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COLORADO DEPARTMENT OF TRANSPORTATION ASPHALT PAVEMENT WHITE PAPER

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16. Abstract

Over the past several years, numerous changes have been incorporated into the hot bituminous pavement design and construction process. Design and construction problems encountered during the 1991 asphalt paving season as a result of these changes have been identified and corrective actions are addressed in this paper.

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EXECUTIVE SUMMARY

Over the past several years, numerous changes have been incorporated into the hot bituminous pavement design and construction process. Design and construction problems encountered during the 1991 asphalt paving season as a result of these changes have been identified and corrective actions are addressed in this paper. The two most notable problems were segregation and compaction. Both problems appeared to have increased this year primarily because of the use of coarser, high stability asphalt mixes with lower asphalt cement content.

The AC contents were lower during the 1991 construction season because of the new design procedure using optimum AC content vs minimum percent AC and the use of the Texas Gyratory Compactor. Low AC content associated with the use of a 2-1/2" samples for Texas Gyratory designs have been identified and corrected with the change to the ASTM 2" high sample. This change in sample height will result in design AC contents averaging approximately 0.5% higher during the 1992 construction season.

A design procedure requiring a minimum lift thickness of 2" has been implemented to reduce compaction problems this next paving season. In addition, a compaction test section specification, requiring the contractor to demonstrate his capability to achieve density, is being developed for implementation in the 1992 paving season.

To help correct the segregation problem, a Colorado Procedure (CP) to better define segregated material has been drafted and is proposed for use in 1992.

Standard HBP gradations for the upcoming paving season will continue to be CDOT Grading (C), (CX), (F), and (G). SHRP Coarse, SHRP Fine and Gap-Graded mixes will be used as designated, and will be used on an evaluation basis.

Coordinated effort between CDOT, local industry and consultants has been established to identify short and long term strategies for improved asphalt pavement construction and performance.

Training needs for this year should be directed towards the issues addressed in this paper. Comprehensive training on new specifications and procedures, as they are implemented, need to be provided to both CDOT and contractor's employees.

COLORADO DEPARTMENT OF TRANSPORTATION

ASPHALT PAVEMENT WHITE PAPER

January 1992

I. BACKGROUND

Early distress on Colorado's asphalt pavements has prompted the Department of Transportation to make modifications to the procedures used in the pavement mix design and material specifications. These modifications, having taken place over the past several years on a statewide basis, have often resulted in a greater amount of observed pavement distress. Many of these short comings have been the result of the failure to coordinate the design changes to the construction process, the lack of communication or training within the industry and other failure mechanisms. Each of these issues has been compounded by the demand on asphalt pavement performance given heavy traffic loadings, increased tire pressures and other environmental factors.

A need was apparent to review the department's current state of the practice and set forth a strategic plan for the short and long term.

II. PURPOSE

The purpose of this paper is to:

1. identify the material problems and construction concerns encountered during 1991,

2. address potential problem area and develop recommendations for the 1992 paving season, and

3. inform Colorado Department of Transportation personnel and contractors of material and construction design changes or new procedures that will be implemented in the beginning of the 1992 construction season.

To provide input for this paper an Advisory Team was established. A Resource Team including some Overview Task Force members reviewed and provided input on the final report. A list of the members of each team is found in Appendix A.

Several projects constructed in each CDOT district during the 1991 were selected in each District for evaluation. The district materials engineers evaluated and prepared a written report on each. The report listed the problem areas, how they were resolved and made recommendations for future projects. These project summaries of the indicated that three major problems existed during the 1991 construction season:

1. compaction (Districts 2, 3, 4, 5, and 6)
2. segregation (Districts 1, 2, 4, and 6)
3. low AC content (Districts 3, 4, 5, and 6)

A summary of each of the projects by District is found in Appendix B.

The FHWA Oversight Pilot Program was established within the Colorado Department of Transportation (CDOT) and the Federal Highway Administration (FHWA) on July 9, 1991. The program created a Quality Assurance (QA) review program and requires the submission of an annual report, which includes findings and recommendations, to the QA Management Team. See Appendix C for the draft Quality Assurance Review Report for 1991.

III. MAJOR ISSUES

A. MIX DESIGN

1. Gradations

Beginning with the 1991 construction season problems with existing stockpiled materials meeting revised design criteria were encountered. These problems are associated with changing design procedures from a minimum % AC criteria and implementing the Texas Gyratory mix design procedure. Because of problems associated with the revised mix design procedures contractors were permitted to change HBP gradations from those specified in the project plans to modified gradings that would also meet design criteria. These changes were allowed to help contractors better utilize their materials and to transition into Texas Gyratory design procedures.

During the 1991 construction season 13 projects utilized CDOT improved gradations [SHRP fine (SF), SHRP coarse (SC), and Gap-Graded (GG)]. The distribution of types of improved designs by District is:

	SF	SC	GG
District 1			2
2	1	1	
3		1	
4	1	2	
5		1	
6		2	2

On these 13 projects, the results of failing stability and Lottman test results from production samples on mixes using the improved gradations during 1991 is as shown:

Stability	Lottman
3 of 65, (4.6%)	0 of 65, (0.0%*)

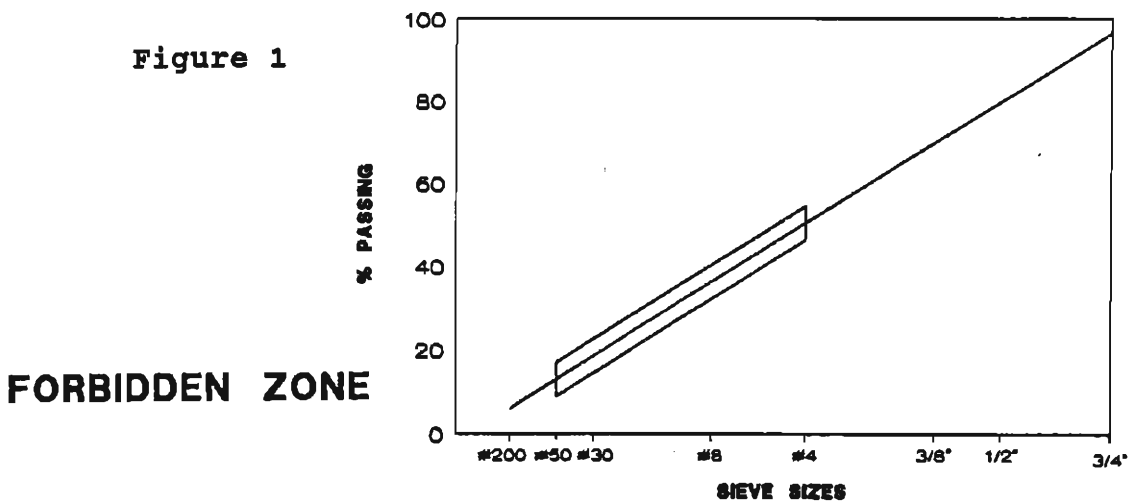
* This is attributed to the use of lime.

Aggregate gradation criteria will be a major area of evaluation during 1992. There are several theories relative to gradation criteria. The degree of mix aggregate density can be represented on a plot of the aggregate distribution (a 0.45 power plot). A 0.45 power plot of a gradation indicates how dense a mix the gradation will produce. A straight line plot indicates a dense mix which will not have sufficient room for both air voids and asphalt cement. Such a mix is sensitive to AC content and may rut or strip if AC varies from optimum.

