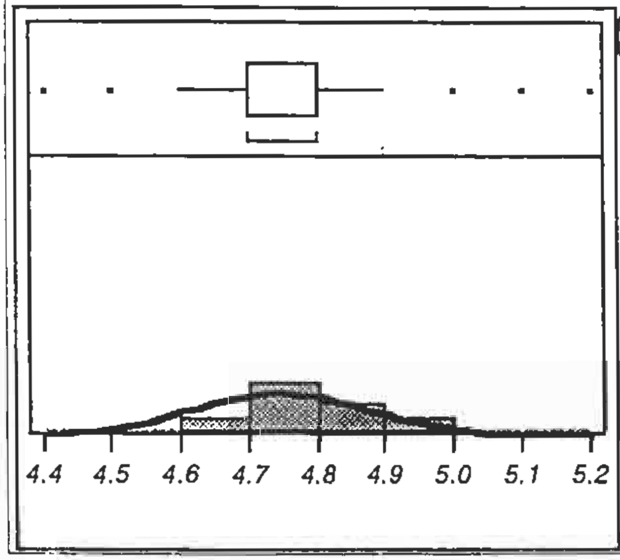


No. 200 Control Charts, Sample Size 4



Asphalt Content Descriptive Statistics

AC



Quantiles

Moments

Mean	4.7426
Std Dev	0.1323
Std Err Mean	0.0120
upper 95% Mean	4.7663
lower 95% Mean	4.7189
N	122.0000
Sum Wgts	122.0000

Project Code 6
Asphalt Content
Descriptive Statistics

Asphalt Content Normality and Control Capability Analysis

Test for Normality

Shapiro-Wilk W Test

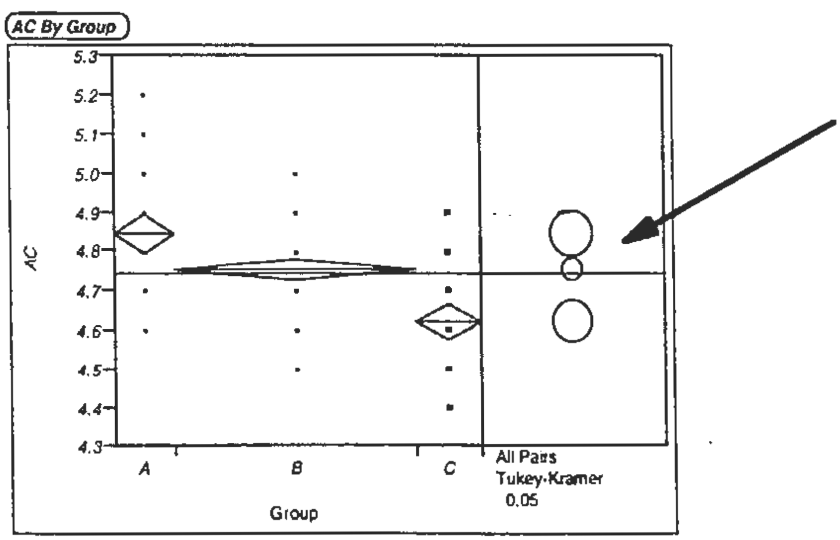
W	Prob<W
0.934360	0.0000

Capability Analysis

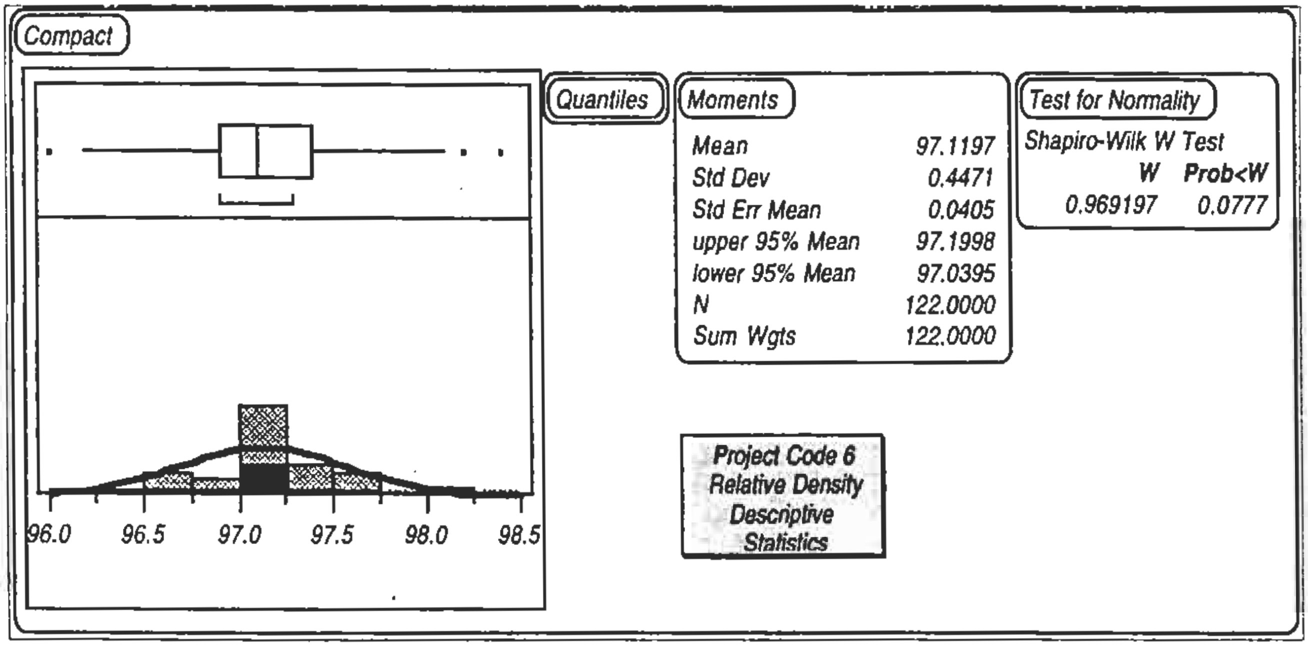
Specification	Value	Percent	Actual	Normal
Lower Spec Limit	4.3	%Below LSL	0.000	0.041
Upper Spec Limit	5.3	%Above USL	0.000	0.001
Spec Target	4.8			

Capability	Index
CPL	1.115
CPU	1.404
CPK	1.115
CP	1.260
CPM	1.156

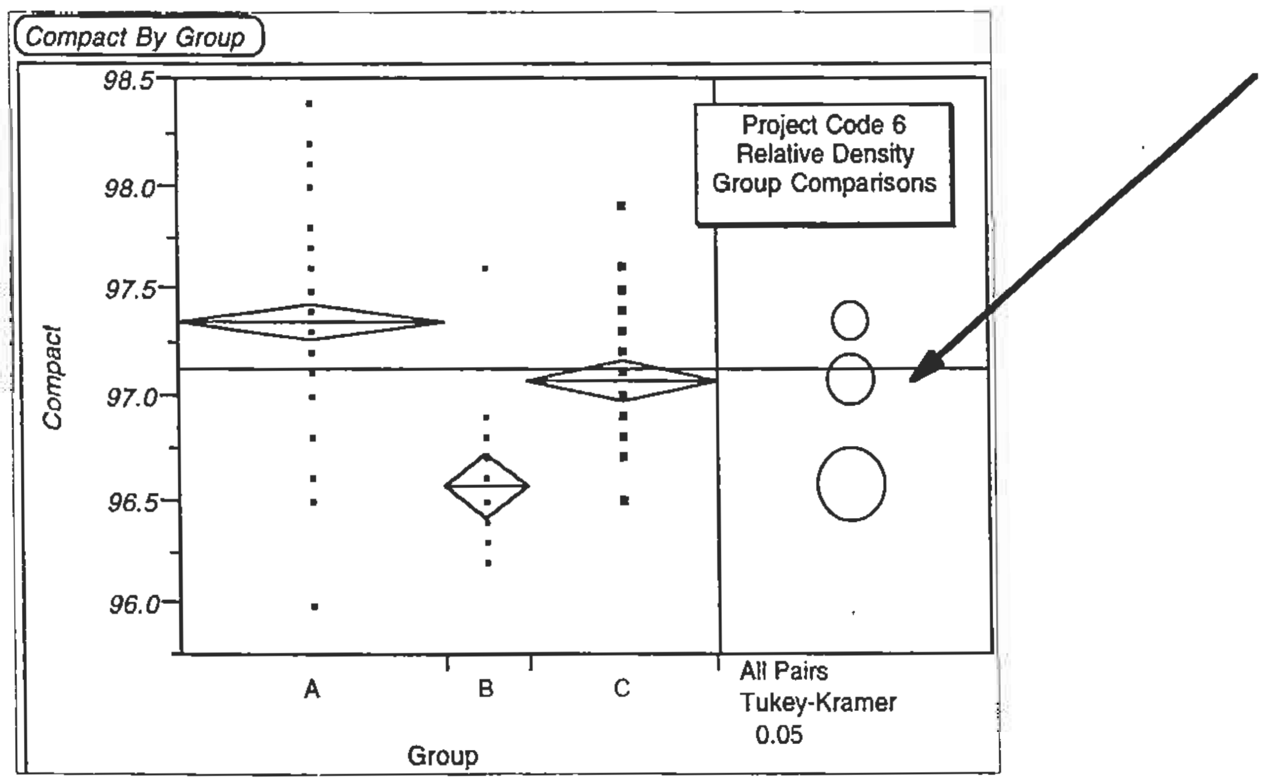
Group Comparison. Group A (Sublots 1-20) v. Group B (Sublots 21-100) v. Group C (Sublots 101-122).



