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Chip-Seal Design Using An Expert System

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ABSTRACT

Current practices for chip-seal design and construction have resulted in limited life expectancy. To check this trend, a rational method was developed for field testing, to aid engineers in designing these surfaces. The method involved adapting techniques used in Australia, and subsequently developing expert system software. Four test sections designed by this method were placed in 1992 and 1993 alongside control sections designed by current conventional practice. Shoulder sections performed satisfactorily -- performance of pavement test sections designed by the expert system was similar to those designed by standard methods. Details are given concerning internet accessibililty of the expert system and a user's manual.

CONTENTS

I. INTRODUCTION

A. Background

Chip seals, also called "sprayed seals" or "stone-and-oil," are bituminous surface treatments consisting of single-size aggregate spread on a road just after spraying with asphalt emulsion. They are generally used to prevent subgrade deterioration by sealing small cracks in the surface, thus preventing intrusion of water, and also to improve roadway skid resistance and riding quality. They are less expensive than conventional overlays, and may be used effectively on lightly traveled roads where the surface is more likely to deteriorate from the gradual effects of aging than from heavy wear by traffic.

Chip seals were widely used by New York State until in the late 1970s, when both reduced funding for maintenance and their history of deficient performance made the Department's Highway Maintenance Division reluctant to use them. Rather than the expected nominal life expectancy of 4 to 7 years, chip seals were documented by Hahn and Hiss to "have a median service life of 3 years" (1). Four causes are generally accepted for this shorter service life:

1. Inappropriate use of the seals, including roadways with high traffic volumes or a high percentage of heavy trucks,

2. Use of poor-quality asphalt and/or aggregate,

3. Improper construction techniques, and

4. Faulty design, including incompatibility of asphalt and aggregate.

The first two problems can be addressed by following earlier guidelines published by others, including an Australian Bituminous Surfacing Manual (2), but more important, designers must be aware that chip seals are not an inexpensive cure for all roadway problems. They do not increase roadway structural strength, and generally should be used only on structurally adequate, low-volume roads. The second and third problems have also been evaluated by many researchers, including recent work in Texas for the Strategic Highway Research Program (SHRP) of the National Research Council. Bullard, Smith, and Freeman (3) advocated use of a "rating tree" to select construction techniques for placement of chip seals. This method inquires into existing conditions as well as possible methods and equipment for placing the materials, and then gives an overall score for construction. Although the rating tree alone cannot guarantee the service life of a chip seal, it can give valuable guidance concerning the effects of construction on service life. More details are given in Appendix A.

The emphasis in the study reported here was on addressing the problem of faulty design. New York State specifications published in 1990 (4) suggested the following application rates: 1) 0.35 gal/sq yd of emulsion for tight surfaces with high-volume traffic, and 0.45 gal/sq yd for porous surfaces with low-volume traffic, and 2) 1ST aggregate at 20 to 24 lb/sq yd, the actual amount to be determined by weighing the aggregate required to cover 1 sq yd completely with a single layer of stone (4). These suggested rates are imprecise for both emulsion and aggregate, and do not consider such factors as type of emulsion, aggregate size and shape, possibility of aggregate penetration into the existing surface, or emulsion absorption by the aggregate or existing surface. Essentially, chip seals have been designed empirically using the engineer's knowledge of what has worked in the past, and/or by recommendations of the emulsion supplier. Although this may sometimes have been relatively successful, it does not consider the parameters that change from project to project. For example, although an emulsion application rate of 0.36 gal/sq yd may have worked on a project that used "cubical" aggregate, it would literally swamp an aggregate having a flat shape. A rational design approach was needed to change current design practice from an art to a science. As a side benefit, a rational approach could be developed into an expert system.

Expert systems are user-friendly computer programs that aid in decisions requiring a certain experience and expertise. They use the knowledge and guidance of experienced professionals to find solutions that can be passed on to others -- for instance, they have been used by physicians for patient diagnosis and treatment. The Department has developed a road-striping expert system to guide the design engineer in choosing the best paint for specific roadway and traffic conditions. These systems are not meant to replace engineers, but to aid them in decisions where their inexperience may require assistance. This study's purpose was to develop a rational chip-seal design method, to evaluate it against current design practice, and to program an expert system for assistance in future designs.

B. Development of a Rational Design Method

Chip-seal design in New York needed conversion from an empirical art to a more rational science. The process began with acquisition of an expert system already in use by the Victoria Country Roads Board in Australia. Their software uses a design created by F.M. Hanson of New Zealand in the 1930s and subsequently improved by Norman McLeod (2). Hanson's method takes into account traffic, and road and material conditions and properties to create a chip-seal design. This includes rates of application for the emulsion and aggregate to be placed for either a single or double course. However, it was created for Australian and New Zealand roads, aggregates, and bituminous materials -- it thus had to be adapted for New York State specifications, aggregate sizes, and materials.

The Australian expert system was meant for a heated bituminous binder, rather than an asphalt emulsion. To convert from binder to emulsion, this method must divide the asphalt binder rate by the minimum percent of binder remaining after distillation, as prescribed by current New York State specifications. In addition, the method uses the metric system. Since New York State decided to convert to metrics by September 1996, customary equivalents were simply added in parentheses after metric amounts so that customary units can eventually be deleted after full metrication . Also, the aggregate application rate is in the form of volume over area (liters per square meter), rather than New York's specifications for weight over area (pounds per square yard). The new method will use volume units, because they avoid the problems of density and are easier to use. Finally, an input variable used by Hanson, called "ALD" or average least dimension of the aggregate, was not used by New York. ALD is the nominal height of one layer of aggregate when all stones have been laid flat, and is integral to the design because it helps determine how much asphalt is needed to secure but not completely immerse the stone. Neither New York nor ASTM currently have tests to measure ALD. After some searching, the Asphalt Institute's McLeod slotted-sieve test (5) was located and then adapted for New York State (Appendix B). Appendix C outlines the chip-seal design method developed and proposed in this study.

Table 1. Summary of test sites.

Test Site	Month Placed	Location Rte	County	Town	Starting Mile Marker*
1	8/92	333	Steuben	Thornton	1022
2	9/92	225	Chemung	Mud Flats	1041
3	9/93	248A	Allegeny	Whitesville	1050
4	9/93	41	Cortland	McGraw	1201

*Each section was 305 m long.

Table 2. Test and control mix designs.

		Bottom Layer, l/m^2		Top Layer, l/m^2	
Site	Section	Emulsion	Aggregate	Emulsion	Aggregate
1	Test	1.81	10.9	1.15	9.2 to 6.5
	Control	1.58	12.2	0.95	7.0
2	Test	1.54	10.0	1.15	9.2 to 3.5
	Control	1.81	8.5	1.58	7.0
3	Test	2.00	10.1	1.15	7.0
	Control	1.36	10.5	2.27	7.0
4	Test	2.09	10.2	--	--
	Control	1.81	8.0	--	--

[a]HFRS-2 emulsion, aggregate: 1ST bottom layer, 1A top layer.
[b]CRS-1 emulsion, aggregate: 1ST bottom layer, 1A top layer.
[c]Single layer on shoulder: HFRS-2 emulsion, 1ST aggregate.

II. FIELD TESTING

A. First-Year Construction (1992)

A field-testing program was developed to determine whether the new design method would succeed, and to indicate any necessary adjustments. For the first testing phase, two experimental sites were selected, both 305 m long and located within chip-seal projects already being placed by maintenance forces. Locations are listed in Table 1. Both sites were double-course, meaning that 1ST aggregate (6 mm nominal size) was used for the bottom course, and 1A aggregate (3 mm nominal size) for the top course. Design of the experimental and control sections is summarized in Table 2. Aggregate ALD for Site 1 was determined by the Asphalt Institute in their Kentucky laboratory. Aggregate ALD for Site 2 was determined by New York researchers using hand calipers on a 4.5 kg aggregate sample. During placement at Site 1, the bottom course was observed to be spreading and adhering properly, but early in top-course placement it was noted that significant amounts of 1A aggregate were not touching the emulsion, indicating an excessive aggregate application rate. This was decreased incrementally until a suitable rate was found. Similar problems were experienced at Site 2, followed by a similar incremental decrease in application rate. From this, it was decided that for the rational design, the 1A aggregate application rate should be decreased from 9.2 to 7.09 L/m^2.

During early service, the test sections at both sites appeared adequate. To monitor performance, designated areas were periodically photographed, and the photos compared for aggregate loss and recurrence of any previous cracks. Within a year after seal placement, Site 1 showed 70- to 80-percent loss of aggregate along wheelpaths, in both test and control sections. This condition was unacceptable, and both chip-seal designs were considered failures by the Regional Highway Maintenance Supervisor.

After 2 years, Site 2 showed recurrence of some cracks, but 90 percent of the aggregate was retained. The Regional Supervisor judged this treatment to be performing adequately -- aggregate in both cases was retained and crack recurrence was minimal. Again, the experimental and control sections showed no visible difference in appearance (Fig. 1).

B. Second-Year Construction (1993)

At Sites 3 and 4, evaluation was broadened by recording cracking and skid resistance both before and after chip-seal application. Both sites had alternating areas of the two mixes, and the SHRP rating tree was used to evaluate construction for both sites.

Figure 1. Pavement surface appearance at Site 2 just after sealing and after 2 years in service.