Because of the need to "go back to the basics", the standard gradations (Appendix D) for the 1992 paving season will continue to be Grading (C), Grading (CX), Grading (F) on low volume roads, and Grading (G) lower lifts. Design criteria for Grading (C) and Grading (CX) mixes will be approached with caution to avoid mixes that

produce a maximum density plot. As a minimum, contractors will be advised to develop mixes 2-3% above or below the maximum density line. It has been recommended by consultants Tom Kennedy and James Scherocman to avoid the "forbidden zone" as shown in figure 1.

Figure 1



This zone is defined as the area within the boundaries of ±4% above and below the maximum density line between the #50 and #4 sieve. Mixes above or below this zone will be more open and less sensitive to AC content; however the exact criteria is not known at this time and mixes will be evaluated during the 1992 construction season for the purpose of establishing acceptable limits. When developing mix designs, contractors will be advised to be aware of the "forbidden zone" and design accordingly.

CDOT modified the SHRP fine (figure 2) and SHRP coarse (figure 3) gradations to avoid dense mixes by forcing gradations above or below the "forbidden zone". The Gap-Graded (figure 4) gradation avoids dense mixes by going above forbidden zone at the fine end, and then crossing over the maximum density line.

IMPROVED AGGREGATE GRADATIONS

Figure 2

SHRP FINE

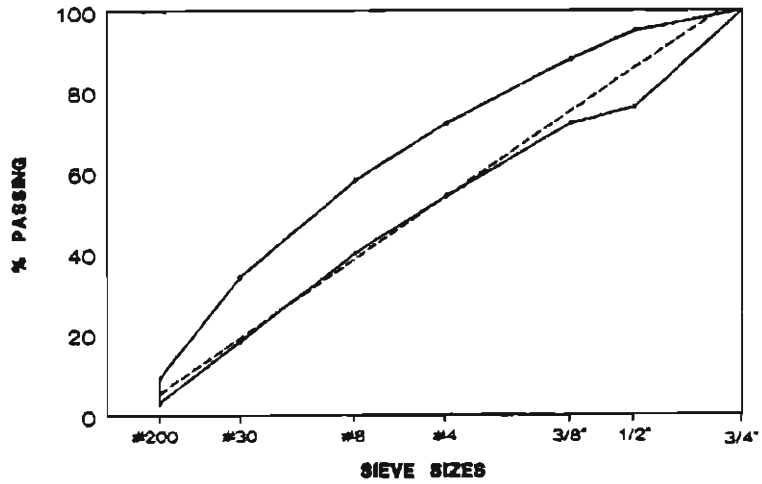


Figure 3

SHRP COARSE

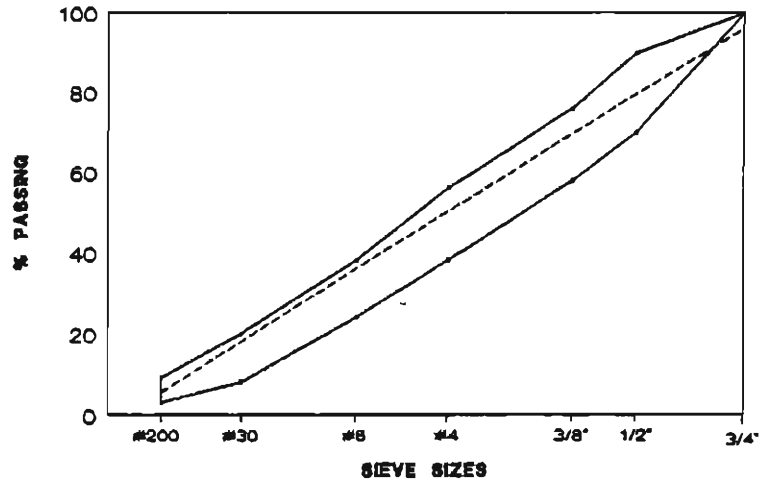
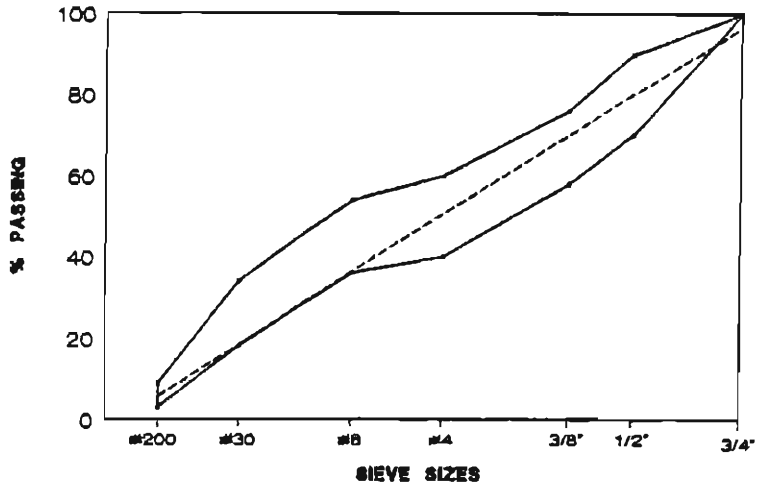


Figure 4

GAP-GRADED



These gradations were modified from those used in 1991 based on construction experience. The modifications addressed workability problems resulting from the coarseness of the SHRP and Gap-Graded gradations. The SHRP and Gap-Graded gradations will continued to be used experimentally on a project by project basis (See Appendix E).

Evaluation of these improved gradation mixes will continue during 1992. The upper limit of SHRP fines mixes has been established at the upper limit of the Grading (C). Several projects will be proposed to evaluate the feasibility of extending the upper limit. It is anticipated that both SHRP fine and Gap-Graded will be specified this season, however SHRP coarse designs will be evaluated on a limited basis. Gradation limits and problems with segregation will continue to be evaluated and fined tuned before more extensive use of the SHRP coarse is recommended. As these "experimental" designs are used, on a limited basis, a demonstration or open house will be organized to illustrate the design and construction experiences. Follow-up testing will also be implemented

When evaluation sections are specified it is recommended that they be of significant quantity (min 2000 tons) to allow for crushed materials to be manufactured within specification requirements, plant operation to be adjusted to produce specified materials, laydown and placement operations to be stabilized to assure that materials to be evaluated are in fact on the project and other variables are eliminated.

Reports summarizing significant findings are recommended to be provided for state wide use when experimental gradations are used.

A cooperative effort between Staff Materials, Staff Construction and field construction will be needed to provide this information.

2. VMA

Beginning this season CDOT will compute VMA using the bulk specific gravity of the aggregates. This will result in lower, yet more accurate, computed VMA's. VMA's using bulk specific gravity will be shown on test reports for information.

VMA is affected by computation method, gradation, and compaction method. All of these have recently changed making it unclear what minimum criteria is appropriate. During 1992 VMA will be reported for information only and not a specification criteria for mix design approval. VMA will be examined at the end of the 1992 paving season to determine an appropriate design criteria.

3. Compaction

During 1991, many projects experienced difficulties obtaining density. This was a state wide problem and was not limited to any one gradation.

Over the past several years numerous changes were incorporated into the hot bituminous pavement design process. These changes were made with the purpose of increasing the long term performance of the pavements.

Compaction is the single most important factor that affects the ultimate performance of the pavement. Achieving adequate compaction increases pavement performance by decreasing rutting, reducing damage due to moisture, and increasing the stability of the mix. However, as a result of these changes, the newer mixes have become more difficult to densify. Changes made in 1991 affecting compaction include:

Aggregate Improvements -- The limit on the use of natural fines was reduced while the percentage of fractured faces was increased. Angular particles offer

more resistance to densification than rounded particles. As the amount of crushed materials increased in the mix, the compactive effort needed to obtain densities was increased.

Gradation of mixes also was modified. Standard mixes now require more intermediate sieves, in effect controlling the percentage of fines in the mix. Improved mixes such as the SHRP fine, SHRP coarse and the Gap-Graded mixes were introduced in order to move away from the traditional easier to compact dense graded mixes. More compactive effort was required to compact the new harsher mixes.