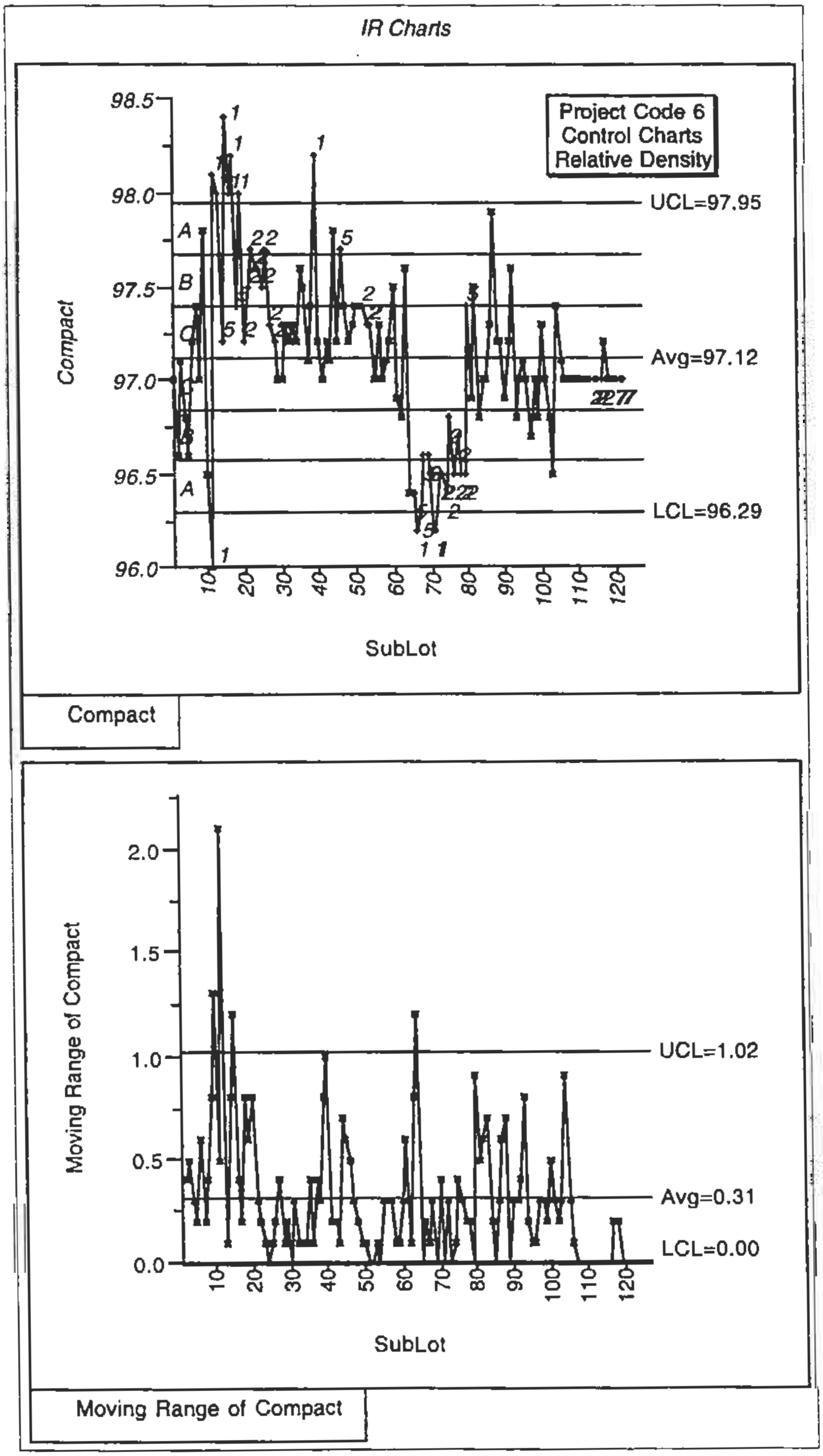
Relative Compaction Descriptive Statistics



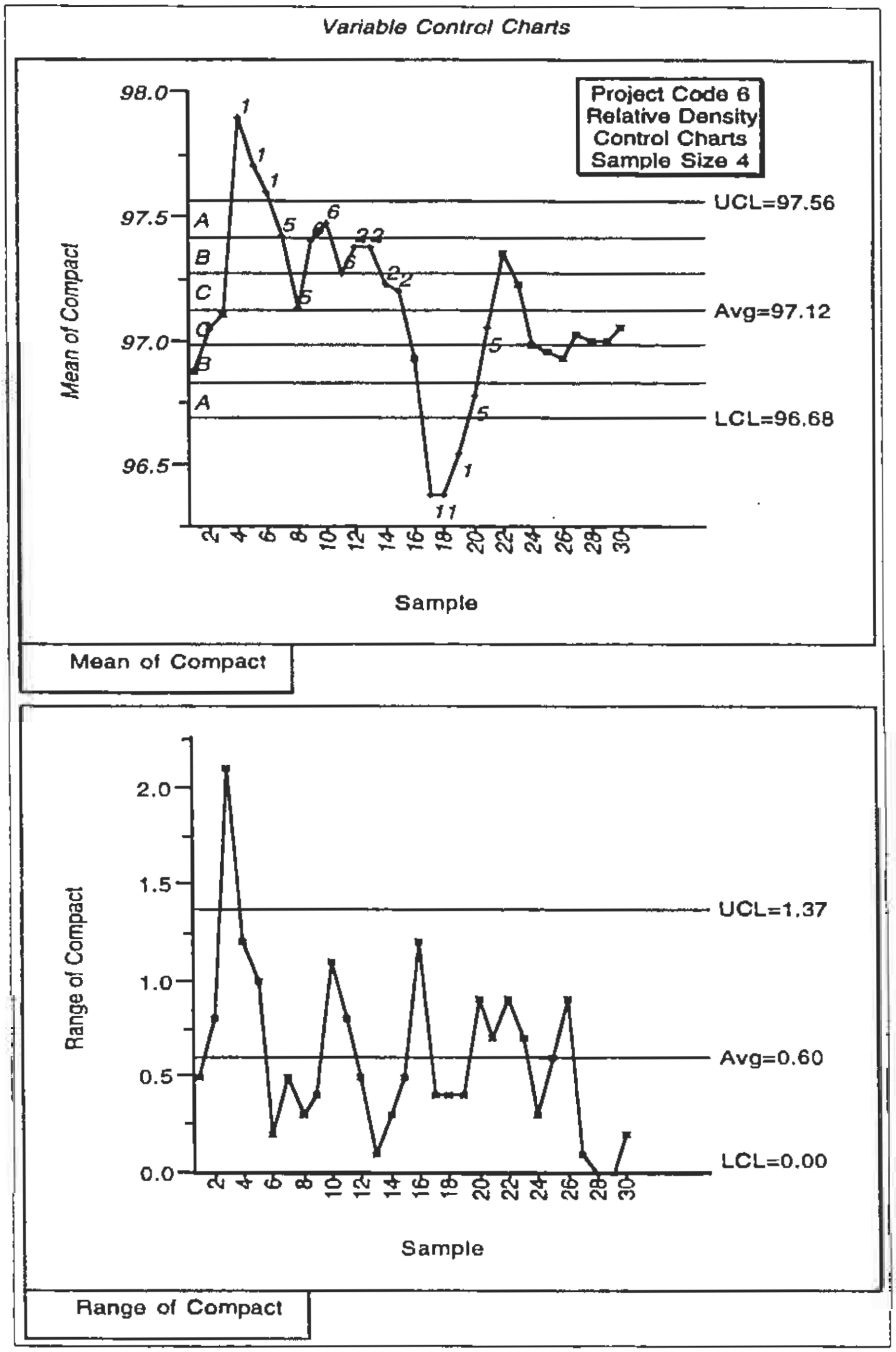
Group Comparison. Group A (Sublots 1-60) v. Group B (Sublots 61-80) v. Group C (Sublots 81-122). Groups are different.



Relative Density Control Charts, Individuals



Relative Density Control Charts, Sample Size 4.



Appendix C

Statistical Summaries

Appendix C

Statistical Summaries

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
1 (Lot 1)	Count	12	12	12	12	12	12	12	12
	Max	100	69	46	37	23	5	5.16	97.9
	Min	95	61	40	34	21	2	4	94.4
	Range	5	8	6	3	2	3	1.16	3.5
	Mean	97.8	66.6	43.6	35.3	21.8	4.67	4.74	96.09
	Std. Dev.	1.85	2.68	1.73	1.14	0.58	0.888	0.303	1.104
	CV, %	1.9	4.0	4.0	3.2	2.6	19.0	6.4	1.1
	Target	100	83	49	38	18	4.0	4.9	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	69	56	41	22	6.0	5.4	
	LSL	95	57	42	31	14	2.0	4.4	96.0
	Normal	No	Yes	Yes	Yes	No	No	Yes	Yes
	In Control	OK	No	No	No	No	Close	Close	No
	Capability	No	OK	Close	OK	No	No	No	NA

30 may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
1 (Lot 2)	Count	11	11	11	11	11	11	11	11
	Max	99	73	53	40	22	5	5.2	97.5
	Min	96	64	45	31	14	4.0	4.8	96.7
	Range	3	9	8	9	8	1	0.4	0.8
	Mean	97.8	67.5	48.4	34.6	18.5	4.73	5.01	97.14
	Std. Dev.	1.08	2.38	2.66	2.58	2.11	0.467	0.103	0.385
	CV, %	1.1	3.5	5.5	7.4	11.5	9.9	2.1	0.4
	Target	100	69	48	34	17	4.0	4.9	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	75	55	39	21	6.0	5.4	
	LSL	95	63	41	29	13	2.0	4.4	96.0
	Normal	Yes	Yes	No	Yes	Yes	No	No	No
	In Control	Close	Marginal	No	ok	ok	Marginal	No	No
	Capability	No	No	No	No	No	No	No	NA