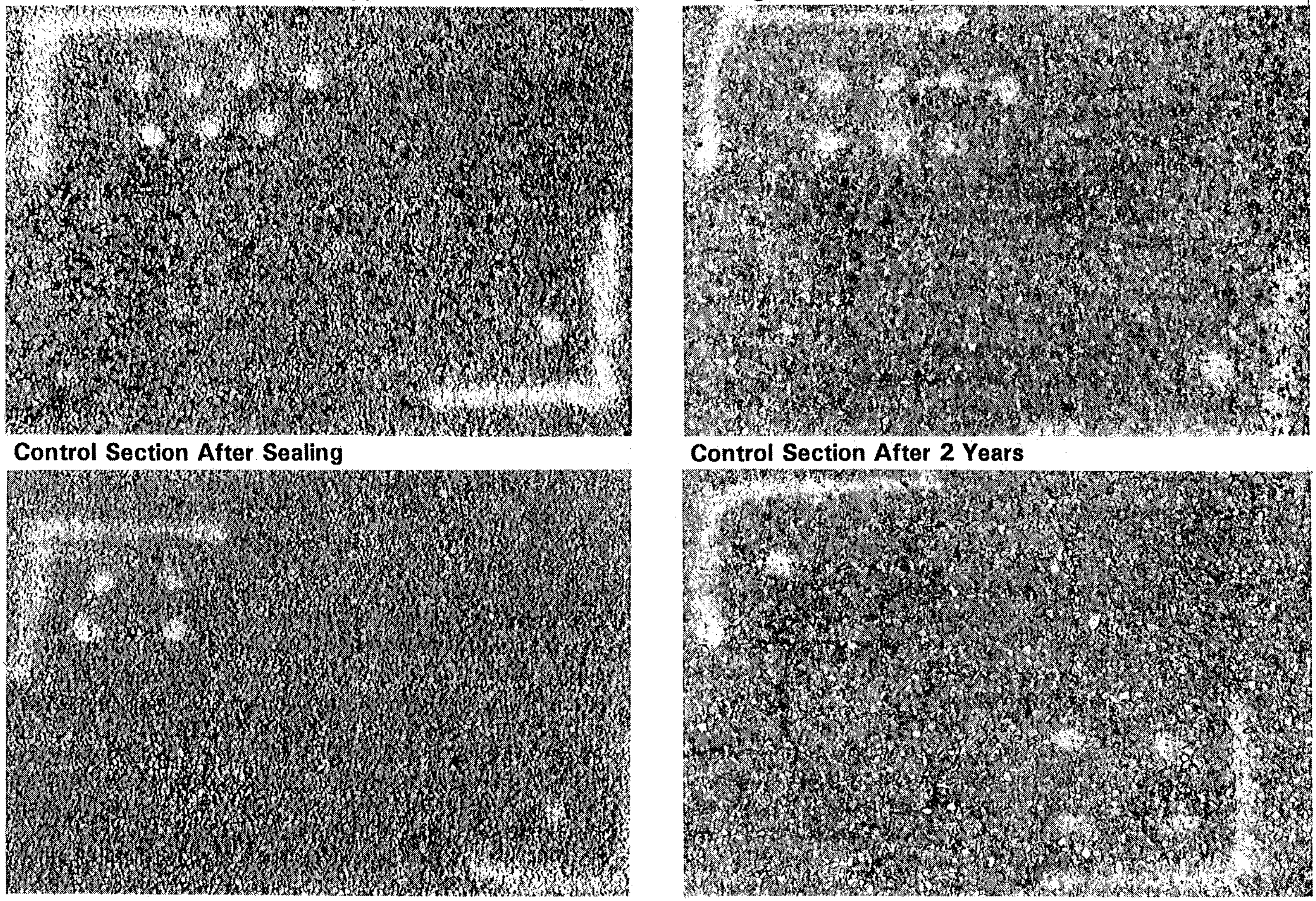


Figure 2. Configuration of Site 3 at the intersection of Rtes 248 and 248A.

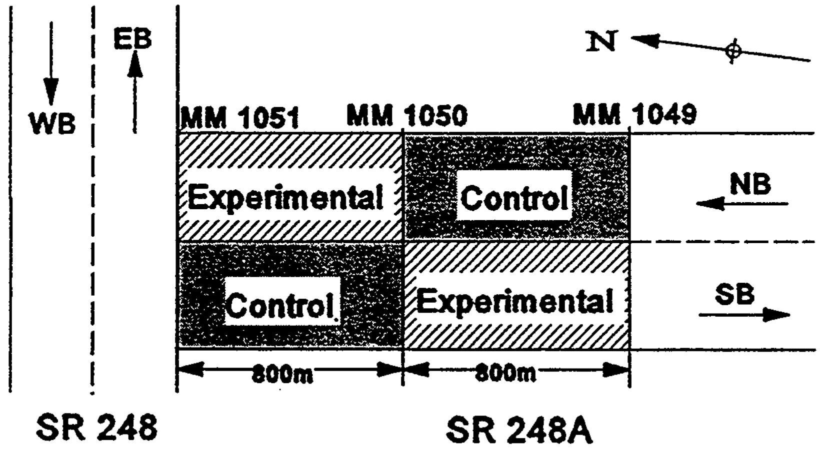


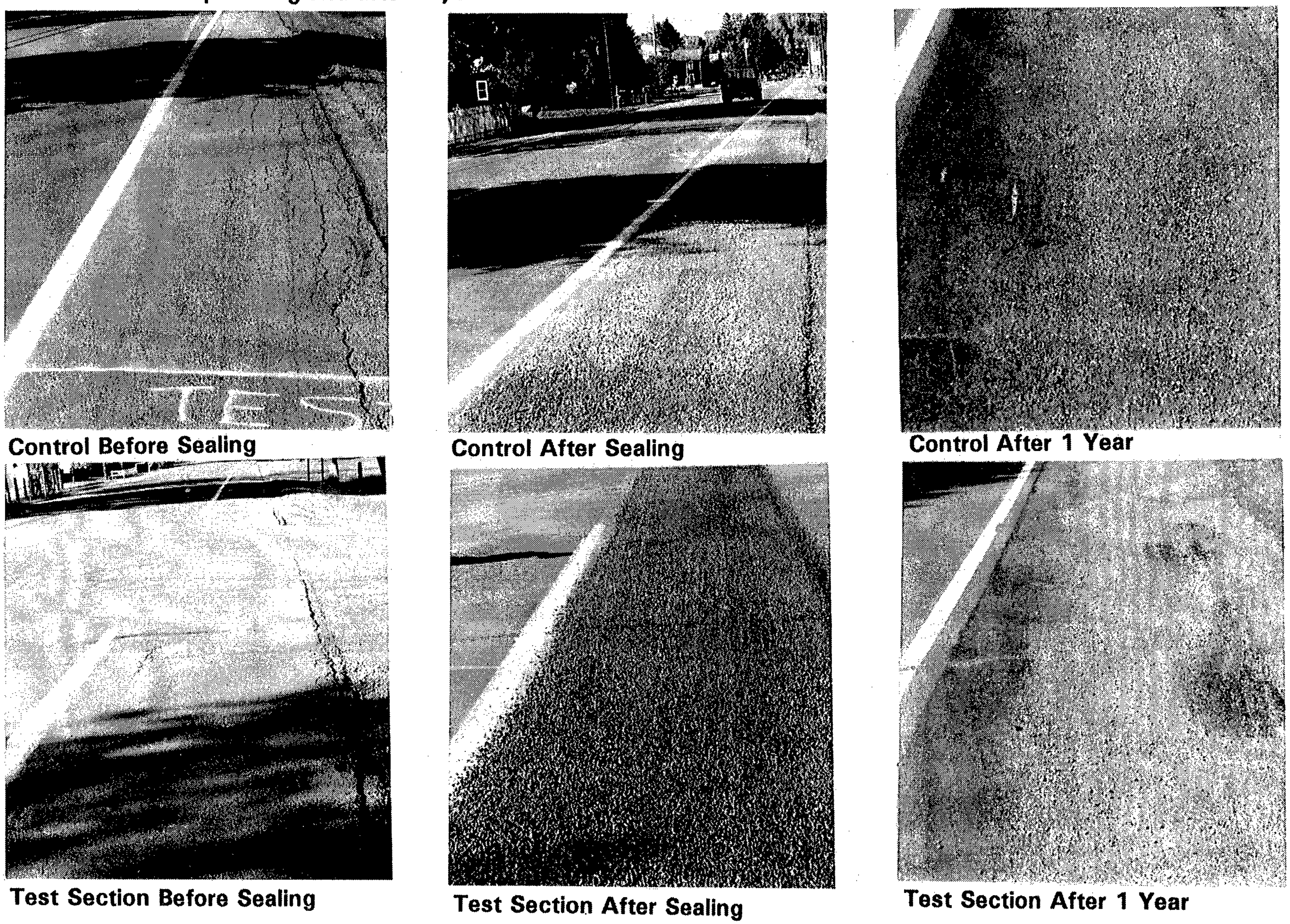
Table 3. Summary of Site 3 skid-resistance numbers (SNs) before and after sealing.

Mark Number	Area	Design	SN Before	SN After
1	1050-1051 SB	Test	55.5	59.6
2	1049-1050 SB	Control	56.7	60.3
5	1049-1050 NB	Test	59.8	59.5
6	1050-1051 NB	Control	58.6	62.7

Site 3 had two-course chip sealing of the two-lane 1600 m roadway pavement and its 1.3 m shoulders, in a checkerboard pattern (Fig. 2). The 1ST aggregate was tested for ALD using the slotted-sieve test at the Materials Bureau lab in Albany, and the experimental sections were then designed by the expert system. The control sections were designed by an engineer from the chip-seal contractor (A. L. Blades, Inc.), who said that he used test patches and previous experience in his calculations (Table 2). Construction was evaluated (using the SHRP rating tree) as 0.90 out of a possible 1.00 (Appendix A), indicating that the crew had followed good construction practices. During early service, aggregate was retained and the chip seal appeared to be in good condition. All cracks recorded before placement had been filled, and skid-resistance testing (Table 3) showed that average skid number (SN) had increased from 57.65 to 60.52.

Site 4 was a single-course chip seal along 800 m on one 1.5 m wide shoulder beside a two-lane pavement. ALD of the 1ST aggregate was determined using the slotted-sieve test, and the mix was designed using the expert system. The control mix was designed by the Cortland County NYSDOT Resident Engineer, who said that he used past experience and visual inspection to create his mix design. Initially, both the control and experimental sections looked good. SHRP rating tree evaluation of construction resulted in a 0.84 rating out of a possible 1.00. Crack mapping showed that all those identified before placement had been sealed. Skid resistance was not tested because the NYSDOT skid truck could not be used on shoulders.

Figure 3. Pavement surface appearance of the Site 4 control section (top) and test section (bottom), just before and after chip sealing and after 1 year in service.



Within 1 year, Site 3 showed 60- to 70-percent loss of aggregate in the wheelpaths. Although aggregate for this project was supplied by a Department-approved source, the project engineer noted during placement that many particles could be pulverized by hand. These easily crushed particles may perhaps have been the major contributor to aggregate loss in the wheelpaths. Since the work had been rated 0.90 on the rating tree, improper construction was ruled out. A 5-percent crack recurrence had occurred by August 1994, with no visible difference between experimental and control areas. The Allegeny County Resident Engineer considered performance of both designs to have been inadequate.

Inspection of Site 4 (shoulder only) in August 1994 almost a year after placement showed a slight loss of aggregate near the roadway, but this was considered normal snowplow damage (Fig. 3). Crack mapping indicated that 92 percent of the old cracks remained filled. Once again, performance of the experimental and control sections did not differ significantly. The Cortland County Resident Engineer remarked that both sections were performing adequately.

To summarize, the rational chip-seal design resulted in performance suitable for shoulders. On all shoulders tested, especially at Site 4, it was equivalent to the control areas, and was judged likely to have a service live of 7 years or more. This makes chip seals cost-effective and competitive with other methods, such as overlays and microsurfacing, for shoulders eligible for surface treatment. On mainline pavement sections, chip seals designed by the expert system showed no difference from those designed by conventional practice and experience, although both design practices still may result in failure. The fact that when designs did fail, both sections looked alike and performed similarly suggests that either the decision to use a chip seal was incorrect for the road's traffic type and volume, or for its structural condition. Their performance also suggest that seals are sensitive to the quality of the aggregates used.