Asphalt Cement -- The change to grade and amount of asphalt cement used in the mix also affected the ability to densify the mix. Changing from the minimum asphalt content to the concept of mix designs based on optimum percentage of AC, and using the Texas Gyratory for designing mixes, lowered the typical asphalt content in mixes from the past. The asphalt cement content in a mix influences compaction, and mixes with lower asphalt content tend to be stiff and require additional compactive effort. In the past, typical designs were based on AC-10 graded asphalt. To reduce the potential of rutting in the pavement, stiffer asphalts, i.e. an AC-20, are typically specified. Again, the stiffer the mix, the more compactive effort was needed to achieve density.

Compaction is a critical item because of the need to assure compliance, a compaction test section specification is being developed for implementation in the 1992 paving season. This specification will require the contractor to demonstrate his ability to obtain density on the first 500 tons that is placed on a project.

Compaction must be accomplished before the mat is allowed to cool. Those factors affecting the cooling rate of the mat include:

Layer thickness
Temperature of mix when placed
Ambient temperature
Temperature of base
Wind conditions

Layer thickness is probable the single most important variable in the cooling rate of an asphalt mat, especially for thin lifts. It has become very difficult to obtain specification density on thin lifts. This is especially true in cool weather because of the rapid loss in temperature in the mix and the inability of the compaction equipment to densify the mix before it cools below 185 ^{o}F. As the thickness of the layer being placed increases, the time available for compaction also increases. Because of problems with losing temperature on thin lifts resulting in compaction difficulties, a design procedure requiring a minimum 2" lift thickness has been implemented.

4. <u>In-Place Voids</u>

It is also recommended that during the 1992 paving season that each District Materials Engineer select projects for the purpose of taking cores to evaluate in-place voids.

5. <u>Segregation</u>

Another major problem encountered during the 1991 construction season was segregation. Because of the coarseness of the mix and the lower asphalt content of the mixes used, segregation was more evident than in the past.

With segregation being a major concern emphasis will be placed on reducing segregation on all projects. A Colorado Procedure (CP) for better defining segregated

material has been drafted and proposed for use in 1992 (See Appendix F). This CP is currently based on compacted material and was developed during the 1991 paving season on various CDOT projects; however, during the 1992 season this procedure will be evaluated to establish criteria to be used on uncompacted material.

There are various causes of segregation yet many are related to inappropriate stockpiling, improper mixing in the drum dryer, surge bin and storage silo separation, improper truck loading techniques and paver operations. Training for both CDOT and contractor employees in recognizing and correcting segregation is recommended.

B. LIME MIXING

The specifications for 1991 required the addition of a minimum 1% lime to the aggregates which was to be thoroughly mixed by an approved pugmill. Several contractors were not equipped at the beginning of the 1991 paving season and a one time exception which allowed to use belt mixers when approved. This exception was for the 1991 paving season only. All lime mixing operations beginning with the 1992 construction season will be in accordance with The 1991 Standard Specifications for Road and Bridge Construction section 401.14, Preparation of Aggregate.

401.14 Preparation of Aggregates.
Heating and drying of the aggregates shall be accomplished without damaging the aggregate. When hydrated lime is used it shall be added to the aggregate in accordance with one of the following methods:
(a) Lime Slurry Added to Aggregate. The hydrated lime shall be added to the aggregate in the form of a slurry and then thoroughly mixed in an approved pugmill. The slurry shall contain a minimum of 70 percent water by weight.

(b) Dry Lime Added to Wet Aggregate. The dry hydrated lime shall be added to wet aggregate (a minimum of three percent above saturated surface dry) and then thoroughly mixed in an approved pugmill.

The lime-aggregate mixture may be fed directly into the hot plant after mixing or it may be stockpiled for not more than 90 days before introduction into the plant for mixing with the bituminous material. The hydrated lime may be added to different sized aggregates and stockpiled, by adding 75 percent of the lime to the aggregate passing the No. 4 sieve and 25 percent to the aggregate retained on the No. 4 sieve.

Adequate moisture on the aggregates prior to the addition of lime was a concern during the 1991 paving season. When dry lime is added to wet aggregate, the specification require the moisture of the aggregate to be a minimum of 3% above saturated surface dry (SSD). A draft specification revision of section 401.14 (b) is proposed establishing moisture determination criteria, sampling frequency, with price reduction factor (F) is recommended and found in Appendix G.

Future items relative to lime mixing that will be analyzed include: specification requirements for measuring moisture of plant produced material, and provisions for weighing the lime being added to the aggregate.

C. CONSTRUCTION/MAINTENANCE SEAL COATS

Districts should inspect projects each Fall and determine if any preventative maintenance in the form of fog sealing, etc. is required. The use of rejuvenating agents should be limited and is not recommended for use on segregated pavements.

D. TRAINING ACTIVITIES

The consensus of the Advisory Team was that training for both department and contractor personnel is a high priority item.

The District Construction and Materials Engineers should include the white paper topics in their winter training sessions. Both project engineers and project testers need to be included in winter training activities relative to the white paper issues.

Changes to design procedures and CDOT expectations need to be disseminated to all contractors and suppliers. The contents of this report should be emphasized. Internal training within the contractor community, geared to field operation personnel needs to be reinforced. Both CDOT and contractor personnel should be trained in identifying causes and solutions associated with equipment and mat problems. Such problems areas in addition to segregation should include:

- tearing
- non-uniform texture
- screed marks
- screed responsiveness
- longitudinal and transverse joint problems
- checking
- shoving
- bleeding and fat spots

A pre-bid conference when major specifications or procedures are implemented, is recommended. Pre-paving conferences need to be comprehensive and details of new specifications and procedures reviewed in detail for the benefit of both state and contractor personnel.

E. REGIONAL DESIGN FACTORS

It is proposed to develop "regional design" criteria based on performance needs. Criteria for mix designs would be based on performance expectation, i.e. high performance design criteria specified for high volume, heavy traffic areas - low volume areas would not require the same criteria and would benefit from a different mix design.

The basis of providing an alternative method would be to allow for the selection of a mix to satisfy both the pavement design and system needs for a specific location. The guidelines for using a "regional design" would be based on good engineering judgement and the proposed criteria for specifying a "regional design" would be:

1. Traffic considerations - locations with relatively low volume (<5,000 ADT) or locations that may have high ADT's but low or restricted truck traffic.

2. High altitude locations- an elevation of 8,000 ft or greater.

3. Resurfacing projects - single lift overlays on structural adequate but with oxidized, cracked pavement. These pavements may be best served with mixes with higher AC contents and a reduced compactive effort.

Because of the numerous combinations of design factors that are encountered throughout the State, it is important to provide the best design for the job. All design factors are to be taken into consideration when evaluating the need for a "regional design"; this alternative method would not be suggested for high volume facilities.

F. ADDITIONAL LABORATORY ISSUES

There are numerous issues relating to asphalt pavement design, performance and constructibility that will continued to be looked into. CDOT, along with FWHA, will be obtaining European testing equipment to develop mix designs. This equipment will be used to determine performance related design criteria.

Aggregate improvement criteria will continue to be investigated. Items that are of concern include:

1. limiting the amount of natural fines on high volume roads
2. angularity of particles
3. cleanliness of aggregates in terms of sand equivalency.

The quality of asphalt cements is a concern and additional criteria such as penetration testing (before and after aging) and ring and ball (before and after aging) are being considered.

Rubberized mixes will continue to be used; however, this will be on a limited basis and districts will determine when to specify rubberized HBP. The use of rubberized plant mixed seal coats are to be limited and only placed on existing pavement or milled surfaces that do not show signs of stripping or severe raveling.