Density may have mulriple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
1 (Lot 3)									
	Count	19	19	19	19	19	19	19	19
	Max	99.0	74.0	55.0	41.0	22.0	6.0	5.0	98.8
	Min	97.0	64.0	42.0	32.0	16.0	4.0	4.5	96.6
	Range	2	10	13	9	6	2.0	1	2
	Mean	97.7	70.6	51.5	36.9	19.6	5.05	4.67	97.23
	Std. Dev.	0.81	2.73	3.42	2.12	1.57	0.621	0.141	0.665
	CV, %	0.8	3.9	6.6	5.7	8.0	12.3	3.0	0.7
	Target	100	69	48	34	17	4.0	4.7	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	75	55	39	21	6.0	5.2	
	LSL	95	63	41	29	13	2.0	4.2	96.0
	Normal	Yes	Yes	Yes	Yes	No	No	Yes	Yes
	In Control	ok	No	No	Yes	Yes	Close	Close	No
	Capability	No	No	No	No	No	Close	No	NA

All gradations and density may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
2	Count	108	108	108	108	108	108	108	108
	Max	99	76	49	38	21	5	4.7	99.9
	Min	90	59	42	30	13	2.0	4.1	96.7
	Range	9	17	7	8	8	3	0.6	3.2
	Mean	96.3	67.4	45.6	35.0	16.6	3.12	4.42	97.73
	Std. Dev.	2.32	2.97	1.44	1.86	2.18	0.524	0.123	0.675
	CV, %	2.4	4.4	3.2	5.3	13.1	16.8	2.8	0.7
	Target	95	65	47	35	17	3.0	4.5	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	71	54	40	21	5.0	5.0	
	LSL	90	59	40	30	13	1.0	4.0	96.0
	Normal	No	Yes	No	No	No	No	No	No
	In Control	No	No	No	No	No	No	Yes	No
	Capability	No	No	Yes	No	No	Close	Close	NA

 # 30 may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
3	Count	78	78	78	78	78	78	78	78
	Max	98	77	52	40	25	4.2	6.4	100.9
	Min	97	70	44	32	19	3.1	5.6	96.1
	Range	1	7	8	8	6	1.1	0.8	4.8
	Mean	97.6	73.4	47.3	36.1	22.9	3.63	5.94	98.83
	Std. Dev.	0.48	1.20	1.93	1.33	1.11	0.252	0.168	1.113
	CV, %	0.5	1.6	4.1	3.7	4.9	7.0	2.8	1.1
	Target	99	75	49	38	21	4.1	5.9	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	81	56	41	25	6.1	6.4	
	LSL	94	69	42	31	17	2.1	5.4	96.0
	Normal	No	No	No	No	No	Yes	No	No
	In Control	No	Close	Close	No	Close	Yes	Yes	No
	Capability	Yes	Close	Close	Yes	No	Yes	Close	NA

Density may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
4	Count	78	78	78	78	78	78	78	78
	Max	98	78	59	45	25	5.3	5.3	100.0
	Min	93	67	46	33	15	3.0	4.1	95.9
	Range	5	11	13	12	10	2.3	1.2	4.1
	Mean	95.6	72.0	53.6	39.1	20.3	4.10	4.79	98.01
	Std. Dev.	1.03	2.22	2.92	2.32	1.81	0.518	0.255	0.856
	CV, %	1.1	3.1	5.4	5.9	8.9	12.6	5.3	0.9
	Target	95	72	53	40	21	4.0	4.7	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	78	60	45	25	6.0	5.2	
	LSL	90	66	46	35	17	2.0	4.2	96.0
	Normal	No	No	Yes	Yes	No	Yes	Yes	No
	In Control	Yes	Close	Close	Yes	Yes	Yes	Close	No
	Capability	Yes	No	No	No	No	Yes	No	NA

3/8, No. 4, asphalt content, anddensity may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
5	Count	45	45	45	45	45	45	45	45
	Max	100	75	52	39	21	4	5.3	99.4
	Min	99	67	47	34	17	2.8	4.9	96.6
	Range	1	8	5	5	4	1.2	0.4	2.8
	Mean	99.9	70.8	48.8	36.3	18.6	3.36	5.07	97.93
	Std. Dev.	0.34	1.75	1.33	1.17	0.91	0.319	0.125	0.726
	CV, %	0.3	2.5	2.7	3.2	4.9	9.5	2.5	0.7
	Target	96	70	49	34	18	3.0	5.0	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	76	56	39	22	5.0	5.5	
	LSL	91	64	42	29	14	1.0	4.5	96.0
	Normal	No	Yes	No	No	No	Yes	No	Yes
	In Control	No	Yes	Close	Yes	Yes	No	Yes	No
	Capability	Close	Close	Yes	Close	Yes	No	Yes	NA

Density may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
6	Count	122	122	122	122	122	122	122	122
	Max	97	78	59	45	21	5.4	5.2	98.4
	Min	90	65	47	35	17	4.2	4.4	96.0
	Range	7	13	12	10	4	1.2	0.8	2.4
	Mean	93.6	70.8	50.4	38.5	18.1	4.60	4.80	97.12
	Std. Dev.	1.65	2.07	1.60	1.29	0.76	0.186	0.132	0.447
	CV, %	1.8	2.9	3.2	3.3	4.2	4.0	2.8	0.5
	Target	95	71	52	40	20	5.0	4.8	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	77	59	45	24	7.0	5.3	
	LSL	90	65	45	35	16	3.0	4.3	96.0
	Normal	No	Yes	No	No	No	No	No	Yes
	In Control	No	Yes	No	Close	Yes	No	Yes	No
	Capability	No	Close	Yes	Close	Yes	Yes	Yes	NA

#8 and density may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
7	Count	124	124	124	124	124	124	124	124
	Max	100	82	56	40	20	6.9	6.5	98.3
	Min	100	75	51	35	15	5.2	5.8	93
	Range	0	7	5	5	5	1.7	0.7	5.3
	Mean	100.0	79.0	53.5	37.9	18.0	6.11	6.11	97.15
	Std. Dev.	0.00	1.51	1.15	1.17	0.99	0.346	0.165	0.540
	CV, %	0.0	1.9	2.2	3.1	5.5	5.7	2.7	0.6
	Target	98	80	54	38	18	5.0	6.2	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	86	61	43	22	7.0	6.7	
	LSL	93	74	47	3	14	3.0	5.7	96.0
	Normal	No	No	No	No	No	No	No	Yes
	In Control	Close	Close	No	No	No	Close	No	No
	Capability	Close	No	No	Yes	Yes	Yes	No	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
8	Count	63	63	63	63	63	63	63	50
	Max	100	70	54	42	23	8	5.6	99.5
	Min	95	58	37	28	15	5.0	4.6	95.0
	Range	5	12	17	14	8	3	1.0	4.5
	Mean	98.2	63.9	44.9	33.7	17.8	6.56	5.15	98.32
	Std. Dev.	1.07	2.89	2.87	2.37	1.38	0.741	0.261	0.906
	CV, %	1.1	4.5	6.4	7.0	7.7	11.3	5.1	0.9
	Target	100	66	48	32	18	6.0	5.1	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	72	53	37	22	8.0	5.6	
	LSL	95	60	39	27	14	4.0	4.6	96.0
	Normal	No	Yes	Yes	Yes	No	No	No	No
	In Control	Close	Close	Close	Yes	Yes	No	Yes	Close
	Capability	No	No	No	No	No	No	No	NA