C. Expert System Creation and Access

After the test sites were placed, an expert system was created using the design method described in Appendix C, using C language and a HI-SCREEN XL design system. Beta testing was performed by personnel of the Transportation Research and Development Bureau and the Maintenance Division. The expert system is essentially the same as obtained from the Victoria Country Roads Board in Australia, with these two exceptions:

1. The design uses an asphalt emulsion rather than a heated bituminous spray, and the program recommends the best emulsion for the type of stone.

2. The design decreases the amount of 2A stone for the top course of a two-course seal from 9.2 to 7.09 L/m^2 (loose), an adjustment resulting from experience at Sites 1 and 2.

This program is now available to interested users both within and outside the New York State Department of Transportation, who are advised that it is intended for initial guidance in design before placing chip seals, bearing in mind the precautions and limitations already stated in this report. It represents current state-of-the-art, and does not replace sound engineering judgment where field adjustments may be necessary. Neither the Federal Highway Administration nor the New York State Department of Transportation are responsible for performance of chip seals designed using this procedure.

For users outside NYSDOT, the chip-seal software is available via anonymous ftp. For a copy, follow these instructions from a computer with internet access that has ftp capability. User entries are bold and others are system reponse. (Note: these users must enter an e-mail address as password for anonymous ftp.)

~ (7) **ftp ftp.dot.state.ny.us**
Connected to punch.dot.state.ny.us.
220-Welcome to NY State Department of Transportation FTP server !
220-
220-Your activity on this host is logged. If you don't like this policy,
220-please disconnect now. Otherwise enjoy yourself!
220-
220-Please contact DOT help desk at (518)485-8111 with any problems.
220-
220-
220 punch FTP server (Version wu-2.4(1) Mon Oct 23 12:43:37 EDT 1995) ready.
Name (ftp.dot.state.ny.us:goveri): **anonymous**
331 Guest login ok, send your complete e-mail address as password.
Password:
230 Guest login ok, access restrictions apply.
ftp> **cd pub**
250 CWD command successful.
ftp> **cd chipseal**
250 CWD command successful.
ftp> **binary**
200 Type set to I.
ftp> **get seal.zip**
200 PORT command successful.
150 Opening BINARY mode data connection for seal.zip (81299 bytes).
226 Transfer complete.
81299 bytes received in 14.1 seconds (5.631 Kbytes/s)
local: seal.zip remote: seal.zip
ftp> **quit**
~ (8)

A zipped version of the program has now been downloaded to the user's computer. To use the program, it must be unzipped using pkunzip software. Users within NYSDOT can use Group Wise to e-mail a request for a copy of the zipped version of the program, addressing NTROXELL

III. CONCLUSIONS

At two of the four test sites, chip seals designed by the rational method were in good condition, and similar in appearance to those designed by engineers with many years of experience. At all four sites, performance of the rational mixes was similar to that of mixes designed by experience. In this respect, the rational design and expert system are a success, duplicating the design and performance achieved by experienced engineers. No further adjustment to the program will be necessary.

Initial performance of all designs was adequate. Had they failed, the 1ST aggregate would have loosened and damaged vehicle paint and windshields. Since that did not happen, selection of emulsions for all designs was correct, and application rate was sufficient -- another success for the expert system.

Long-term performance of shoulder areas of all designs was adequate, meaning that the expert system was successful for chip seals on shoulders. Engineers reluctant to use this treatment because of little experience in chip seal design may comfortably use the expert system for guidance in designing these shoulder surface treatments. This may be the most significant benefit of the expert system, because chip seals are much cheaper than hot mix and thus offer potential savings.

Finally, initial chip-seal performance at all four sites was satisfactory, indicating that ALD is important in determining the proper asphalt emulsion application rate. The slotted-sieve test (Appendix B) is a cost-effective, accurate method for determining ALD, and should be considered for adoption as a standard Department test procedure.

On the other hand, long-term performance of chip seals on pavement mainline areas remains marginal, especially under heavy truck traffic. Although a success at Site 2, aggregate loss occurred in wheelpaths at Sites 1 and 3 in sections designed both by past experience and the expert system. It thus is again recommended that chip seals not be used on a mainline traveled by heavy trucks (such as those carrying lumber or stone) or where AADT is over 1000. Other solutions may be studied, such as use of polymer-enhanced emulsions or heated bituminous sprays, but these were beyond the scope of this investigation.

The SHRP rating tree was useful for evaluating both construction techniques and equipment. It scored placement quality and warned the engineer of possible shortcomings. Its use is recommended as a guidance tool when placing a chip seal.

ACKNOWLEDGMENTS

The authors thank the following persons for their help in this study: Region 6 Maintenance Engineer Fred F. Ames, Jr., Chemung West-Steuben East Resident Engineer C. Jeff Carris, Cortland/Tompkins Resident Engineer Gordon Reimels, Gary Faux of Suite-Kote Corporation, and Dr. Deniz Sandhu of the Transportation Research and Development Bureau. For their assistance in preparing this report, the authors also especially thank Edward J. Denehy of the Transportation Maintenance Division, and Robert A. Valenti of the Transportation Research and Development Bureau.

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3. Bullard, D.J., Smith, R.E., and Freeman, T.J. Development of a Procedure to Rate the Application of Pavement Maintenance Treatments. Report SHRP-M/FR-92-102 (subsequently renumbered SHRP-H-322), Texas Transportation Institute, Texas A&M University, for the Strategic Highway Research Program, National Research Council, 1992.

4. Standard Specifications, New York State Department of Transportation, January 2, 1990, p. 4-26.

5. A Basic Asphalt Emulsion Manual. Manual Series Publication MS-19, Asphalt Institute, 1979, pp. 223-29.

6. Ibid, p. 14.

APPENDIX A. SHRP RATING TREES FOR 1993 TEST SITES

As published by SHRP (3), the rating tree was used to rate construction techniques for chip seals. It also gives guidance to engineers in identifying specific weak points in construction. Although the tree alone cannot guarantee service life of a chip seal, it can provide valuable guidance concerning the effects of construction on service life.

Procedure

The rating tree asks what conditions, procedures, and equipment were involved in construction. Each item is given an individual rating from 1.0 to 0.0, which is then multiplied by a weight between 1.0 and 0.0. This weighted rating is added to other weighted ratings to create a total score for each of five program areas: environment, surface condition, equipment, construction, and curing/traffic control. These program area ratings are then weighted and totaled for an overall score for the chip seal's construction. Perfect construction would earn a 1.0 for each selection, and after being weighted the items should total 1.0. If the total is less than 1.0, the engineer can follow the pathways back to find the most significant weaknesses. For the 1993 test sites, pages from the SHRP manual were photocopied and items were circled. The weighting and adding were done directly on the tree for the final rating. Although calculations were made to three decimal places, only two places can be considered significant.

Test Site 3

The next eight pages document the rating tree for construction at Site 3. The overall rating was 0.90, which is considered excellent, suggesting that construction operations would not detrimentally affect service life. Tracing back through the tree, one may see than some weak points included the short time allowed for the coat to cure between rolling and opening to traffic, and placing the seal after August 31.

Test Site 4

The last eight pages (from p. 28) document the rating tree for seal placed on the shoulder at Site 4. The overall rating was good, but needing improvement. It is possible but unlikely that chip seal service life might be affected. Some weak points included lateness in the construction season, low temperature during curing, and lack of full traffic control during placement.

SITE 3 RATING TREE IN 15 STEPS (Fig. 1 omitted)