Evaluation of polymers, as defined by AASHTO Task Force 31, will continue during the 1992 paving season.

In the past experimental features have been implemented without significant performance evaluation and has lead to significant design changes. It is felt that experimental features should be considered in the form of demonstration projects only and not implemented on a state wide basis until substantial performance results have been

achieved. Items new that may be considered in the future would include: warranty projects, split mastic asphalt designs (SMA), QA/QC projects with incentive and disincentives. Incentives and disincentives based on gradation, % AC, compaction, and asphalt smoothness will be developed for use in 1992.

IV. OTHER FLEXIBLE PAVEMENT ACTIVITIES

The Colorado Flexible Pavement Oversight Group has been formed to address asphalt pavement issues. This group is organized into the following categories:

1. Pavement Management
2. Pavement Design and Rehabilitation
3. Material Selection Specifications
4. Mix Design Systems
5. Training
6. New Materials Technologies
7. Constructibility Factor
8. QA/QC
9. Awards

A list of the group members can be found in Appendix H.

V. STAFF MATERIALS FLEXIBLE PAVEMENT UNIT'S POSITION STATEMENT

Low Asphalt Cement Content

Problem: Use of the gyratory compactor has resulted in lower optimum asphalt cement contents than were obtained in the past using the kneader compactor. This has caused field compaction difficulties (below) and has raised concerns about durability. Solution: The gyratory compactor test procedure is being modified (Appendix I) by reducing specimen height. This will result in higher optimum asphalt cement content. In addition we are considering using even higher asphalt cement contents for pavements with low traffic, high altitude and/or thin lifts. We are in the process of hiring a consultant to examine our mix design process and make recommendations on asphalt cement content, gradations, etc.

Compaction Difficulties

Problem: Low asphalt cement contents has resulted in compaction difficulties. Contractors have difficulty obtaining the specified minimum density of 92% of maximum. Thin lifts and/or high altitudes aggravates the problem.

Solution: This problem will be reduced by the higher asphalt cement contents obtained by modification of the gyratory procedure. Training of CDOT and Contractor personnel will familiarize them with steps to take to overcome compaction difficulties (available training listed below). Specifications are being developed that require the Contractor to demonstrate the ability to obtain compaction on a test strip before paving is allowed.

Segregation

Problem: Segregation has been a serious problem for CDOT pavements for many years. The use of coarser gradations and lower asphalt cement contents has aggravated the problem. Segregation is the result of poor construction techniques. Coarse segregated areas tend to ravel prematurely.

Solution: CDOT and Contractor personnel need to be trained on the causes of segregation and techniques for prevention. Training which will address segregation is listed below.

Lime Mixing

Problem: Hydrated lime is required in most CDOT mixes to prevent stripping. It is critical that the proper amount of lime and water be added to the aggregate and that it be thoroughly mixed in. Some Contractors have been reluctant to install an adequate pugmill for mixing in the lime. On many projects it has been noted that too little moisture is being added and/or it is not being added uniformly.

Solution: Most Contractors now have adequate pugmills for mixing the lime with the aggregate. We must now focus on adding sufficient moisture to the aggregate in a uniform manner. This will require new procedures for Staff Materials and project testers. Staff Materials must provide the saturated surface dry (SSD) moisture content to the project tester. On the project the moisture content after moisture is added must be determined. If moisture content is less than the required 3% over SSD the Contractor must correct the problem. Project personnel need to be trained on all aspects of lime addition, including moisture content. The uniformity and amount of lime added is another important issue that should be addressed.

Asphalt Mix Testing in District Labs

Problem: District labs are being equipped this winter to conduct Hveem stability and Lottman tests on asphalt mix. It is intended that most testing of project produced mix be conducted in the district. It is critical that the results obtained by the district be accurate and credible.

Solution: The following steps will be taken to assure the quality and credibility of the district testing of asphalt mixes.

1. District materials testers are being trained in Staff Materials on the Hveem and Lottman tests.

2. After all equipment is installed and operating, each district lab will be inspected by a team from Staff Materials to assure that equipment is properly set up and procedures and being followed.

3. Round-robin testing will be conducted to compare results obtained by each district and Staff Materials. There will be a follow-up on any substantial discrepancies.

4. At the start of next season, production samples will be tested both in the district and in Staff Materials. This parallel testing will continue until confidence in the results is established.

Lottman Credibility

Problem: The Lottman test is the standard CDOT test for moisture susceptibility of asphalt mixes. Contractors have repeatedly attacked this test, claiming that it is not repeatable.

Solution: A research study is underway to determine the repeatability of the Lottman test.

Critical Asphalt Mix Training

CDOT Winter Training for Project Personnel
This training should address field compaction, segregation, and lime mixing.

Certification Course for Bituminous Materials Technicians
This course is sponsored by CAPA. The level II course will cover compaction measurement. It would be desirable if this course covered segregation and compaction difficulties.

Technical Training Program by James Scherocman / Tom Kennedy
This 4 1/2 day course was sponsored by CAPA. Topics included placement and compaction of asphalt mixes. Segregation and compaction problems were covered.

APPENDIX A

CDOT ASPHALT WHITE PAPER REPORT MEMBERS

CDOT ASPHALT WHITE PAPER REPORT MEMBERS

ADVISORY TEAM

Denis Donnelly, Chairman Staff Materials
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Dick Hines, Staff Materials
Steve Horton, Staff Design
Sid Motchan, District 6 Materials
Gerry Peterson, District 1 Materials
Hal Toland, Staff Construction
Ken Wood, District 4 Materials

RESOURCE TEAM

Vuk Aguirre, Aguirre Engineers Inc.
Skip Bettis, Bituminous Roadways of Colorado, Inc.
Bob Bisgard, Asphalt Paving Co.
Doyt Bolling, FHWA
Bud Brakey, Staff Materials
Tony Collins, Kiewit Western Co.
Rick De La Castro, CAPA
Joe Murry
Ira Paulin, Carder, Inc.
Bob Rask, Asphalt Institute
Doug Shaffer, Director of Maintenance and Operation
Mark Swanlund, FHWA
Rick Yowell, District 1 Construction

APPENDIX B

PROJECT REVIEWS

PROJECT REVIEWS

DISTRICT ONE

PROJECT IR(CX) 070-4(157) (Cedar Point west - westbound): The plans called for HBP Gr. C rubberized, but that was changed to a rubberized **gap graded** mixture by CMO. A minor problem was the rubberized mix being picked-up by the pneumatic roller. This was solved by the use of only steel rollers. Everything else went well on the project except for a segregation problem.

The segregation occurred at the end of the dump trucks. After a meeting with the project personnel, district materials personnel and the contractor's representative, the following procedures were adopted to correct the problem: The windrows would be overlapped, the hopper would never be allowed to get below half full before stopping the lay down machine, and the material in the hopper at the end of the day would be wasted. This solved the majority of the segregation problems.

Density tests were performed on and adjacent to areas that looked segregated. The segregated sections were from 3% to 14% less dense than the adjacent sections. Two extremely bad areas were removed and replaced at the end of construction. Obviously segregated areas directly behind the lay-down machine were removed and replaced before compaction.

Sample specifications for using this method to test for segregation are included in Appendix E.

PROJECT FRI(CX)CY 070-5(59) (East of Limon - milling): **Grading G** inlay in various locations, followed by a fog seal over the entire project. Conveyor type trailers have been used to fill the lay-down machine in order to reduce segregation. Everything seems OK with the project except for the Lottman values and some stripping.