3/8 and density may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
9	Count	74	74	74	74	74	74	74	74
	Max	100	74	59	39	20	5	5.5	100
	Min	96	61	43	25	12	2.6	3.8	94.2
	Range	4	13	16	14	8	2.4	1.7	5.8
	Mean	98.8	65.9	48.4	32.5	16.3	3.61	4.62	97.58
	Std. Dev.	0.87	2.62	2.78	3.40	1.86	0.497	0.345	1.348
	CV, %	0.9	4.0	5.7	10.5	11.4	13.8	7.5	1.4
	Target	98	68	48	32	18	3.0	4.7	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	74	55	37	22	5.0	5.2	
	LSL	93	62	41	27	14	1.0	4.2	96.0
	Normal	No	Yes	No	No	No	No	Yes	Yes
	In Control	No	Close	Yes	Yes	Yes	Yes	No	Close
	Capability	No	No	No	No	No	No	No	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
10	Count	45	45	45	45	45	45	45	
	Max	97	73	50	39	21	5	4.8	
	Min	94	68	45	33	17	4.0	4.4	
	Range	3	5	5	6	4	1	0.4	
	Mean	95.6	70.5	47.4	35.8	18.8	4.44	4.62	
	Std. Dev.	1.01	1.24	1.20	1.21	1.04	0.503	0.100	
	CV, %	1.1	1.8	2.5	3.4	5.5	11.3	2.2	
	Target	95	69	47	3	18	4.0	4.6	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	75	54	41	22	6.0	5.1	
	LSL	90	63	40	31	14	2.0	4.1	96.0
	Normal	No	No	No	No	No	No	No	No
	In Control	Close	Yes	Yes	Yes	No	Yes	Yes	Yes
	Capability	Yes	Yes	Yes	Yes	Close	Close	Yes	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
11	Count	60	60	60	60	60	60	60	24
	Max	98	75	57	45	24	7	5.6	97.9
	Min	97	70	48	36	16	4	4.7	96.1
	Range	1	5	9	9	8	3	0.9	1.8
	Mean	97.2	72.1	52.4	39.7	19.1	4.98	5.26	96.9125
	Std. Dev.	0.39	1.05	1.98	1.77	1.53	0.813	0.189	0.418
	CV, %	0.4	1.5	3.8	4.5	8.1	16.3	3.6	0.4
	Target	95	71	51	38	20	6.0	5.2	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	77	58	43	24	8.0	5.7	
	LSL	90	65	44	33	16	4.0	4.7	96.0
	Normal	No	No	Yes	No	No	No	No	Yes
	In Control	No	Yes	No	Yes	Yes	Close	Yes	Yes
	Capability	Close	Yes	No	No	No	No	No	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
12	Count	52	52	52	52	52	52	52	52
	Max	100	74	51	39	21	4.1	5.4	100.0
	Min	99	70	47	33	14	2.4	4.6	96.9
	Range	1	4	4	6	7	1.7	0.8	3.1
	Mean	99.9	72.0	49.2	36.0	18.1	3.30	5.04	98.88
	Std. Dev.	0.24	1.27	1.18	1.26	1.49	0.381	0.199	0.723
	CV, %	0.2	1.8	2.4	3.5	8.2	11.5	4.0	0.7
	Target	97	72	49	34	18	3.0	5.0	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	78	56	39	22	5.0	5.5	
	LSL	92	66	42	29	14	1.0	4.5	96.0
	Normal	No	No	No	No	No	No	Yes	No
	In Control	No	Yes	Close	Yes	Yes	Yes	Yes	No
	Capability	No	Yes	Yes	No	No	Yes	No	NA

Density may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
13	Count	38	38	38	38	38	38	38	38
	Max	100	73	54	42	22	6	5.3	98.3
	Min	98	68	50	37	18	4.7	4.6	95.5
	Range	2	5	4	5	4	1.3	0.7	2.8
	Mean	99.1	70.4	53.0	40.2	20.8	5.38	4.96	97.4553
	Std. Dev.	0.67	1.44	1.12	1.52	1.06	0.417	0.170	0.454
	CV, %	0.7	2.0	2.1	3.8	5.1	7.8	3.4	0.5
	Target	98	71	53	40	21	5.0	5.1	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	77	60	45	25	7.0	5.6	
	LSL	94	65	46	35	17	3.0	4.6	96.0
	Normal	No	No	No	No	No	No	Yes	No
	In Control	No	No	Close	No	Close	Close	Yes	Yes
	Capability	Close	Yes	Yes	Close	Yes	Yes	No	NA

#8 and 200 may have multiple populations

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
14	Count	46	46	46	46	46	46	46	
	Max	96	75	59	43	21	5	7.3	
	Min	90	67	48	32	13	2.0	5.3	
	Range	6	8	11	11	8	3	2.0	
	Mean	94.1	73.0	53.7	38.9	16.6	3.30	6.38	
	Std. Dev.	1.43	1.84	2.25	2.90	2.08	0.813	0.334	
	CV, %	1.5	2.5	4.2	7.5	12.5	24.6	5.2	
	Target	95	72	53	40	18	4.0	6.2	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	78	60	45	22	6.0	6.7	
	LSL	90	66	46	35	14	2.0	5.7	
	Normal	No	No	Yes	No	Yes	No	No	
	In Control	Yes	Yes	Yes	Yes	Yes	No	Yes	
	Capability	No	No	No	No	No	No	No	

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
16 (Lot 1)	Count	6	6	6	6	6	6	6	6
	Max	95	70	48	37	20	4.1	5.6	98.9
	Min	94	63	46	34	18	3	4.5	97.1
	Range	1	7	2	3	2	1.1	1.1	1.8
	Mean	94.3	65.8	46.8	35.3	18.8	3.30	5.23	97.85
	Std. Dev.	0.52	2.79	0.98	1.37	0.98	0.429	0.383	0.599
	CV, %	0.5	4.2	2.1	3.9	5.2	13.0	7.3	0.6
	Target	95	72	53	40	21	3.0	4.9	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	78	60	45	25	5.0	5.4	
	LSL	90	66	46	35	17	1.0	4.4	96.0
	Normal	No	Yes	No	Yes	No	No	Yes	Yes
	In Control	No	No	No	No	No	No	No	Close
	Capability	No	No	No	No	No	Yes	No	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
16 (Lot 2)	Count	11	11	11	11	11	11	11	11
	Max	96	71	51	38	20	4.8	5.0	97.1
	Min	92	67	47	35	19	2.5	4.2	95.8
	Range	4	4	4	3	1	2.3	0.8	1.3
	Mean	94.0	69.6	49.5	36.5	19.5	3.92	4.55	96.67
	Std. Dev.	1.10	1.50	1.29	0.82	0.52	0.615	0.262	0.582
	CV, %	1.2	2.2	2.6	2.2	2.7	15.7	5.8	0.6
	Target	95	72	53	40	21	3.0	4.8	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	78	60	45	25	5.0	5.3	
	LSL	90	66	46	35	17	1.0	4.3	96.0
	Normal	Yes	No	No	Yes	No	Yes	Yes	No
	In Control	No	No	No	No	No	Yes	No	No
	Capability	Yes	No	No	No	No	No	No	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
16 (Lot 3)	Count	21	21	21	21	21	21	21	21
	Max	98	75	56	44	24	4.6	4.8	99.2
	Min	94	69	50	36	19	3.6	4.3	96.7
	Range	4	6	6	8	5	1	0.5	2.5
	Mean	95.4	72.5	52.8	39.4	21.6	4.02	4.57	97.381
	Std. Dev.	1.08	1.97	1.78	2.13	1.33	0.293	0.155	0.603
	CV, %	1.1	2.7	3.4	5.4	6.1	7.3	3.4	0.6
	Target	95	72	53	40	21	3.0	4.6	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	78	60	45	25	5.0	5.1	
	LSL	90	66	46	35	17	1.0	4.1	96.0
	Normal	No	Yes	No	Yes	Yes	No	Yes	No
	In Control	No	No	No	No	Yes	No	Yes	Yes
	Capability	Yes	No	Yes	No	No	No	No	NA

Code	Stat.	3/4	3/8	4	8	30	200	AC	Compact.
17	Count	97	97	97	97	97	97	97	97
	Max	100	76	59	46	25	6	5.2	98.2
	Min	95	64	48	36	17	3.0	4.3	95.6
	Range	5	12	11	10	8	3	0.9	2.6
	Mean	98.0	69.5	53.7	41.5	21.4	4.01	4.67	96.87
	Std. Dev.	1.13	2.88	2.90	2.23	1.72	0.685	0.166	0.505
	CV, %	1.2	4.1	5.4	5.4	8.0	17.1	3.6	0.5
	Target	98	71	53	39	20	4.6	4.7	
	± Spec Limits	5	12	12	10	8	4.0	1.0	
	USL	100	77	60	44	24	6.6	5.2	
	LSL	93	65	46	34	16	2.6	4.2	96.0
	Normal	No	No	No	No	No	No	No	Yes
	in Control	No	Yes	Yes	Yes	Yes	No	Yes	No
	Capability	No	No	No	No	No	No	No	NA

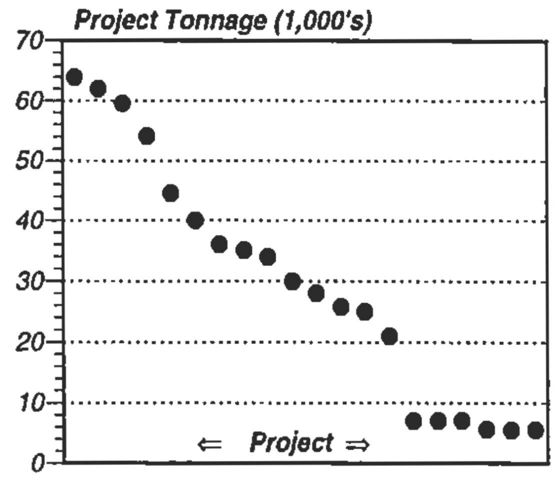
#200 May have multipie populations

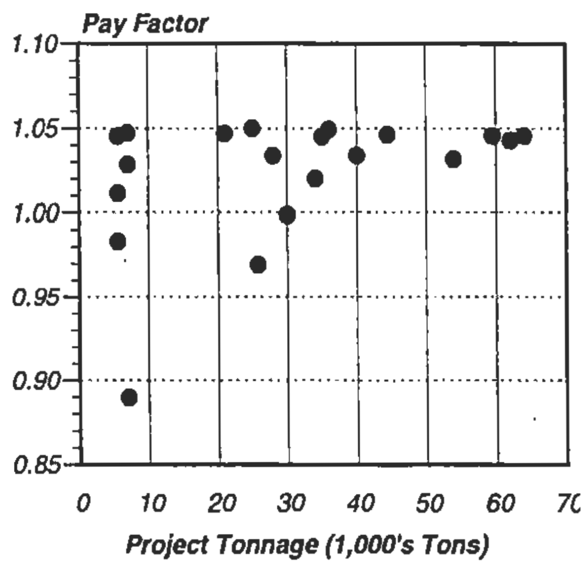
Appendix D

Pay Factors and Tonnage

Table D1, Pay Factor and Tonnages

Proj	PF	Tonnage
A	0.8901	7,000
B	1.0472	7,000
C	1.0288	7,000
D	1.0457	64,000
E	1.0452	35,000
F	1.0342	40,000
G	1.0495	36,000
H	1.0459	59,500
I	1.0430	62,000
J	1.0340	28,000
K	0.9697	25,700
L	1.0500	25,000
M	1.0207	34,000
N	1.0465	44,500
O	1.0470	21,000
P	0.9989	30,000
Q	0.9837	5,600
R	1.0115	5,600
S	1.0455	5,600
T	1.0320	54,000
Ave.	**1.0235**	**29,825**