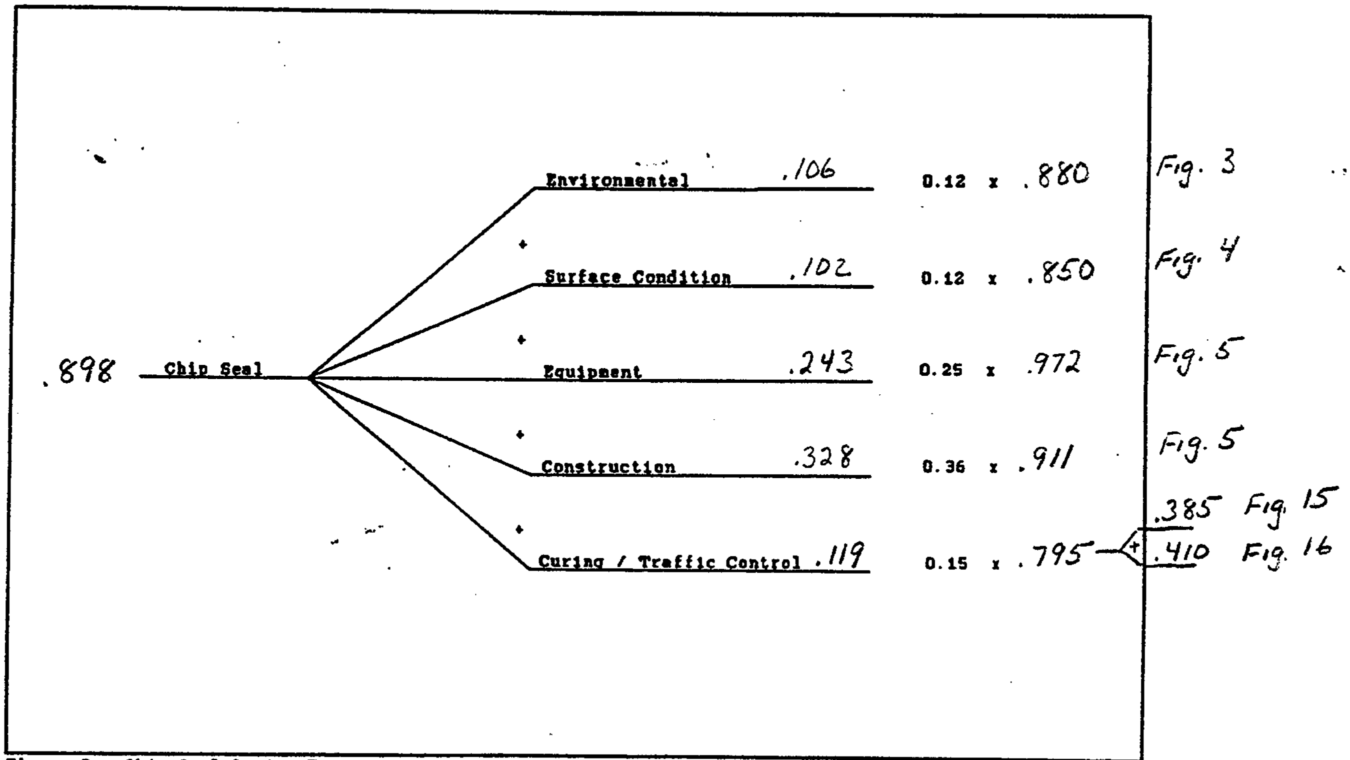


Figure 2. Chip Seal Rating Tree Main Attribute Branches

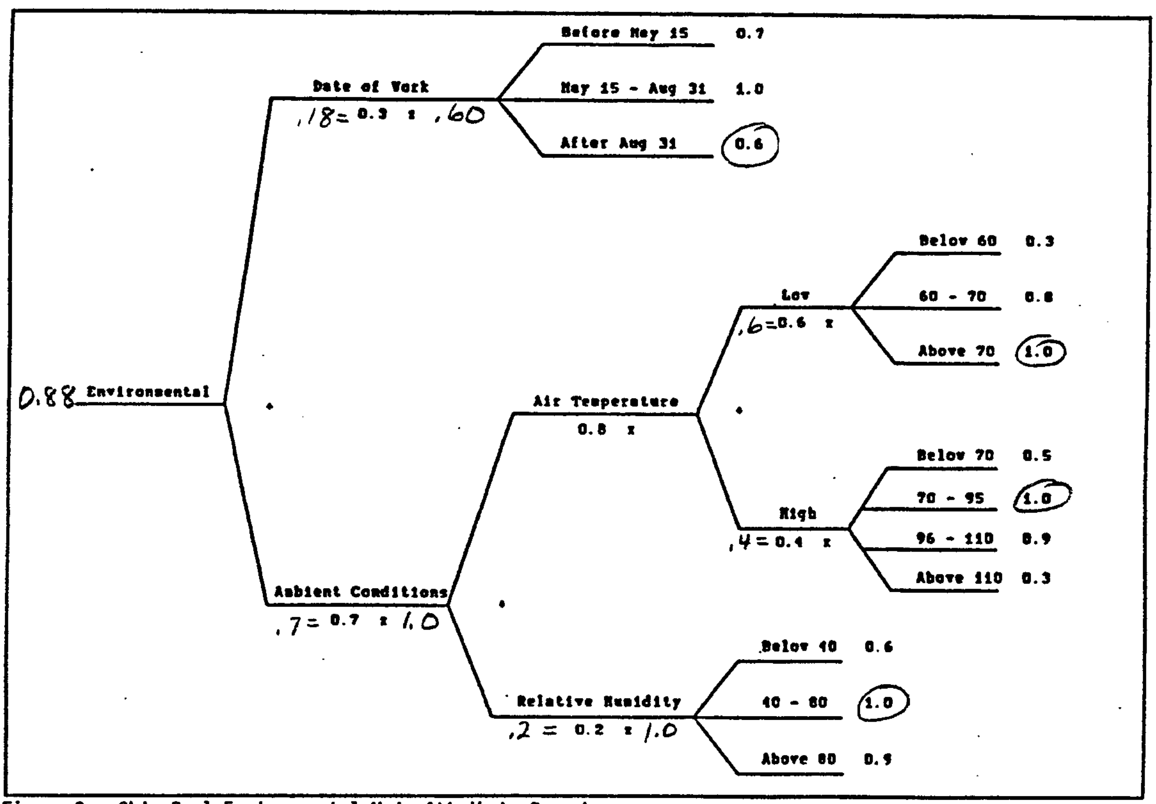


Figure 3. Chip Seal Environmental Main Attribute Branch

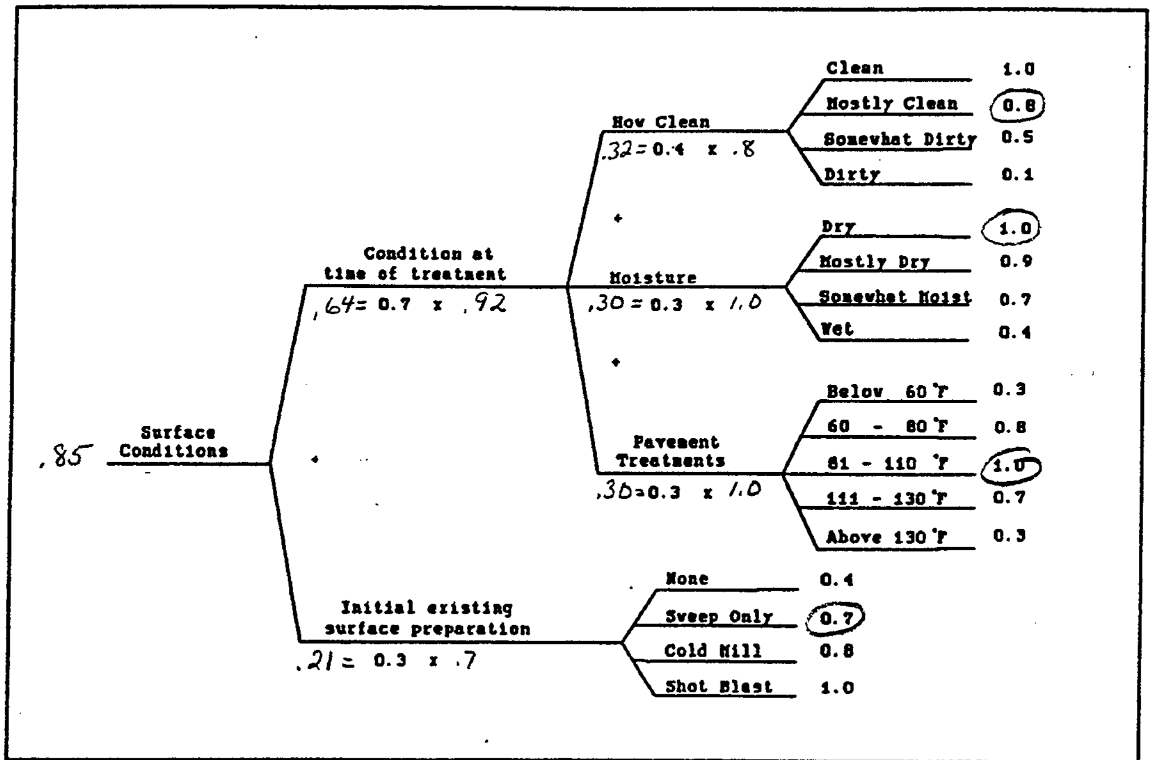


Figure 4. Chip Seal Surface Conditions Main Attribute Branch

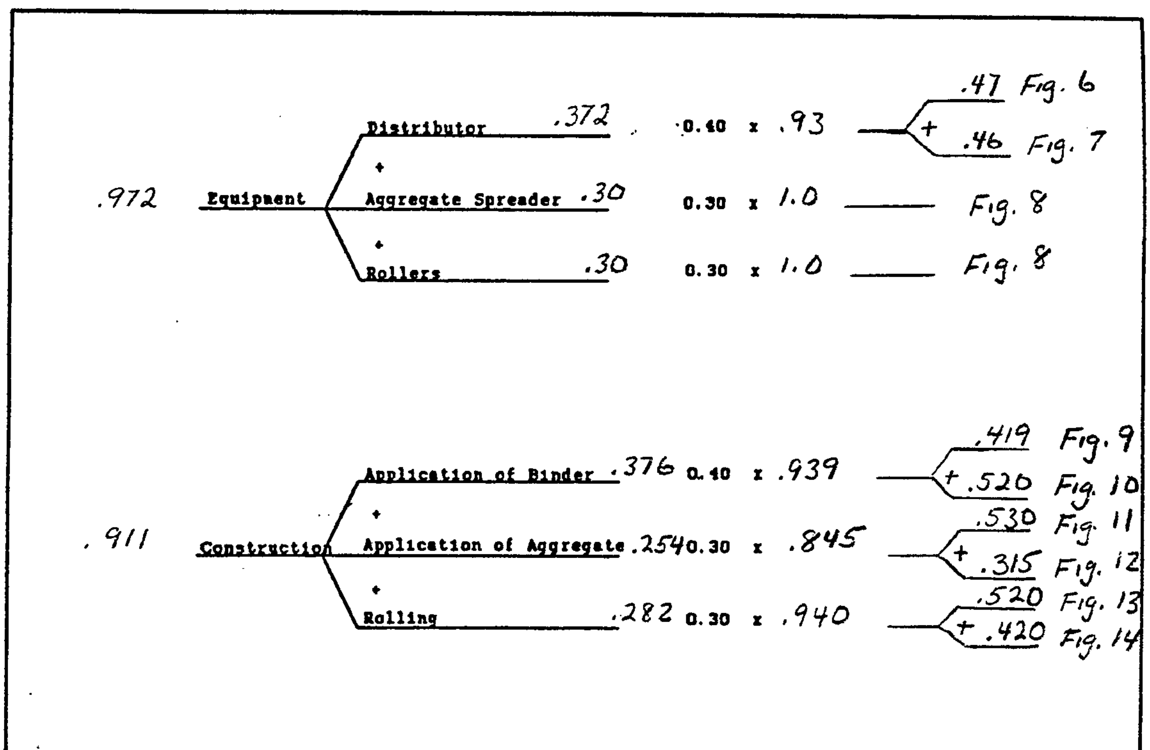


Figure 5. Chip Seal Equipment and Construction Main Attribute Branches

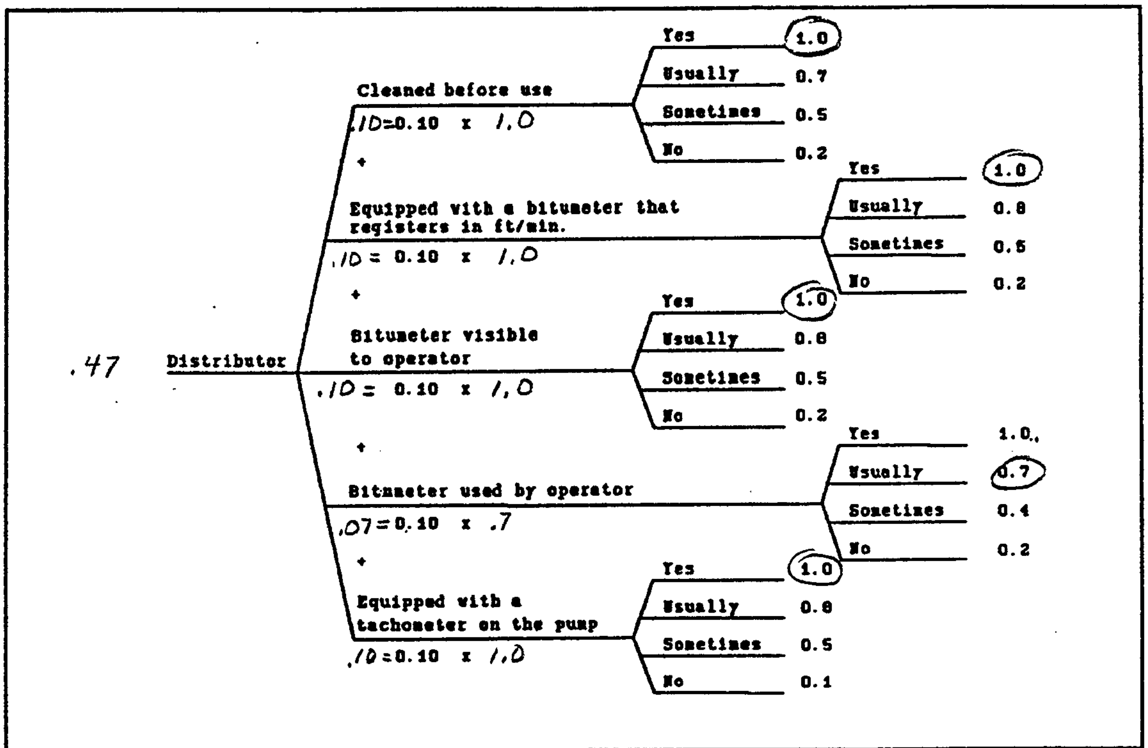


Figure 6. Chip Seal Distributor Attribute Branch (part 1 of 2)