Lottman values have not met the specified minimum of 80. It was thought that this was attributed to insufficient moisture (spec 3% above SSD) on the aggregate before the introduction of the lime. The contractor increased the amount of water sprayed on the aggregates, but they were still unable to get passing Lottmans. They replaced some of the natural fines with crusher fines and were able to get passing Lottmans.

Stripping has occurred at five locations, each about four foot square. As a short term solution, the contractor has placed a tack coat and compacted some fines at each location. Each area will eventually be removed and replaced.

DISTRICT TWO

PROJECT CXFR 17-0287-08 (12.5 miles south of Lamar - south): This project was constructed in September and October of 1990. It consisted of placing an HBP **Gr. CX leveling course** followed by Petromat and 4-1/2" to 6" of **HBP Gr. C** in three lifts. Major distress was noticed in the roadway in July of 1991. Problems on and after the project included: segregation, inadequate compaction (high air voids), stripping, bleeding and rutting.

Assurance tests taken after the project was completed indicated compaction was only 89% to 91% as opposed to the 92% to 93% measured by quality control testing based upon the RICE method. District personnel indicated this was not uncommon.

Project personnel waged a continuous struggle to mitigate the segregation problem, but were not successful. The segregation was caused by the contractor's stockpiling technique and plant operations.

At the end of the project, an asphalt rejuvenating agent (ARA) was sprayed over the entire surface to fill the excess voids since segregation was so severe. This seems to have severely aggravated the problem. The application of the ARA penetrated the air voids and softened the asphalt. The soft asphalt was very susceptible to stripping. Moisture penetration with high heat and traffic caused stripping to occur. The stripped asphalt bled to the surface, weakened the section, and then rutted.

The stripping was occurring predominantly in the top lift. Moisture could be seen seeping from the surface several days after a rain shower. Bleeding occurred in the wheel paths throughout the project.

PROJECT CX 04-0083-41 (Jct SH 83 Spur - south): Samples run at 4.4% AC at 2-1/2" height passed the Hveem but failed the Lottman. The mix was re-run with 2" high samples and a new optimum AC of 5.0% was obtained and the Lottman's passed. The rice value was adjusted based on numerous tests on the project produced material. Before the AC content was increased, a previous experimental **SHRP Fine** mix was used with the same aggregate and an AC content of 4.7%. It was difficult to get density with this AC content. Passing densities were obtained, but there was evidence of aggregate breakage. This problem was eliminated with the new higher AC content.

The QC/QA specification seemed to help on this project. The contractor's own quality control person caught an error in the AC content and corrected it before the required tonnage for the first random field acceptance test. In addition, the contractor had a nuclear density gauge on the project at all times. They were thus able to develop their own rolling patterns and check it themselves, this freed up the project tester. The success of the

QC/QA was attributed to the experience and proficiency of the contractor's QC person.

Only one acceptance test out of 29 failed density.

There were no failures on AC content acceptance tests at both the original and revised AC contents. One Central Lab check test failed, but the retained split passed in the District Lab.

There were no failing gradation tests and consequently the frequency of testing was reduced after the first ten tests.

Dry lime was mixed in a 10 ft. pugmill with wet aggregate and stockpiled. This provided two benefits; consistently high lottman values, and the ability to check if the lime was actually added (it could clearly be seen in the stockpile).

DISTRICT THREE

PROJECT CY 59-0125-19 (SH 125 and SH 127 Wyoming line south): The design mix was marginal but was approved. Construction began about July 15, 1991.

The major problem with this project was density. A minor problem was some gradation variation.

The quality control subcontractor had problems getting their nuclear testing equipment by the time paving started. This created some problems with the calibration for asphalt content tests. In addition, the QC subcontractor, though knowledgeable about testing and inspecting, was not familiar with CDOT methods and documentation procedures.

AC contents and gradations were erratic the first few days. Some gradation problems occurred because aggregate was taken directly from the crusher to the hot plant rather than stockpiling.

Densities at first averaged 87%. One of the contractor's rollers was broken down during part of this time. Different roller patterns were tried and the densities were increased to 91%. A thicker lift was placed on the theory that the previous lift may have been too thin to get valid results, but this did not help.

On August 15, the AC was increased from 4.3% to 5.5%. The density problem was solved, but the increased AC may make the stability of the mix lower.

PROJECT CC-CX-21-0050-15 (Cimarron): The mix was designed with the Texas Gyratory procedure, using highly absorptive aggregate. Paving began on September 23, 1991. The major problem encountered on this project was inadequate compaction. A secondary problem was high moisture content.

The contractor was shut down after three days because of densities around 86%.

CDOT observations of the roller operation:
1. The rollers stopped when the laydown machine stopped.
2. The rollers were going too fast.
3. No real attempt to establish a consistent rolling pattern.

Contractor's proposed corrective actions:
1. Increase AC to 6.2% from 5.9%
2. Increase hot plant temperature and dry the moisture out of the mix (CDOT suggestion)
3. Slow down the breakdown roller (CDOT suggestion)

The contractor was allowed to proceed after a test patch with these corrective actions. The vibrating screed was not working properly, but was fixed as well. Densities of 93%+ were achieved.

On the last patch the AC was again reduced to 5.9% and 93% density was still achieved.

In some, if not all cases, it may be necessary for the contractor to have two breakdown rollers in order to keep production rates up.

DISTRICT FOUR

PROJECT FRI(CX) 025-3(114) (Owl Canyon north): At the contractor's request, this mix was changed from a grading C to an SC (**SHRP Coarse**). Stabilities have been 40 plus and Lottman's have been 95 to 100. This project is an overlay of a PCCP pavement. This project was started late in the 1991 paving season and will be completed next spring. The lay down of this mix has gone fairly well. There have been two problems; compaction and segregation.

Densities are low, but the contractor has been able to meet specifications. With the rock to rock contact in the thin (1-1/2") lift, the vibratory roller may actually be reducing compaction after a point. Rubber tire rollers have been substituted now for breakdown with some success. The lift should be increased to 2".

Going from a 2-1/2" sample height to a 2" sample height has increased the AC content from 4.3% to 4.4%. This increase in AC content also helps with compaction.

Cooler fall temperatures have also made it more difficult to obtain compaction.

Segregation has occurred, and with it, some ravelling (but not stripping) in the surface of the mat. This ravelling is also

associated with the low AC content. Switching to a rubber tired roller for breakdown may have reduced the ravelling by kneading and turning the coarser particles to optimize their fit at the surface. The mix must not be allowed to cool off too much because coarser particles separate and roll when cool.

The project was partially sealed with CSS-1h to help prevent further ravelling of the surface.

Contractors need to learn how to handle these types of mixes better. They may need to buy more rollers or upgrade the equipment they have, keep laydown machines adjusted, understand roller tire pressures and what happens when they heat up and/or cool down, learn how to handle material from the hopper to the storage silo to loading the trucks to depositing the material on the roadway would go a long way towards a better product.

PROJECT FR(CX) 085-3(13) (Lone Tree Creek to Little Owl Creek): This mix was a **grading C** with an optimum AC content of 4.8%, designed by the Texas Gyratory method. The pavement was placed in May and June of 1991. The major problems on this project were segregation and insufficient densities. Additional related problems were a non-uniform mix, non-uniform addition of lime, and sometimes excess moisture.

The contractor was unable to achieve density during the first three days. After that he was able most of the time, but not all of the time. No consistent increase was achieved by simply increasing the AC. Changing the rolling pattern did not seem to help much, except for the use of a rubber tired roller for breakdown sometimes. When he was able to reduce segregation, that helped increase the density. The non-uniform mix was difficult to compact. In addition, the contractor was not able to take advantage of what uniformly added lime does for the compactive effort. The excess moisture made the mix tender at first, then cooled the material so that it was impossible to achieve density.