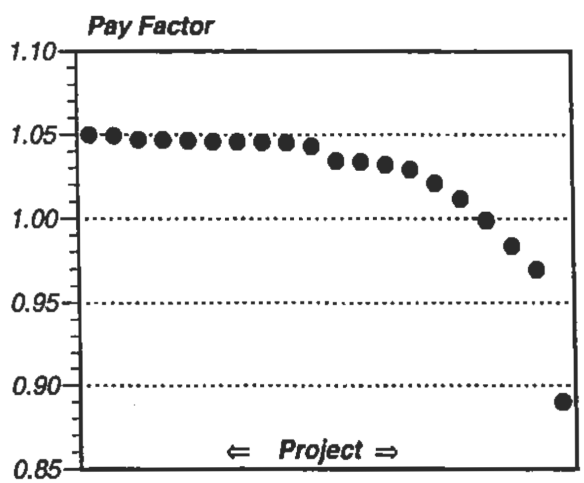


Table D2. Summary of ANOVA and Regressions.
Effects of Specification Elements on Pay Factor

Pay Factor Versus	Type of Fit	R2
Tonnage	Linear	0.16
Tonnage	Quadratic	0.17
Tonnage	Cubic	0.17
3/4 Std. Deviation	Quadratic	0.09
3/8 Std. Deviation	Quadratic	0.12
No. 4 Std. Deviation	Quadratic	0.03
No. 8 Std. Deviation	Quadratic	0.19
No. 30 Std. Deviation	Quadratic	0.20
No. 200 Std. Deviation	Quadratic	0.42
AC Std. Deviation	Quadratic	0.51
Density Std. Deviation	Quadratic	0.30
3/4 Coeff. of Variation	Quadratic	0.08
3/8 Coeff. of Variation	Quadratic	0.14
No. 4 Coeff. of Variation	Quadratic	0.06
No. 8 Coeff. of Variation	Quadratic	0.14
No. 30 Coeff. of Variation	Quadratic	0.25
No. 200 Coeff. of Variation	Quadratic	0.31
AC Coeff. of Variation	Quadratic	0.31
Density Coeff. of Variation	Quadratic	0.29
Overall Ave. Std. Deviation	Quadratic	0.08
Overall Ave. Coeff. of Variation	Quadratic	0.19
Std. Deviation: Multiple Regression on No. 200, AC, and Density with second and third order interactions	[200] + [AC] + [Den] + [(200)x(AC)] + [(200)x(Den)] + [(AC)x(Den)] + [(200)x(AC)x(Den)]	0.90
Coeff. of Variation: (Same as multiple regression for std. deviation)		0.97

Appendix E

Variability

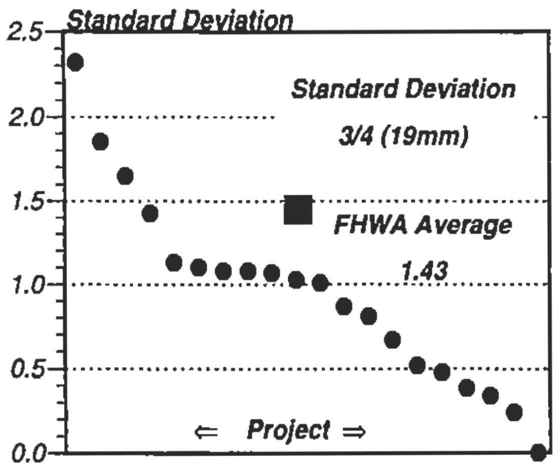
Appendix E

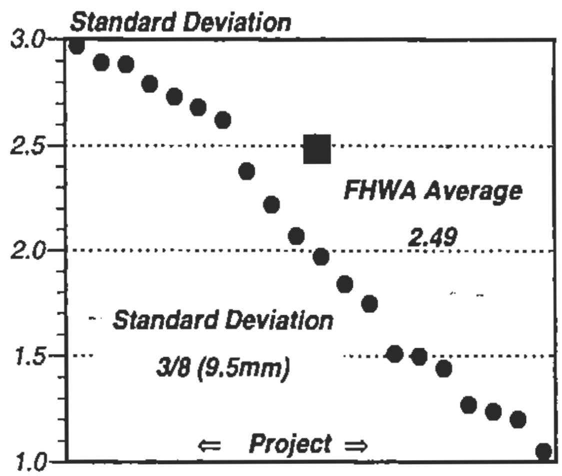
Variability

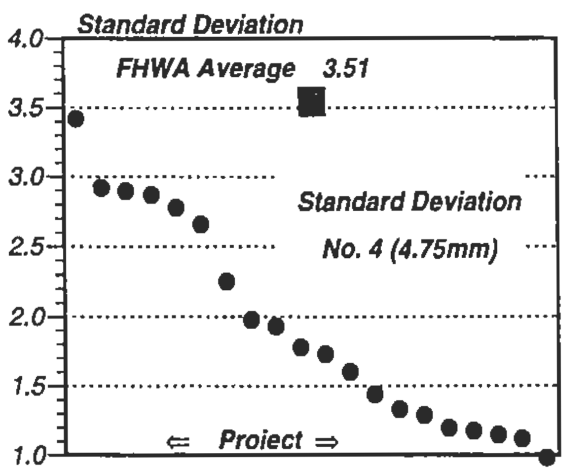
Table E1. Project Variability

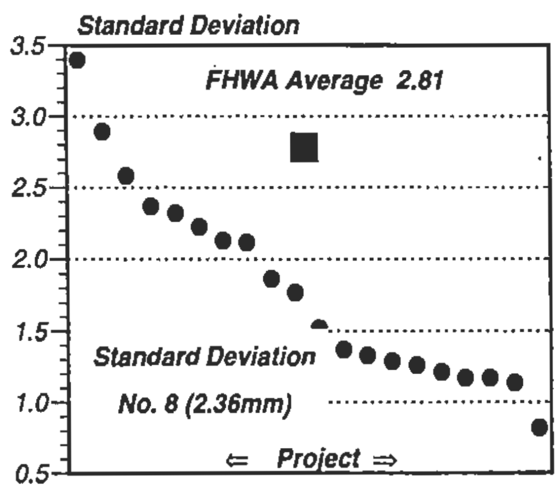
	Standard Deviations, SD								Coefficients of Variation, CV							
Proj	3/4	3/8	4	8	30	200	AC	Comp	3/4	3/8	4	8	30	200	AC	Comp
1 (Lot 1)	1.85	2.678	1.73	1.138	0.577	0.888	0.303	1.104	1.9	4.0	4.0	3.2	2.6	19.0	6.4	1.1
1 (Lot 2)	1.079	2.382	2.656	2.58	2.115	0.467	0.103	0.385	1.1	3.5	5.5	7.4	11.5	9.9	2.1	0.4
1(Lot 3)	0.806	2.735	3.422	2.121	1.575	0.621	0.141	0.665	0.8	3.9	6.6	5.7	8.0	12.3	3.0	0.7
2	2.325	2.974	1.436	1.862	2.181	0.524	0.123	0.675	2.4	4.4	3.2	5.3	13.1	16.8	2.8	0.7
3	0.483	1.198	1.931	1.333	1.112	0.252	0.168	1.113	0.5	1.6	4.1	3.7	4.9	7.0	2.8	1.1
4	1.032	2.224	2.919	2.316	1.807	0.518	0.255	0.856	1.1	3.1	5.4	5.9	8.9	12.6	5.3	0.9
5	0.344	1.753	1.334	1.168	0.908	0.319	0.125	0.726	0.3	2.5	2.7	3.2	4.9	9.5	2.5	0.7
6	1.654	2.068	1.603	1.287	0.76	0.186	0.132	0.447	1.8	2.9	3.2	3.3	4.2	4.0	2.8	0.5
7	0	1.508	1.151	1.17	0.992	0.346	0.165	0.54	0.0	1.9	2.2	3.1	5.5	5.7	2.7	0.6
8	1.069	2.895	2.87	2.369	1.378	0.741	0.261	0.906	1.1	4.5	6.4	7.0	7.7	11.3	5.1	0.9
9	0.869	2.624	2.78	3.397	1.862	0.497	0.345	1.348	0.9	4.0	5.7	10.5	11.4	13.8	7.5	1.4
10	1.009	1.236	1.196	1.205	1.036	0.503	0.1		1.1	1.8	2.5	3.4	5.5	11.3	2.2	
11	0.39	1.049	1.985	1.774	1.534	0.813	0.189	0.418	0.4	1.5	3.8	4.5	8.1	16.3	3.6	0.4
12	0.235	1.268	1.177	1.26	1.491	0.381	0.199	0.723	0.2	1.8	2.4	3.5	8.2	11.5	4.0	0.7
13	0.673	1.441	1.115	1.522	1.062	0.417	0.17	0.454	0.7	2.0	2.1	3.8	5.1	7.8	3.4	0.5
14	1.433	1.844	2.245	2.903	2.081	0.813	0.334		1.5	2.5	4.2	7.5	12.5	24.6	5.2	
16 (Lot 1)	0.516	2.787	0.983	1.366	0.983	0.429	0.383	0.599	0.5	4.2	2.1	3.9	5.2	13.0	7.3	0.6
16 (Lot 2)	1.095	1.502	1.293	0.82	0.522	0.615	0.262	0.582	1.2	2.2	2.6	2.2	2.7	15.7	5.8	0.6
16 (Lot 3)	1.076	1.965	1.778	2.133	1.326	0.293	0.155	0.603	1.1	2.7	3.4	5.4	6.1	7.3	3.4	0.6
17	1.127	2.88	2.899	2.227	1.719	0.685	0.166	0.505	1.2	4.1	5.4	5.4	8.0	17.1	3.6	0.5