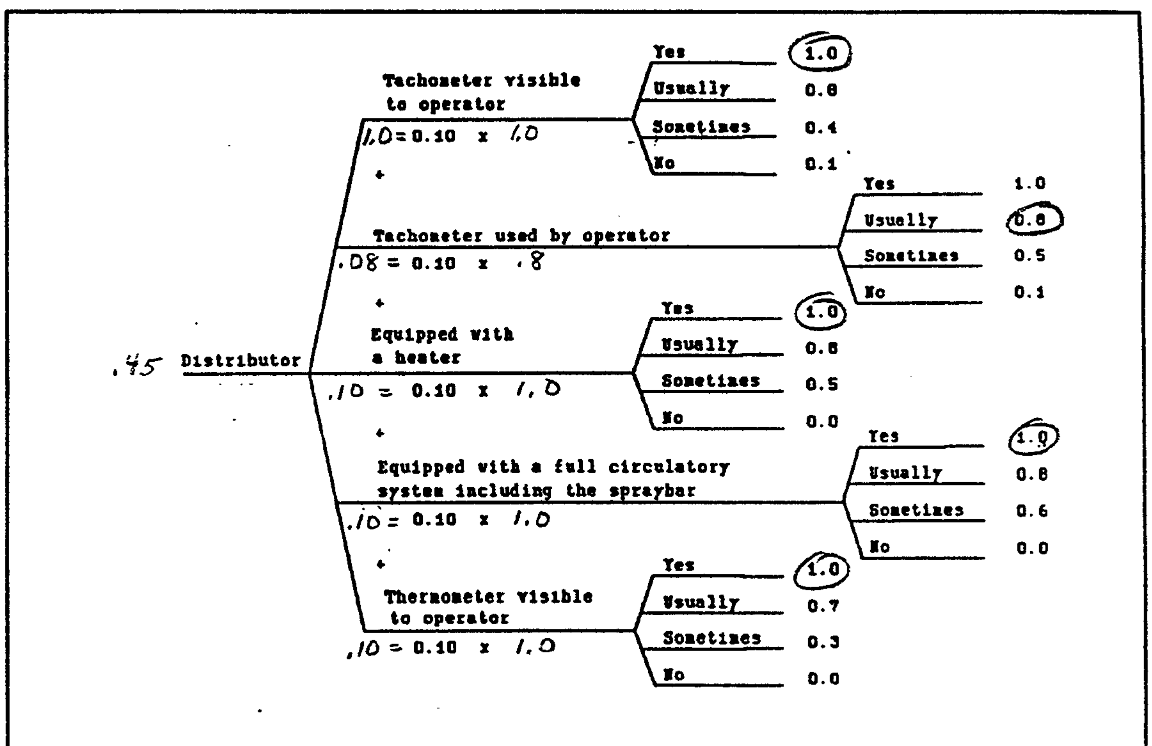


Figure 7. Chip Seal Distributor Attribute Branch (part 2 of 2)

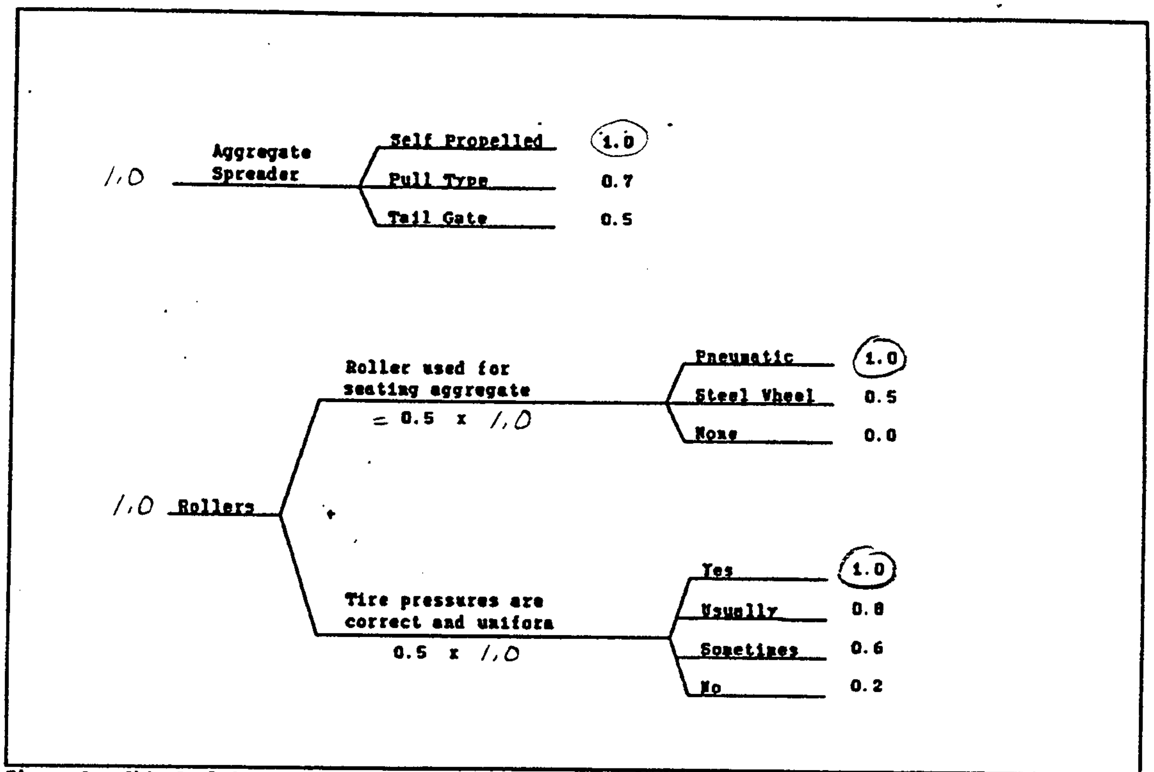


Figure 8. Chip Seal Aggregate Spreader and Roller Attribute Branches

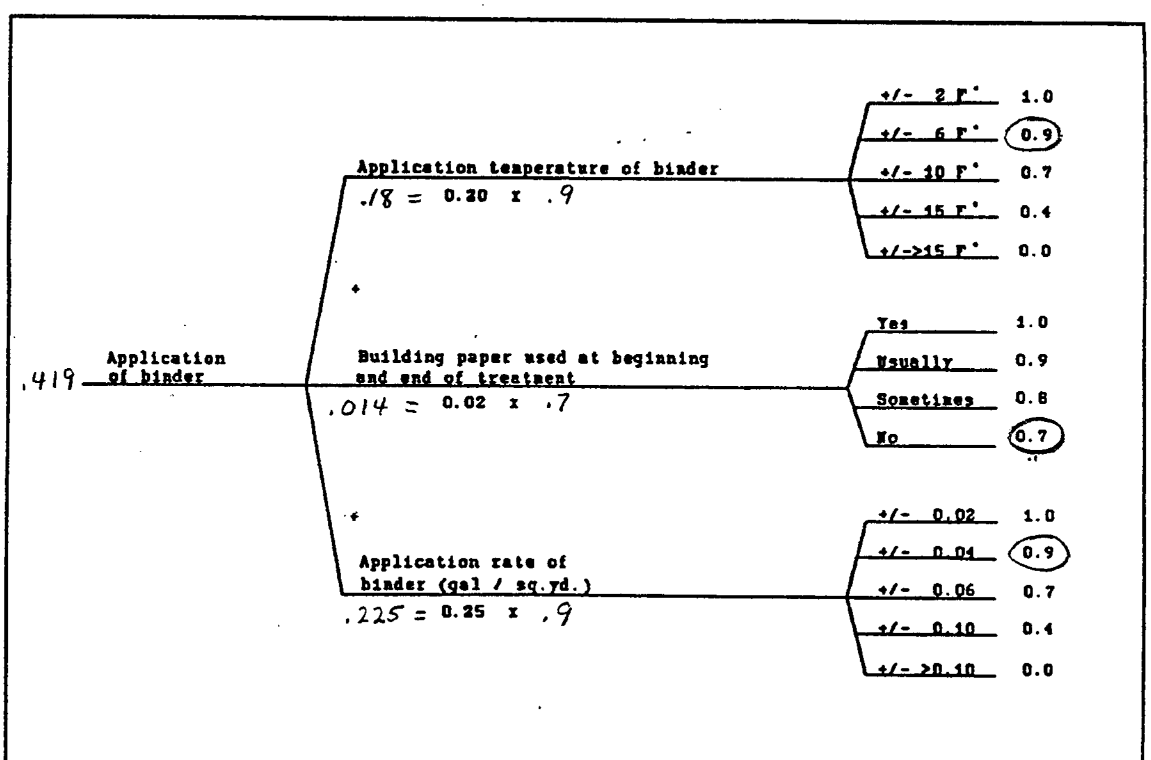


Figure 9. Chip Seal Application of Binder Attribute Branch (part 1 of 2)