In the last days of the project, a previously developed **SHRP Coarse mix** was substituted, and with the contractor's experience during the beginning of this project, he was able to produce a good quality pavement.

In general, the contractor's inexperience with these unforgiving mixes, and his inconsistent production were the cause of the segregation and density problems.

The surface has been treated with .05 gal/sy of CSS-1h to stabilize the open and segregated surface. Reclamite was used briefly, but was too slick.

To address the compaction problems, a first day evaluation of the placement and rolling operations is now performed using a

prepared checklist, which provides some guidance for the project engineer and contractor.

Other recommendations: Increase AC, pay extra for the required compaction, more and/or heavier rollers, rubber tired rollers.

DISTRICT FIVE

PROJECT CY 32-0666-02 (South of Cortez): The project consisted of cold recycling the existing pavement 4" deep with a 4-1/4" HBP overlay, place with a 1-1/2" bottom mat and a 2-3/4" top mat. The grading was changed from C to SHRP Coarse at the contractors request. The material actually placed was **somewhat finer than an actual SHRP Coarse** mix. The design AC was 4.2%.

The major problem on this project was compaction. Segregation was a problem early, but that was remedied.

The contractor tried various rolling patterns but was still unable to get compaction. After meeting with CDOT, the contractor increased the AC content by .5%, increased the depth of the bottom mat from 1-1/2" to 2-1/4", and increased the mix temperature. This cured the compaction problems, but not until the bottom mat was completed.

There was some concern that the cold recycle was not sufficiently strong to allow compaction of material place on top of it. However, cores taken in the bottom mat showed broken aggregate in the new paving material and it was concluded that that wasn't the problem.

The District does not recommend continuing with the extremely coarse aggregate mixes and also opposes low asphalt content.

DISTRICT SIX

PROJECT CX 01-0025-58 (I-25, Colorado to 6th): This project consists of planing and 2" of HBP with a polymer additive. Prior to construction, the grading CX was changed to **SHRP Coarse** with no lime.

Four different mixes were placed on this project with substitutions of aggregate and AC type, each with its own 1st rep and 10k series.

Construction started out well. After the fourth night of paving, compaction problems developed. A roller pattern study determined that two passes of the breakdown roller and three passes of the intermediate roller (both vibratory) were optimal. This pattern was continued for the rest of the project and no more compaction problems occurred.

Longitudinal joint problems occurred. The contractor used a 10" fabricated shoe to taper the lift from 2" to 0". The coarse aggregate needed to be swept up in the adjacent lane. When the adjacent lane was paved, segregation occurred at the joint because of the thinness of the lift.

Some suggestions from the RE were to place the coarse mix projects early in the season to allow traffic to heal the surface during hot weather, and to place a +/- 1% tolerance on the -#200 sieve for coarse mixes. Since film thickness could be significantly affected at the lower optimum AC contents used in the coarse mixes.

APPENDIX C

DRAFT QUALITY ASSURANCE REVIEW REPORT FOR 1991

DRAFT QUALITY ASSURANCE REVIEW REPORT FOR 1991

DRAFT

PROGRAM REVIEWS - SPECIAL EMPHASIS AREAS

The program established joint FHWA/CDOT teams to make QA project reviews. The emphasis areas chosen for program review in 1991 were:

1. Asphalt Pavement
2. Concrete Pavement
3. Work Zone Traffic Control

EMPHASIS AREA # 1 - ASPHALT PAVEMENT

PROJECTS REVIEWED

Asphalt Pavement QA Reviews were conducted during the period from June to October 1991 and the following projects were inspected:

1. IR(CX) 70-4(157)
2. CX-01-0025-58
3. FCU(CX) 093-1(12)
4. I(CX) 70-2(141)
5. CX 99-6000-57
6. FRI - 70-5(56)
7. FR(CX) 014-2(24)
8. FRI(CX) 25-3(114)

TEAM MEMBERS

The members of the 1991 QA Review Team for Asphalt Pavement were:

1. Mark Swanlund - FHWA - Team Leader
2. Joe Seitz - CDOT - Staff Construction
3. Steve Horton - CDOT - Staff Design
4. Dick Hines - CDOT - Staff Materials

The appropriate District Materials Engineer, District Construction Engineer, Resident Engineer and Project Engineer were included as members of the review team for each individual project.

FINDINGS AND RECOMMENDATIONS

I. Compaction:

A. Findings:

1. The majority of the projects reviewed experienced problems obtaining the required density.

2. The CDOT changed their method of designing asphalt pavement mixes this year. The new procedure uses a Texas Gyratory Compactor. The previous procedure used a Kneading Compactor. This change in design procedure resulted in lower asphalt cement contents and the new mixes required an increased compactive effort to obtain the required densities.

3. The new asphalt mixes recommended by the Strategic Highway Research Program (SHRP) (SHRP Fine, SHRP Coarse and SHRP Gap Graded) were used on several of the projects that were reviewed. These new mixes also require more compactive effort than the traditional mixes used by CDOT. (Grading C, CX, etc.)

B. Recommendations:

1. The compaction test section specification, being proposed by CDOT, should be implemented statewide for the 1992 construction season. This specification requires that contractors demonstrate the ability to obtain the specified density on the first 500 tons of asphalt pavement placed on each project.

2. The minimum lift thickness of two inches, being proposed by CDOT, should be implemented statewide for the 1992 construction season. This additional thickness will help maintain the temperature of the asphalt mat and allow more time to obtain compaction. This is especially critical in the following areas:

   a. Asphalt pavement being placed at night.

   b. Asphalt pavement being placed early in the spring or late in the fall.

3. When a contractor experiences difficulty obtaining density , the following procedures should be tried before considering a change in the asphalt mix design or density requirements:

   a. Rollers should be operated as close to the asphalt paver as possible.

   b. Rubber tired rollers should be used to breakdown roll.

   c. Larger rollers should be used.

   d. The temperature of the asphalt mix at delivery should be raised.

EMPHASIS AREA # 1 - ASPHALT PAVEMENT

II. Segregation:

A. Findings:

1. Segregation was a moderate to severe problem on most projects.

2. Factors contributing to segregation:

a. Material handing techniques.

b. Asphalt paver operation.

c. Coarse graded asphalt mixes.

d. Low asphalt cement content.

e. Thin lifts.

3. The following are some procedures that were observed to reduce segregation:

a. Use of flow-boy hauling units.

b. Using a windrow pickup machine.

c. Dumping the wings on the hopper of the asphalt paver only occasionally.

d. Keeping the hopper on the asphalt paver at least half full at all times.

e. Proper material handling.

B. Recommendations:

1. The specification to determine segregation, being developed by CDOT, should be implemented statewide for the 1992 construction season. This specifications utilizes the nuclear density gauge to determine segregated areas immediately behind the asphalt paver. It is intended that the segregated areas will be removed and replaced while the material is still hot.

2. Extensive training, in the methods and procedures to minimize segregation, should be provided to all CDOT construction personnel and the contractor's employees before the start of the 1992 construction season. (The joint FHWA/CDOT 2 day training session, "Hot Mix Asphalt Paving", that will be offered to each CDOT construction employee and contractor personnel this winter will provide this training.)

3. When segregation occurs on a project the following should be carefully reviewed in an attempt to minimize the segregation:

   a. Material handling techniques.

   b. Asphalt paver operation.

III. Contract Modification Orders (CMOs):

A. Finding:

1. On several of the project reviewed, the specified asphalt mix gradings had been changed by CMO to other gradings. (SHRP Fine, SHRP Coarse, or Gap Graded)

B. Recommendations

1. Specified asphalt mix gradings should not be changed by CMO. The asphalt mix gradings that were specified should be constructed as advertised and bid.