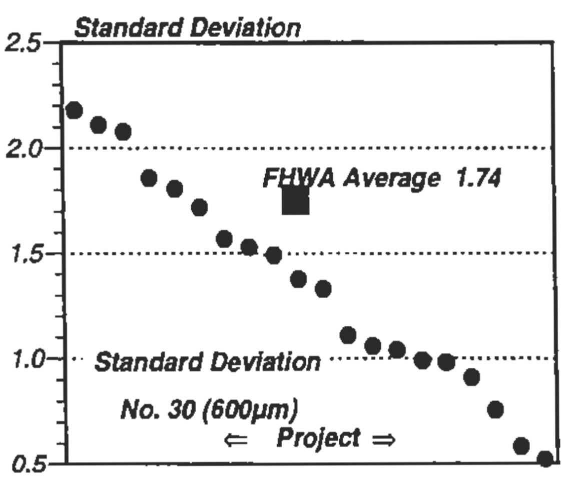
Standard Deviations

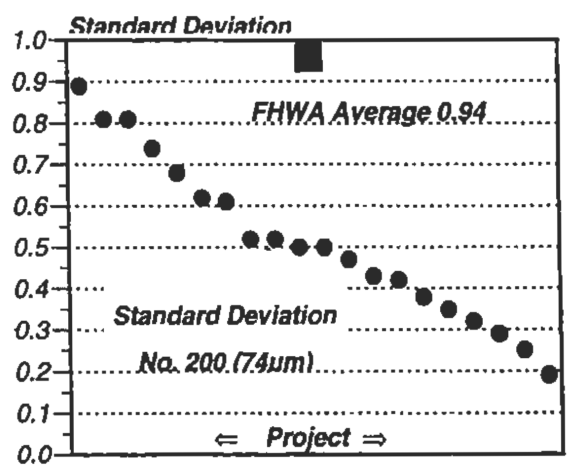

Standard Deviation
Standard Deviation
3/4 (19mm)
FHWA Average
1.43
⇐ Project ⇒
2.5
2.0
1.5
1.0
0.5
0.0

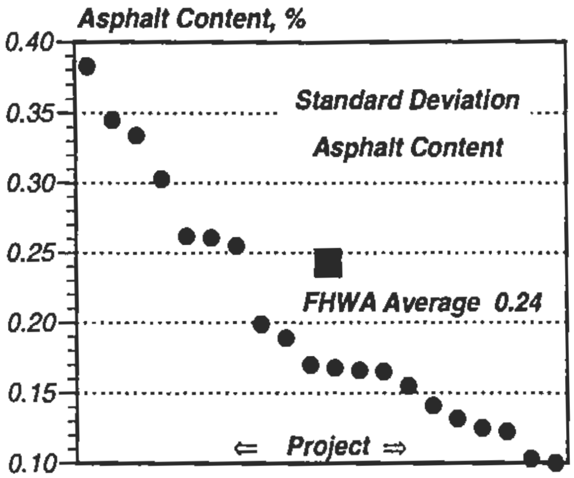

Standard Deviation
FHWA Average
2.49
Standard Deviation
3/8 (9.5mm)
⇐ Project ⇒
3.0
2.5
2.0
1.5
1.0

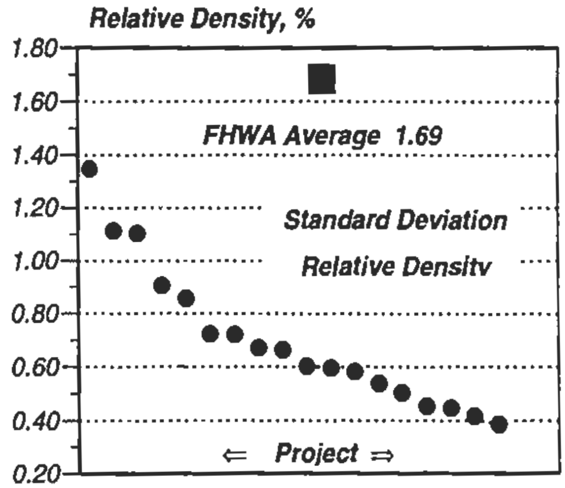

Standard Deviation
FHWA Average 3.51
Standard Deviation
No. 4 (4.75mm)
⇐ Project ⇒
4.0
3.5
3.0
2.5
2.0
1.5
1.0


Standard Deviation
FHWA Average 2.81
Standard Deviation
No. 8 (2.36mm)
⇐ Project ⇒
3.5
3.0
2.5
2.0
1.5
1.0
0.5

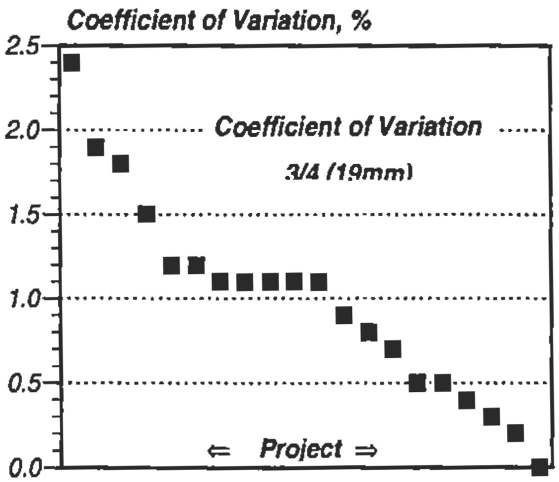

Standard Deviation
FHWA Average 1.74
Standard Deviation
No. 30 (600µm)
⇐ Project ⇒
2.5
2.0
1.5
1.0
0.5

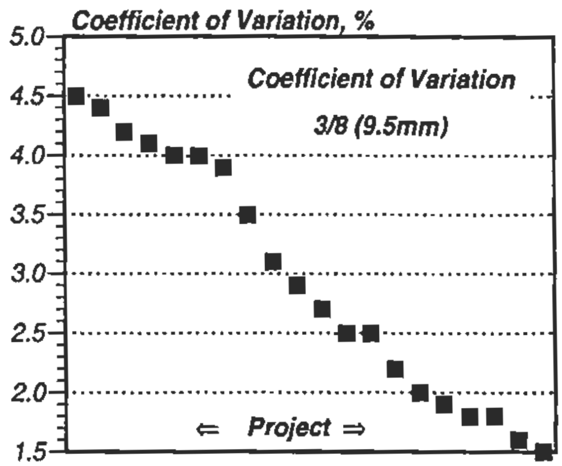

Standard Deviation
FHWA Average 0.94
Standard Deviation
No. 200 (74µm)
⇐ Project ⇒
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

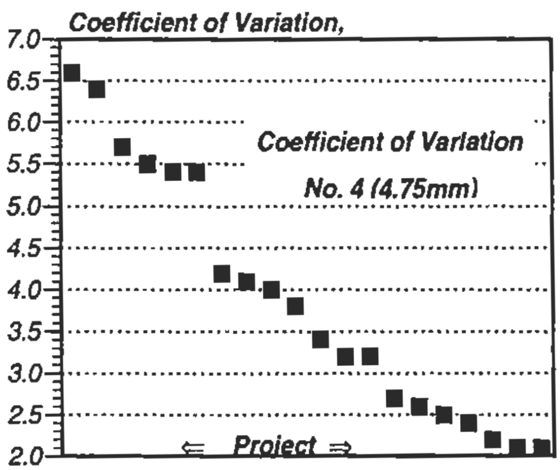

Asphalt Content, %
0.40
0.35
0.30
0.25
0.20
0.15
0.10
Standard Deviation
Asphalt Content
FHWA Average 0.24
⇐ Project ⇒

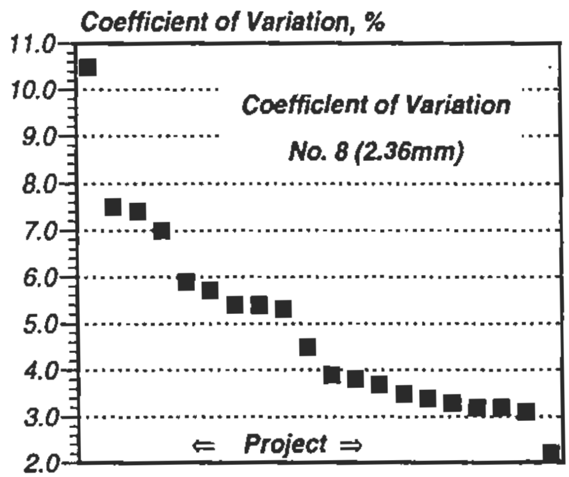

Relative Density, %
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
FHWA Average 1.69
Standard Deviation
Relative Densitv
⇐ Project ⇒