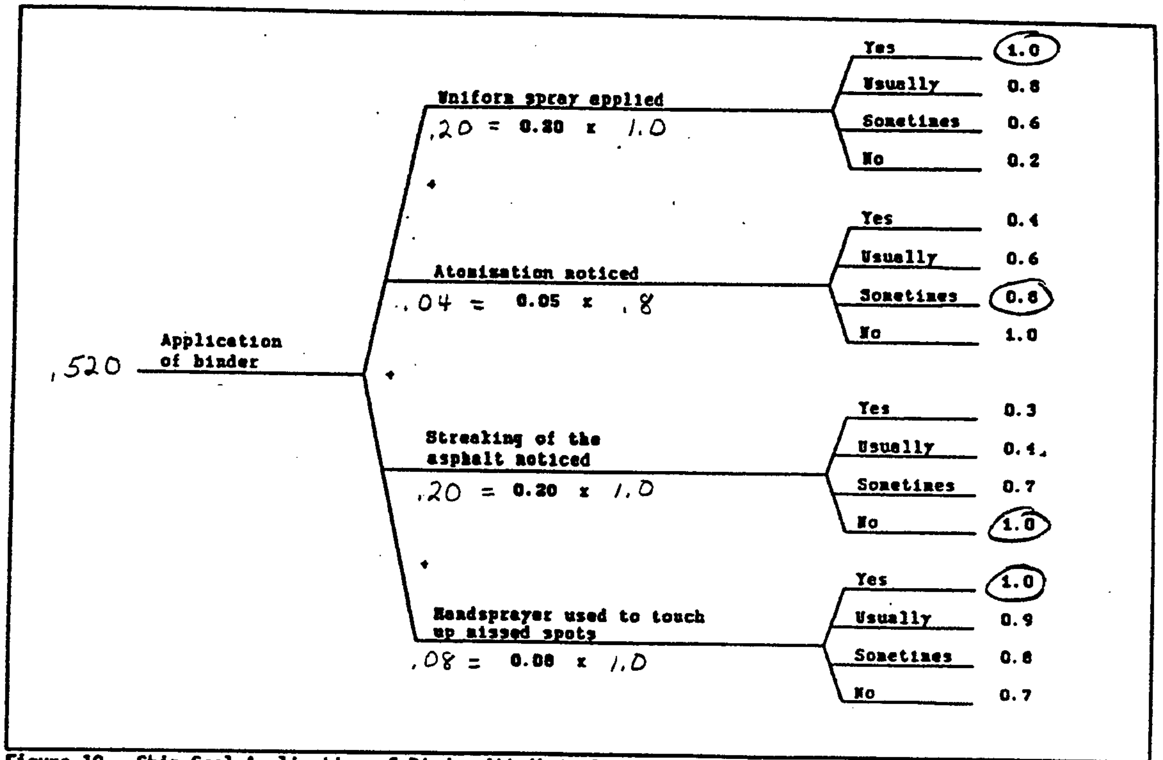


Figure 10. Chip Seal Application of Binder Attribute Branch (part 2 of 2)

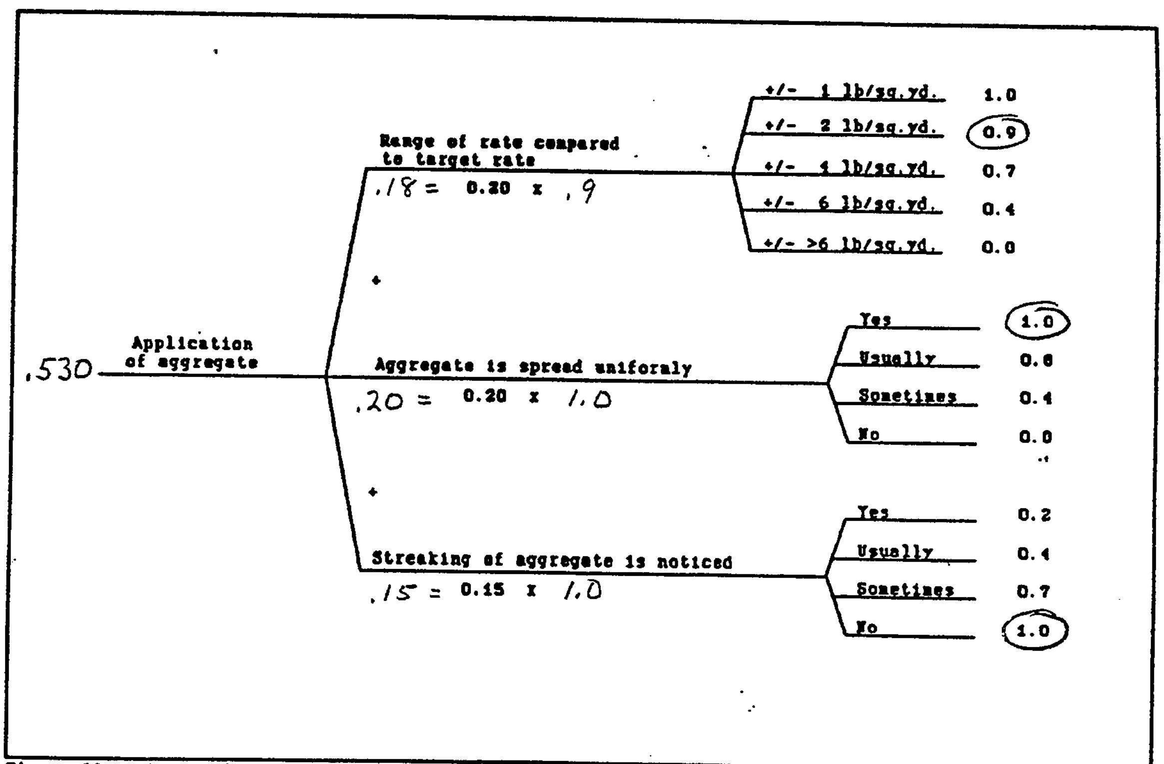


Figure 11. Chip Seal Application of Aggregate Attribute Branch (part 1 of 2)

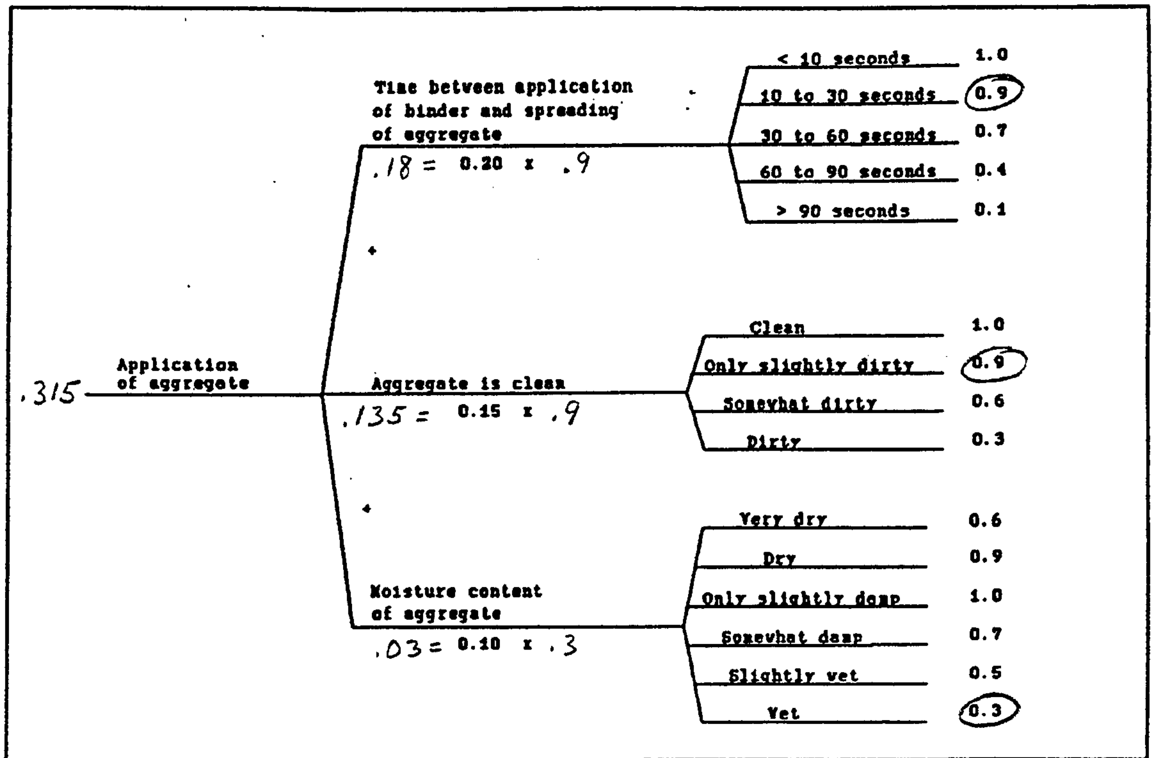


Figure 12. Chip Seal Application of Aggregate Attribute Branch (part 2 of 2)

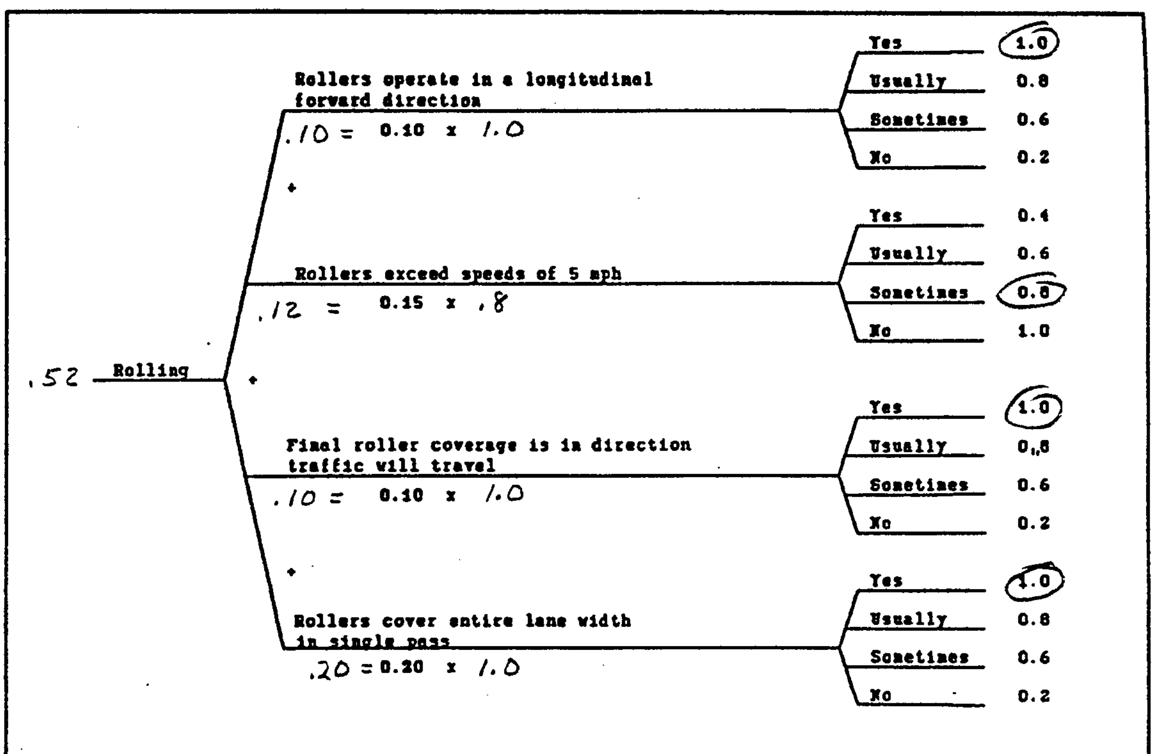


Figure 13. Chip Seal Rolling Attribute Branch (part 1 of 2)