2. If it is desirable to use other asphalt mix gradings, they should be included in the preconstruction process and advertised and bid.

IV. Longitudinal Joints:

A. Finding:

1. Excessive raking of the longitudinal joint on several projects resulted in an open surface and poorly constructed joints.

B. Recommendations:

1. Contractor and CDOT construction personnel should receive training in the proper construction of longitudinal joints before the start of the 1992 construction season. (The joint FHWA/CDOT training session, "Hot Mix Asphalt Paving" which will be offered to each CDOT construction employee and contractor's personnel this winter will provide this training.)

2. Longitudinal joints should be constructed as follows:

a. The screed of the asphalt paver should overlap, onto the previously placed mat, approximately two inches.

b. The depth of the new asphalt material in the overlapped area should be one quarter of an inch deep for each inch of thickness being placed.

c. Very little , if any, raking of the joint should be done.

V. Independent Assurance Test Results:

A. Finding:

1. The Independent assurance test results were not available on most of the projects at the time of the review.

B. Recommendation:

1. New procedures need to be implemented to ensure more timely reporting of these test results. (The District Materials Labs are purchasing equipment to perform these tests. Operation of this new equipment by the District labs should provide a quicker response.)

VI. Quality of Contract Documents:

A. Finding:

Several project personnel felt that the contract documents were not adequate. They stated that they did not feel they had enough time to properly review the contract documents before the project went to bid.

B. Recommendation:

1. The preconstruction process should provide more time for the construction personnel to review and comment.

EMPHASIS AREA # 1 - ASPHALT PAVEMENT

VII. Including Baghouse Fines in Asphalt Pavement Mixes:

A. Findings:

1. Aggregate gradation acceptance test sampling for all projects was done off the cold feed belt.

2. The Contractor was reintroducing "baghouse fines" into the dryer drum on some projects.

3. There was no consideration given to this material when the gradation test were run.

B. Recommendations:

1. The impact of the introduction of baghouse fines should be carefully studied during the 1992 construction season. Both the amount and the gradation of this material need to be investigated.

2. A correlation should be made from the above research for use in future years.

APPENDIX D

MASTER RANGE TABLE FOR HBP

MASTER RANGE TABLE FOR HBP

TABLE 703-3

Master Range Table For Hot Bituminous Pavement

Sieve Size	Percent by Weight Passing Square Mesh Sieves			
	Grading G	Grading C	Grading CX	Grading F
1-1/2"	100			
1"				100
3/4"	63-85	100		
1/2"	46-78	70-95	100	
3/8"		60-88	74-95	
#4	22-54	44-72	50-78	
#8	13-43	30-58	32-60	45-85
#30	4-22	12-34	12-34	
#200	1-8	3-9	3-9	7-13

Passing No. 8 and larger sieves	±8%
Passing No. 30 sieve	±6%
Passing No. 200 sieve	±2%

APPENDIX E

MODIFIED RANGE TABLE FOR HBP
(IMPROVED GRADATIONS)

MODIFIED MASTER RANGE TABLE FOR HBP
(IMPROVED GRADATIONS)

DRAFT 1-16-92

TABLE 703-3
MASTER RANGE TABLE AND TOLERANCE
TABLE FOR HOT BITUMINOUS PAVEMENT

Sieve Designation	Percent by Weight Passing Sieve			Tolerance
	Grading SF	Grading SC	Grading GG	
3/4"	100	100	100	
1/2"	76-95	70-90	70-90	±6
3/8"	72-88	58-76	58-76	±5
#4	54-72	38-56	40-60	±5
#8	40-58	24-38	36-54	±4
#30	18-34	8-20	18-34	±4
#200	3-9	3-9	3-9	±2.0

APPENDIX F

PROPOSED COLORADO PROCEDURE FOR DETERMINING SEGREGATION

PROPOSED COLORADO PROCEDURE FOR DETERMINING SEGREGATION

DRAFT

COLORADO PROCEDURE _____

FOR DETERMINING SEGREGATION IN
HOT BITUMINOUS PAVEMENT

1. Place the nuclear density gauge on the visually suspect area of the compacted surface. Move the handle down to the backscatter position and take a one minute count. Determine the density in PCF and record this as reading A.

2. Place the nuclear density gauge on an adjacent area of the compacted surface. Move the handle down to the backscatter position and take a one minute count. Determine the density in PCF and record this as reading B.

3. If B-A is greater than 5 PCF, the material in the suspect area is segregated and should be removed.

Note: This procedure is intended to establish a method to identify segregated areas. After confidence is reached, segregation can be determined by visual inspection alone.

APPENDIX G

AGGREGATE MOISTURE CONTENT WITH LIME

AGGREGATE MOISTURE CONTENT WITH LIME

DRAFT

December 6, 1991

REVISION OF SECTION 401
PLANT MIXED PAVEMENTS-GENERAL

Section 401 of the standard specifications is hereby revised for this project as follows:

Subsection 401.14 (b) shall include the following:

Moisture content of the wet aggregate will be determined by the Division by drying to a constant weight at 230°F ± 9. Minimum sampling frequency will be 1/1000 tons or fraction thereof of mix produced. If moisture contents do not conform to specifications, payment for Hot Bituminous Pavement shall be reduced in accordance with 105.03 with an F factor of 20.

ALTERNATIVE
Below is an alternative specification using total moisture in place of moisture above SSD. Since SSD for typical aggregates average 1.5% the 4.5% required below is equivalent to 3% above SSD.

December 6, 1991

REVISION OF SECTION 401
PLANT MIXED PAVEMENTS-GENERAL

Section 401 of the standard specifications is hereby revised for this project as follows:

Omit subsection 401.14 (b) and replace with the following.

(b) Dry Lime Added to Wet Aggregate. The dry hydrated lime shall be added to wet aggregate (a minimum of 4.5% total moisture) and then thoroughly mixed in a an approved pugmill. Moisture content of the wet aggregate will be determined by the Division by drying to a constant weight at 230°F ± 9. Minimum sampling frequency will be 1/1000 tons or fraction thereof of mix produced. If moisture contents do not conform to specifications, payment for Hot Bituminous Pavement shall be reduced in accordance with 105.03 with an F factor of 20.

APPENDIX H

COLORADO FLEXIBLE PAVEMENT OVERSIGHT GROUP TASK FORCE MEMBERS

Colorado Flexible Pavement Oversight Group
Task Force Members

Category:	Pavement Management	Steve Horton, Chair
Issues:	- Historic Data Base	Dave Fraser
	- Project Selection	Bill Keller
	- Joint Review Committee	Jim DeBerry
	- Economic Analysis	Doyt Y. Bolling
	- Inventory Element	A.G. Peterson
	- Monitoring Element	Robert Rask
	- Other	Bill Lauer
		Ira Paulin
		Paul Rippy
		Gene Arnold

Category:	Pavement Design and Rehabilitation	Robert Rask, Chair
Issues:	- Rehabilitation Strategies	Ken Mauro
	- Embankment & Drainage Requirements	Dave Fraser
	- Maintenance Strategies	Skip Bettis
	- Other	Paul Rippy
		Dick Klinker
		Steve Horton
		Carl Stuka
		Rose McDonald
		Tom Claret
		Doyt Bolling
		Bob Bisgard
		Ira Paulin