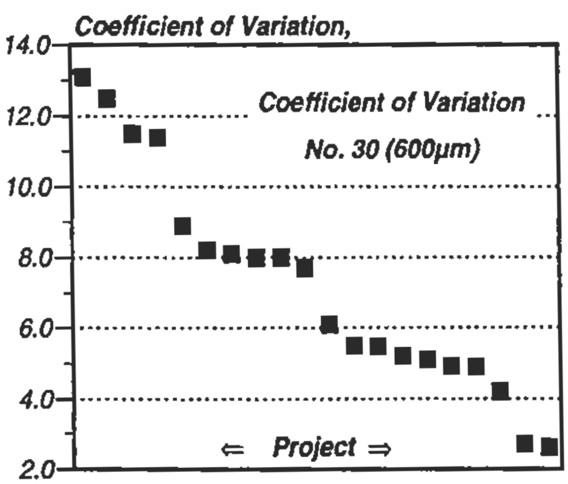
Coefficients of Variation

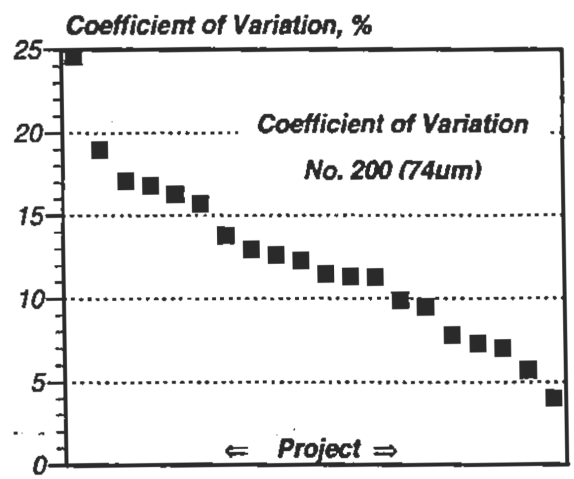

Coefficient of Variation, %
2.5
2.0
1.5
1.0
0.5
0.0
Coefficient of Variation
3/4 (19mm)
⇐ Project ⇒

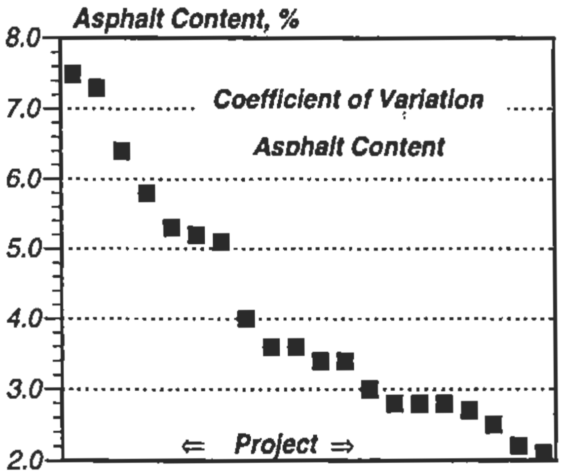

Coefficient of Variation, %
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Coefficient of Variation
3/8 (9.5mm)
⇐ Project ⇒

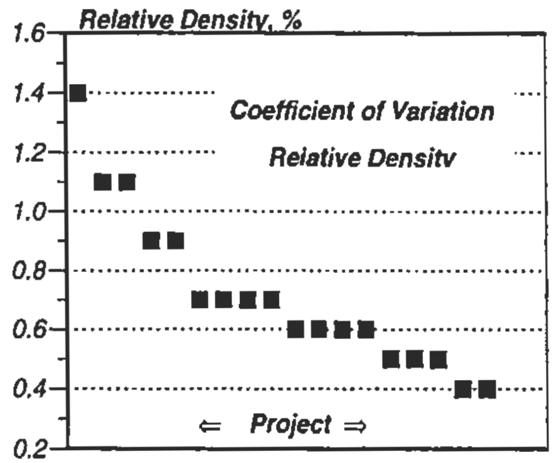

Coefficient of Variation,
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Coefficient of Variation
No. 4 (4.75mm)
⇐ Project ⇒


Coefficient of Variation, %
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
Coefficient of Variation
No. 8 (2.36mm)
⇐ Project ⇒


Coefficient of Variation,
14.0
12.0
10.0
8.0
6.0
4.0
2.0
Coefficient of Variation
No. 30 (600µm)
⇐ Project ⇒


Coefficient of Variation, %
25
20
15
10
5
0
Coefficient of Variation
No. 200 (74um)
⇐ Project ⇒

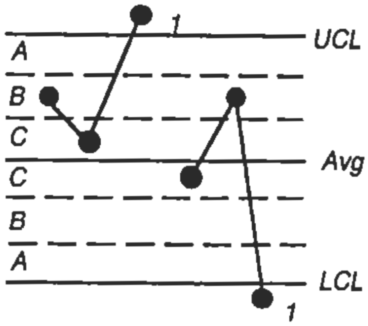

Asphalt Content, %
8.0
7.0
6.0
5.0
4.0
3.0
2.0
Coefficient of Variation
Asphalt Content
⇐ Project ⇒


Relative Density, %
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Coefficient of Variation
Relative Density
⇐ Project ⇒

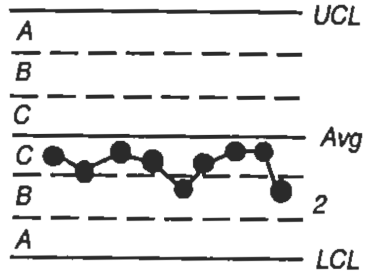
Appendix F

Western Electric Rules for Statistical Process Control Charts

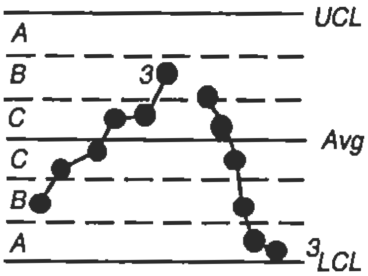
__Test 1 :__ One point beyond zone A



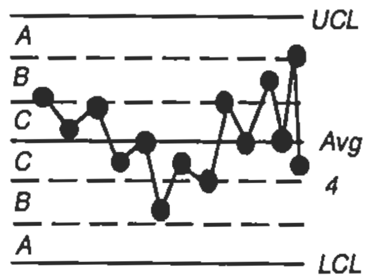
__Test 2 :__ Nine points in a row in Zone C or beyond.



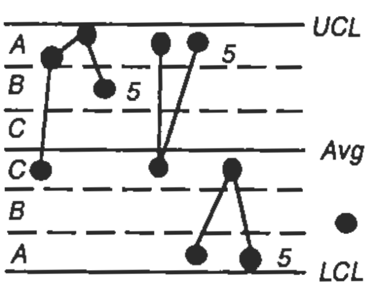
__Test 3 :__ Six points in a row steadily increasing or decreasing.



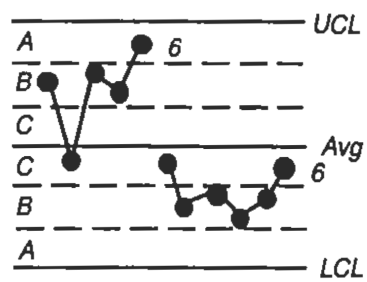
__Test 4 :__ Fourteen points in a row alternating up or down.



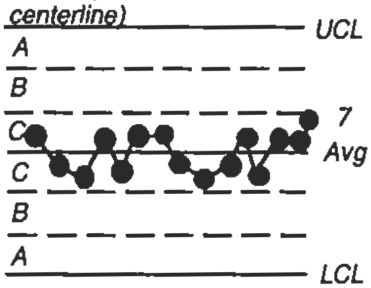
__Test 5 :__ Two out of three points in a row in Zone A or beyond.



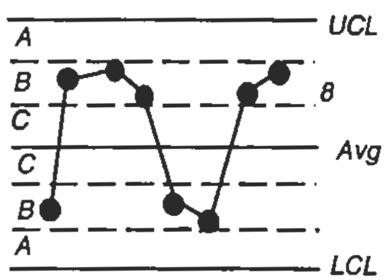
__Test 6 :__ Four out of five points in a row in Zone B or beyond.



__Test 7 :__ Fifteen points in a row in ZoneC (above and below the centerline)



__Test 8 :__ Eight points in a row on both sides of the centerline with none in Zone C.



Nelson, L., (1984), "The Shewhart Control Chart – Tests for Special Causes, Journal of Quality Technology, 15, 237-239

Nelson, L. (1985), "Interpreting Shewhart X Control Charts, Journal of Quality Technology, 17, 114-116

Appendix G

Verification Comparison

Appendix G

Verification Comparison

Population S: Mean 5.0, SD 0.2
Population A : Mean 5.0, SD 0.4
Specification Target 5.0 ±0.5 or (4.5 to 5.5)

Sample Size 50 from population S (Mean 5.0, SD 0.15)
10 Sets of samples from population A (sets S1, S2,. . . S10)