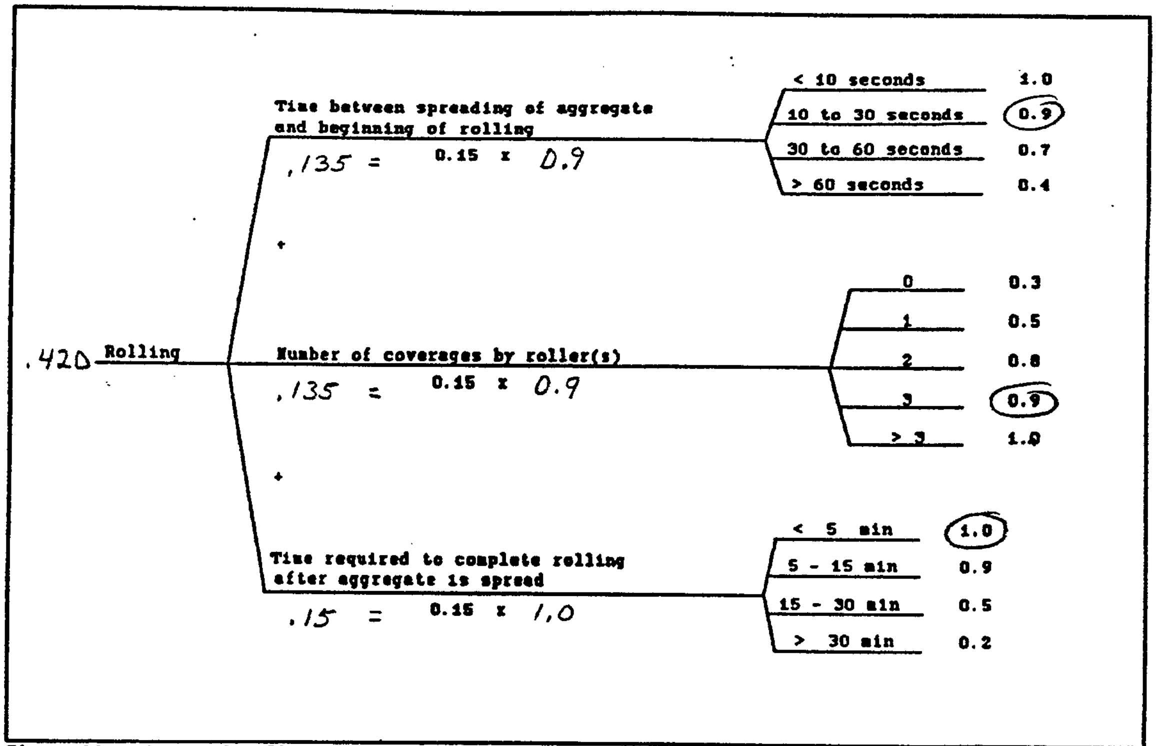


Figure 14. Chip Seal Rolling Attribute Branch (part 2 of 2)

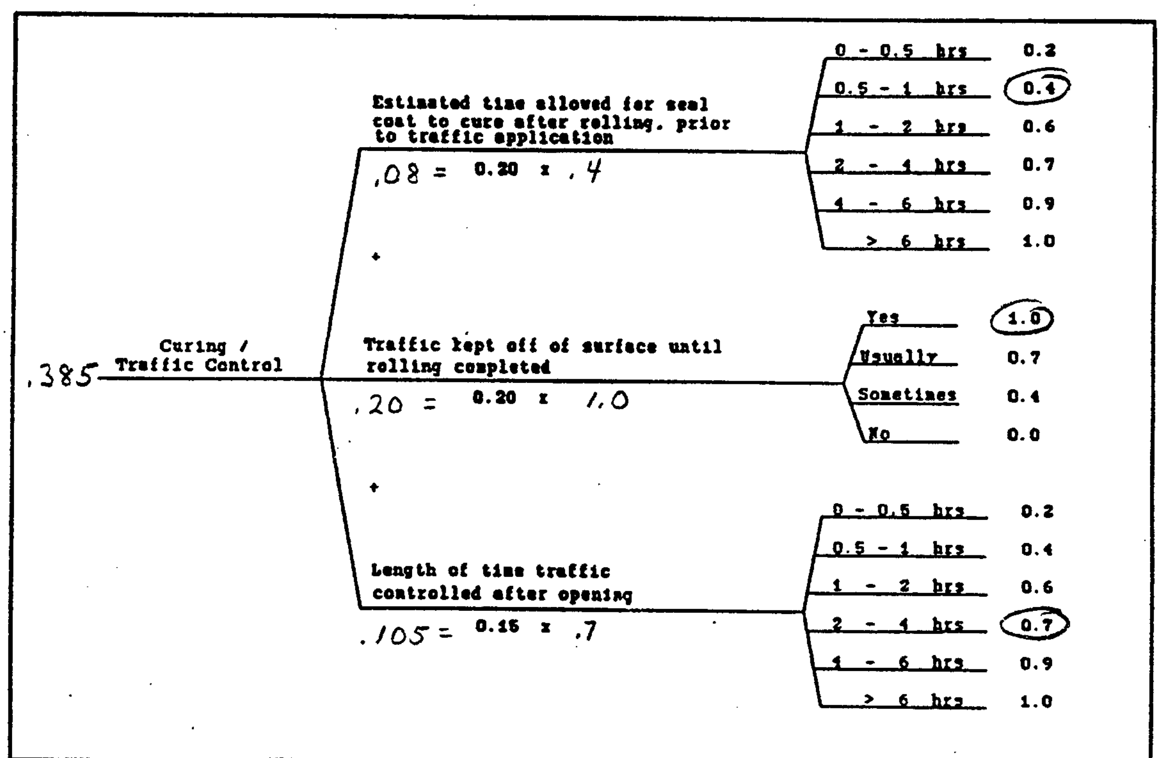


Figure 15. Chip Seal Curing / Traffic Control Main Attribute Branch (part 1 of 2)

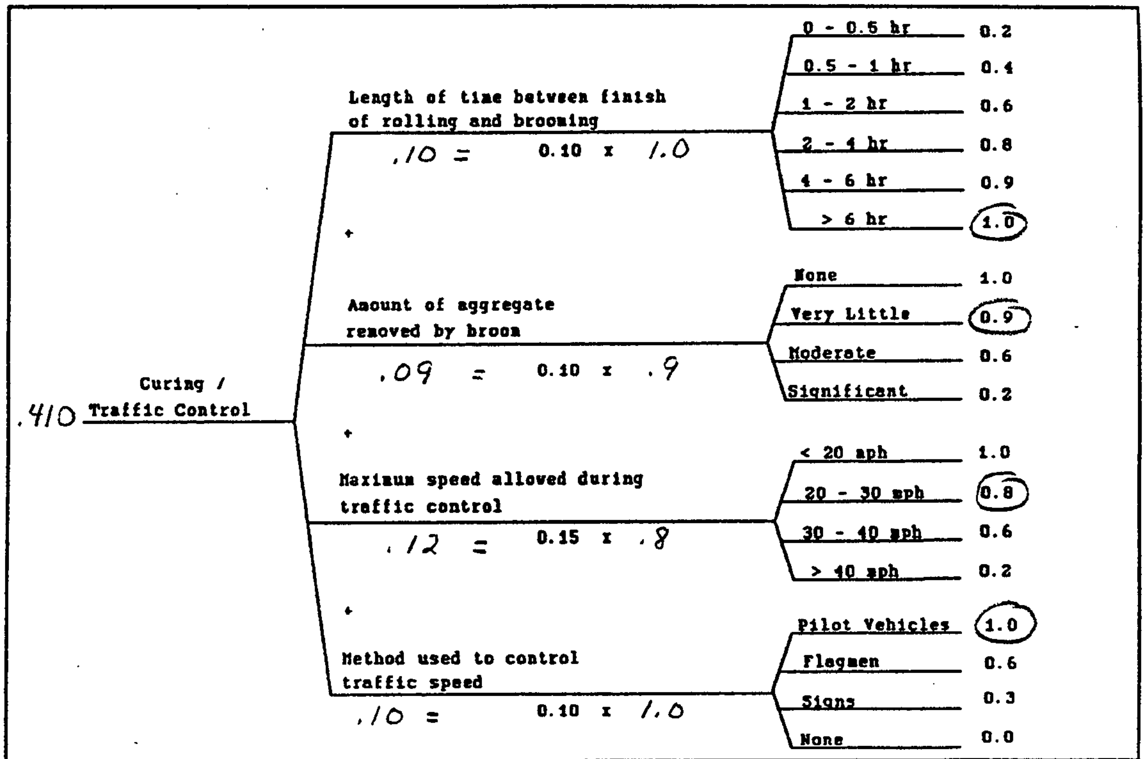


Figure 16. Chip Seal Curing / Traffic Control Main Attribute Branch (part 2 of 2)

SITE 4 RATING TREE IN 15 STEPS (Fig. 1 omitted)