Category:	<u>Material Selection Specifications</u>	Dick Hines, Chair
Issues:	- Mix Design Criteria	Vuk Aguirre
	- Binder Specifications	Paul Rippy
	- Aggregate Contractor Sources	Tony Collins
	- Lime Antistrip	Mark Swanlund
	- Other	Carl Stuka
		Charlie Atherton
		Ken Mauro
		Jim DeBerry
		Robert Rask
		Larry Johnson
		Bob Bisgard
		Skip Bettis
		Sid Motchan
Category:	<u>Mix Design Systems</u>	Tim Aschenbrener, Chair
Issues:	- Texas Gyratory	Jim Fife
	- SHRP AAMAS (Superphalt)	Harold Elam
	- European AAMAS	Tony Collins
	- Other	Ken Mauro
		Tom Claret
		A.G. Peterson
		L. Scott Hendricks
		Victoria Peters
		Bob Welch
Category:	<u>Training</u>	Mark Swanlund, Chair
Issues:	- Mix Design - Laboratory Testing	Jim Fife
	- Pavement Management	Harold Elam
	- NICET/Bitum. Technical Cert.	Tony Collins
	- Aggregate Technical Cert.	Victoria Peters
	- Plant Operation	Carl Stuka
	- Construction Procedures Inspection	Ken Wood
		Tony Ursini
	- Pavement Maintenance and Rehabilitation	Bud Brakey
	- Training Opportunities for Development	
	- Other	

Category:	New Materials Technologies	Ken Wood, Chair
Issues:	- Modifiers	Jim Fife
	- Fabrics	Tony Collins
	- Drainable Bases	Owen Hill
	- Stone Mastic Asphalt	Denis Donnelly
	- Other	Jim DeBerry
		Stan Peters
		Buck Richardson
		Sid Motchan

Category:	Constructability Factor	Tony Ursini, Chair
Issues:	- Designing for Constructability	Bill Lauer
	- Pre-bid/Pre-Construction /Pre-paving Conferencing	Harold Elam
		Paul Rippy
	- Field Constructability Assessment (CMO's)	Carl Stuka
		Jeff Killer
	- Workmanship	Skip Bettis
	- Aggregate Stockpiles	Mike Mikkelson
	- Plant Operations	John Unbewust
	- Transport	
	- Laydown	
	- Compaction	
	- Specification Review	
	- Project Closeout Review	
	- Project Site Logistic/Traffic Constraints	
	- Automated Equipment Controls	
	- Other	

Category:	QA/QC	Denis Donnelly, Chair
Issues:	- Test Methods, Accuracy and Precision	John Unbewust
		Dick Klinker
	- Testing Frequency	Bud Brakey
	- Independent Assurance	Carl Stuka
	- Sampling Techniques (size, location, safety)	John Unbewust
		Ken Mauro
	- Quality Control and Producer Capability	Ira Paulin
	- Plant Certification and Calibration	
	- Acceptance Procedures Plan	
	- Identification and Evaluation of Well Performing Projects	
	- Performance Monitoring (as constructed conditions)	
	- Inspection procedures	
	- Other	

Category: Awards

Issues:
- Pavement Quality Workmanship Award
- Incentives
- Publicity
- Other

Rick DeLaCastro, Chair
Mike Mikkelson
Dick Klinker
Curt Marrel
Charlie Atherton
Ken Mauro
Doyt Bolling
Jim DeBerry
George Osborne
Bob Clevenger
Bill Keller

APPENDIX I

GYRATORY COMPACTOR TEST PROCEDURE

MEMORANDUM

DEPARTMENT OF HIGHWAYS
4201 East Arkansas Ave.
Denver, Colorado 80222

DATE: November 26, 1991

TO: District Materials Engineers

Dick Hines

FROM: Dick Hines

SUBJECT: Modification of the Gyratory Compaction for Hveem

The compaction of Hveem specimens on the gyratory compactor has been modified by reducing the specimen height to 2". The revised procedure is attached. This revised procedure will now be used for all Hveem compactions.

This modification will result in higher asphalt contents at optimum. The attached correlation study shows how compaction method affected the optimum AC for 10 mixes.

This new method will result in mixes that are less difficult to compact and less susceptable to moisture damage.

DH/hs
cc Clevenger/Shaffer
Donnelly
Unbewust
Horton
Bill Grey, Design
Rick DeLaCastro, CAPA
Jay Lower, CCA

Colorado Procedure
L-5105

Revised
Nov 1991

Method of Test For

RESISTANCE TO DEFORMATION OF BITUMINOUS MIXTURES BY MEANS OF HVEEM STABILOMETER

Test specimens will be prepared in accordance with ASTM D 4013 (modified). Bulk specific gravity is then determined in accordance with AASHTO T 166. Hveem Stability is then determined in accordance with AASHTO T 246 (modified).

SELECTION OF BITUMEN CONTENT FOR SPECIMENS

1.1 Determine an estimated asphalt cement content for the specimen. Normally, tests will be conducted using four asphalt cement contents, with an incremental change of 0.5 %.

PREPARATION OF SPECIMENS

2.1 Specimens will be mixed and compacted in accordance with ASTM D 4013 as modified below. Specimen height shall be from 2.00 to 2.19 inches. Total loads on the 4" diameter specimen for pregyration stress, end point stress, and consolidation stress are 400 lb., 1200 lb. and 20,000 lb. respectively. This corresponds to gauge pressures of 50 psi, 150 psi, and 2500 psi for a ram diameter of 3.19 in.

2.2 Mixing and compaction shall be at the temperatures shown in the following table for normal asphalt cement and asphalt cement that has been modified by addition of rubber or polymer. The tolerances for each shall be ± 5°F.

	Normal	Modified
Mixing	275°F	325°F
Compact	250°F	300°F

2.3 Aggregate and asphalt cement shall be heated a minimum of 2 hours before mixing. The mix shall then be reheated for a minimum of 30 minutes before compacting. Mixed production samples shall be heated for a minimum of 2 hours before compaction. If a production sample is received at a temperature of 200°F or higher, the heating time can be reduced to 30 minutes.

Note 1: For a smooth top and bottom on the specimen place 30 to 50 g. of fine material on the top and bottom when loading for compaction.

Note 2: Apply the pump strokes smoothly when checking the end point stress and applying the consolidation (leveling) load. The leveling load strokes should be applied at the rate of one stroke per second, after the change to the high range gauge.

BULK SPECIFIC GRAVITY DETERMINATION

3.1 Determine bulk specific gravity of specimen in accordance with AASHTO T 166. This is used with the maximum specific gravity (AASHTO T 209) to compute the air voids as follows:

Percent air voids =

$$\left(1 - \frac{\text{bulk sp. gr.}}{\text{Max. sp. gr.}}\right) \times 100$$

HVEEM STABILITY DETERMINATION

4.1 Hveem Stability shall be determined in accordance with AASHTO T 246 sections 4, 5, and 6 with the following modifications. The specimen is to be transferred from the oven to the stabilometer, not pushed from the mold. The stabilometer gauge reading is recorded only at a vertical load of 5000 lbf.

HEATING FOR HVEEM STABILITY

5.1 Bring the specimen to a temperature of 140° ± 5° F by preheating at that temperature for a minimum of 1 1/2 hours.

5.2 The stabilometer base and follower will be preheated at 140° ± 5° F for a minimum of 1 hour.

SELECTION OF OPTIMUM ASPHALT CEMENT CONTENT

6.1 Optimum asphalt cement content is chosen where all the design criteria are satisfied. Design criteria are specified in the plans (voids, stability, VMA, and asphalt cement film thickness). In addition, the mix should conform to a dust to asphalt ratio criteria of 0.6 to 1.2.

6.2 Optimum shall be established at the center of the void range if all the above criteria are satisfied at the corresponding asphalt cement content. If the design criteria are not satisfied at the center of the void range, then optimum shall be established at the closest asphalt cement content which satisfies all design criteria. If there is no asphalt cement content at which all specified design criteria are satisfied, then the mix is not acceptable.

6.3 The moisture susceptibility test shall be conducted at the final optimum asphalt cement content. If the moisture susceptibility test meets the specified design criteria, the mix is acceptable.