Table G-1. *t-Tests for Verification Sample Size 5 (10 Sets form Population A)*

	Sample Set									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
A	5.7	4.4	4.5	5.2	5.5	4.8	5.4	4.6	4.5	4.4
B	5.0	5.9	4.9	4.9	4.9	4.4	5.7	5.3	4.9	5.1
C	5.0	4.9	3.8	5.0	5.1	4.9	5.1	4.4	4.7	5.2
D	5.9	5.2	5.2	5.2	5.5	5.4	5.0	4.3	5.3	5.2
E	4.9	5.9	4.6	5.1	4.9	5.1	4.8	4.3	5.3	5.1
n_v	5	5	5	5	5	5	5	5	5	5
$n_v - 1$	4	4	4	4	4	4	4	4	4	4
Xv	5.30	5.26	4.60	5.08	5.18	4.92	5.20	4.58	4.94	5.00
Sv	0.464	0.650	0.524	0.130	0.303	0.370	0.354	0.421	0.358	0.339
S_v^2	0.215	0.423	0.275	0.017	0.092	0.137	0.125	0.177	0.128	0.115
n_c	50	50	50	50	50	50	50	50	50	50
$n_c - 1$	49	49	49	49	49	49	49	49	49	49
X_c	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
S_c	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
S_c^2	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
S_p^2 >	0.037	0.052	0.041	0.022	0.027	0.031	0.030	0.034	0.030	0.029
S_p >	0.191	0.229	0.203	0.147	0.165	0.175	0.173	0.184	0.173	0.170
Den >	0.090	0.107	0.095	0.069	0.077	0.082	0.081	0.086	0.081	0.080
Num >	0.300	0.260	0.400	0.080	0.180	0.080	0.200	0.420	0.060	0.000
t >	3.345	2.425	4.207	1.160	2.323	0.974	2.471	4.878	0.739	0.000
t_{53}	2.675	2.675	2.675	2.675	2.675	2.675	2.675	2.675	2.675	2.675
Verify ?	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes

Table G-2. *Analysis of Variance for Verification Sample Size 5 (10 Sets from Population A)*

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	10	2.912300	0.291230	3.2746
Error	89	7.915200	0.088935	Prob>F
C Total	99	10.827500		0.0012

Means for Oneway Anova

Level	Number	Mean	Std Error
Con	50	5.00400	0.04217
S1	5	5.30000	0.13337
S10	5	5.00000	0.13337
S2	5	5.26000	0.13337
S3	5	4.60000	0.13337
S4	5	5.08000	0.13337
S5	5	5.18000	0.13337
S6	5	4.92000	0.13337
S7	5	5.20000	0.13337
S8	5	4.58000	0.13337
S9	5	4.94000	0.13337

Std Error uses a pooled estimate of error variance

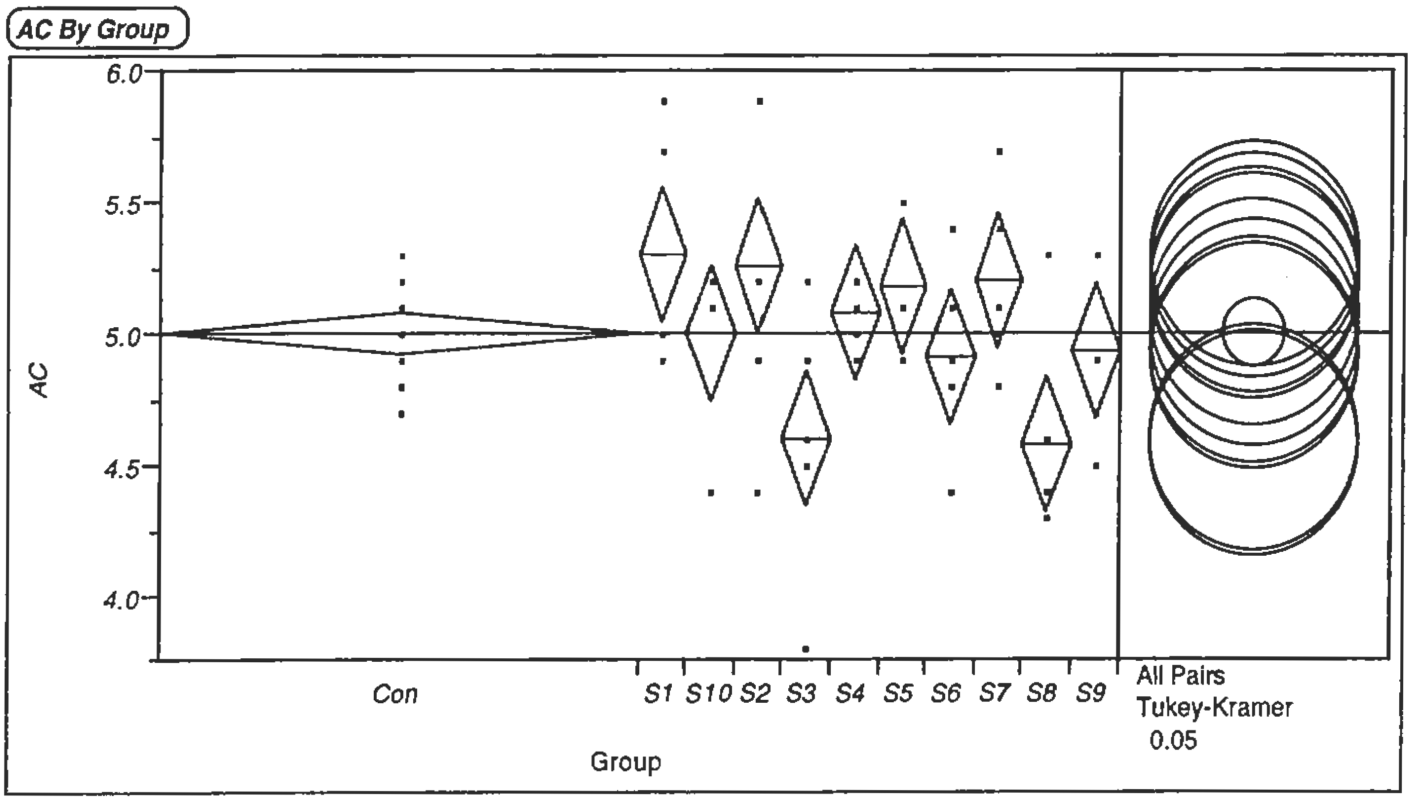


Figure G-1 *. Analysis of Variance for Verificationand Tukey-Kramer Comparison of Means Sample Size 5 (10 Sets from Population A)*

Table G-3 . Pairs Comparisons

Means Comparisons

Dif=Mean[i]-Mean[j]	S1	S2	S7	S5	S4	Con	S10	S9	S6	S3	S8
S1	0.000000	0.040000	0.100000	0.120000	0.220000	0.296000	0.300000	0.360000	0.380000	0.700000	0.720000
S2	-0.04	0.000000	0.060000	0.080000	0.180000	0.256000	0.260000	0.320000	0.340000	0.660000	0.680000
S7	-0.1	-0.06	0.000000	0.020000	0.120000	0.196000	0.200000	0.260000	0.280000	0.600000	0.620000
S5	-0.12	-0.08	-0.02	0.000000	0.100000	0.176000	0.180000	0.240000	0.260000	0.580000	0.600000
S4	-0.22	-0.18	-0.12	-0.1	0.000000	0.076000	0.080000	0.140000	0.160000	0.480000	0.500000
Con	-0.296	-0.256	-0.196	-0.176	-0.076	0.000000	0.004000	0.064000	0.084000	0.404000	0.424000
S10	-0.3	-0.26	-0.2	-0.18	-0.08	-0.004	0.000000	0.060000	0.080000	0.400000	0.420000
S9	-0.36	-0.32	-0.26	-0.24	-0.14	-0.064	-0.06	0.000000	0.020000	0.340000	0.360000
S6	-0.38	-0.34	-0.28	-0.26	-0.16	-0.084	-0.08	-0.02	0.000000	0.320000	0.340000
S3	-0.7	-0.66	-0.6	-0.58	-0.48	-0.404	-0.4	-0.34	-0.32	0.000000	0.020000
S8	-0.72	-0.68	-0.62	-0.6	-0.5	-0.424	-0.42	-0.36	-0.34	-0.02	0.000000

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*

3.30395

Abs(Dif)-LSD	S1	S2	S7	S5	S4	Con	S10	S9	S6	S3	S8
S1	-0.62316	-0.58316	-0.52316	-0.50316	-0.40316	-0.16615	-0.32316	-0.26316	-0.24316	0.076839	0.096839
S2	-0.58316	-0.62316	-0.56316	-0.54316	-0.44316	-0.20615	-0.36316	-0.30316	-0.28316	0.036839	0.056839
S7	-0.52316	-0.56316	-0.62316	-0.60316	-0.50316	-0.26615	-0.42316	-0.36316	-0.34316	-0.02316	-0.00316
S5	-0.50316	-0.54316	-0.60316	-0.62316	-0.52316	-0.28615	-0.44316	-0.38316	-0.36316	-0.04316	-0.02316
S4	-0.40316	-0.44316	-0.50316	-0.52316	-0.62316	-0.38615	-0.54316	-0.48316	-0.46316	-0.14316	-0.12316
Con	-0.16615	-0.20615	-0.26615	-0.28615	-0.38615	-0.19706	-0.45815	-0.39815	-0.37815	-0.05815	-0.03815
S10	-0.32316	-0.36316	-0.42316	-0.44316	-0.54316	-0.45815	-0.62316	-0.56316	-0.54316	-0.22316	-0.20316
S9	-0.26316	-0.30316	-0.36316	-0.38316	-0.48316	-0.39815	-0.56316	-0.62316	-0.60316	-0.28316	-0.26316
S6	-0.24316	-0.28316	-0.34316	-0.36316	-0.46316	-0.37815	-0.54316	-0.60316	-0.62316	-0.30316	-0.28316
S3	0.076839	0.036839	-0.02316	-0.04316	-0.14316	-0.05815	-0.22316	-0.28316	-0.30316	-0.62316	-0.60316
S8	0.096839	0.056839	-0.00316	-0.02316	-0.12316	-0.03815	-0.20316	-0.26316	-0.28316	-0.60316	-0.62316

Positive values show pairs of means that are significantly different.