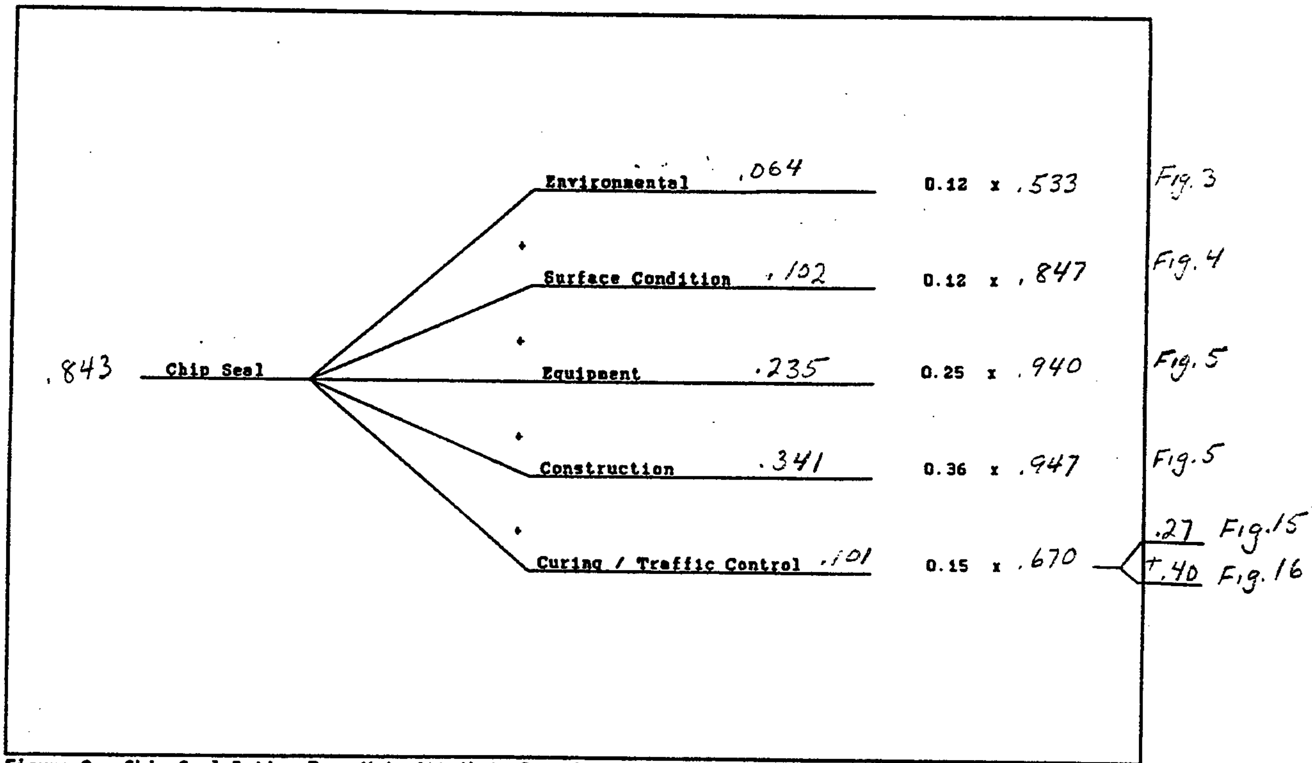


Figure 2. Chip Seal Rating Tree Main Attribute Branches

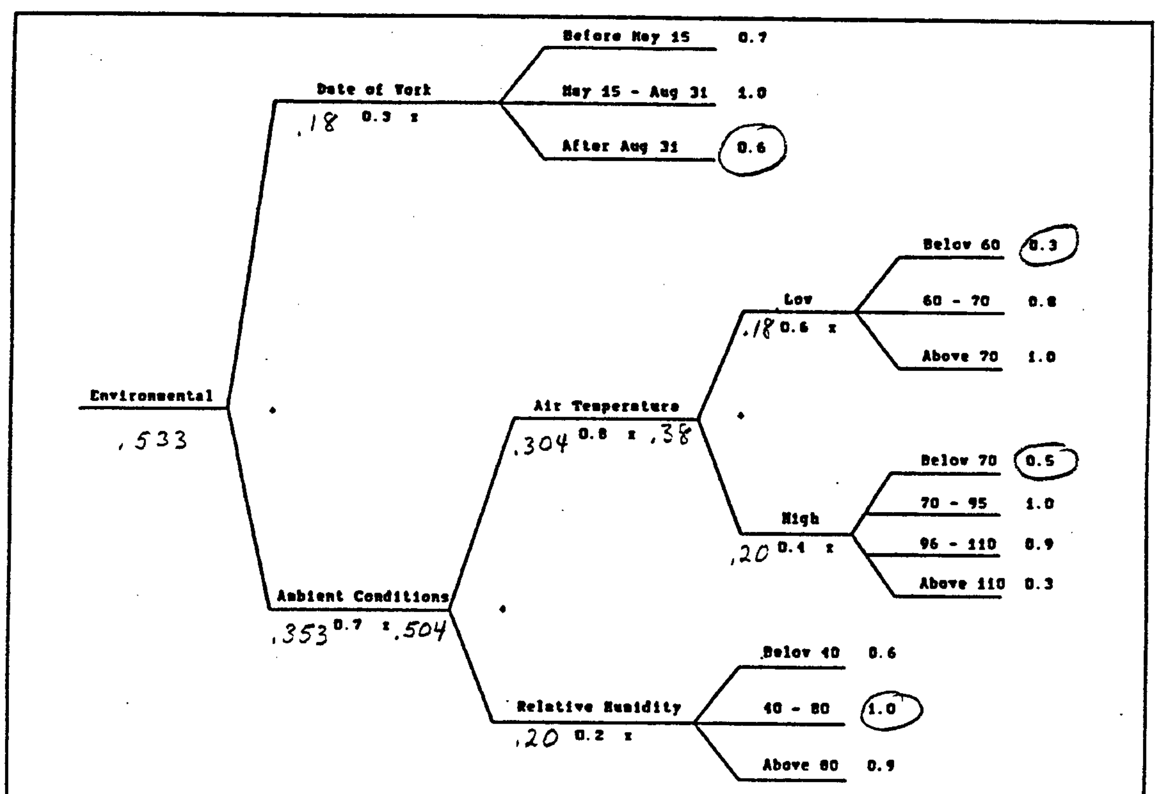


Figure 3. Chip Seal Environmental Main Attribute Branch

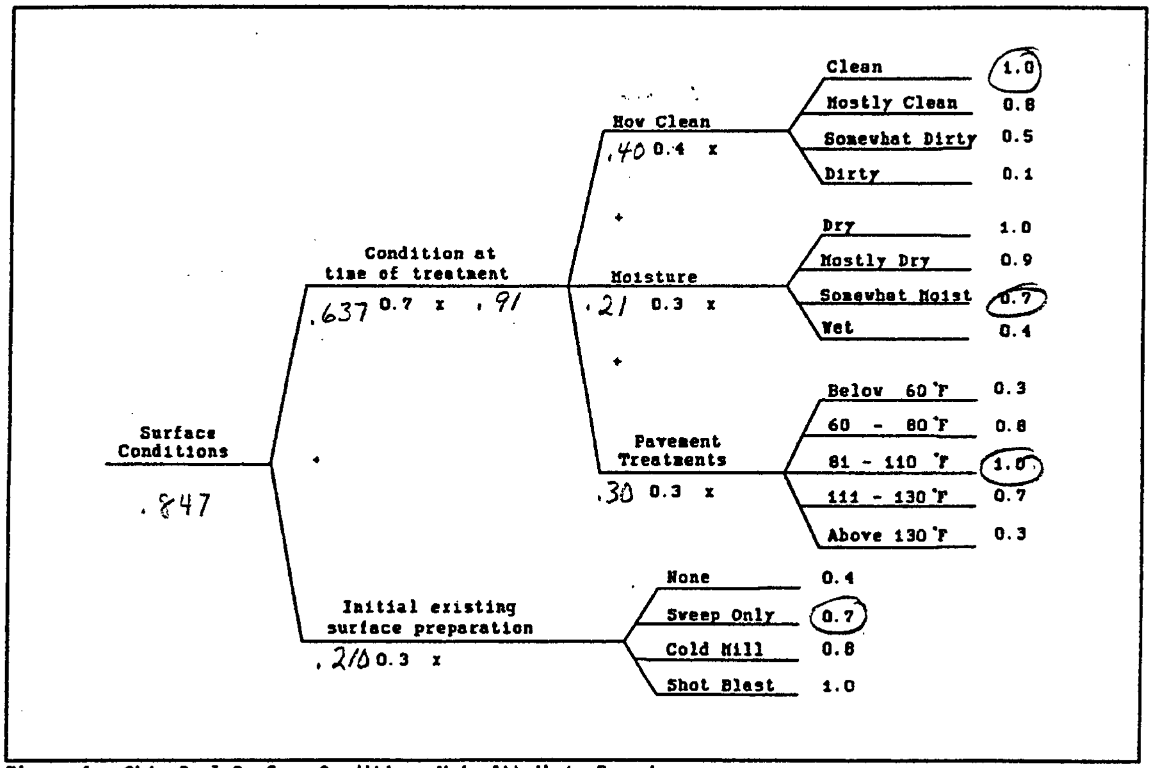


Figure 4. Chip Seal Surface Conditions Main Attribute Branch

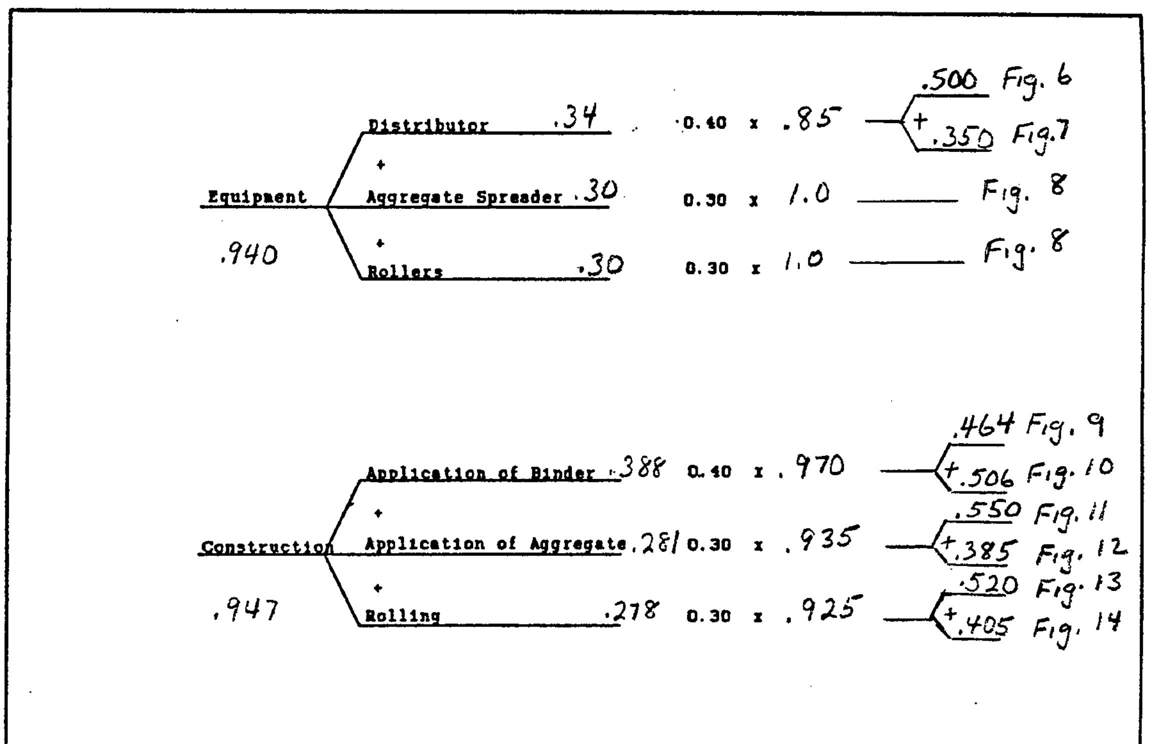


Figure 5. Chip Seal Equipment and Construction Main Attribute Branches

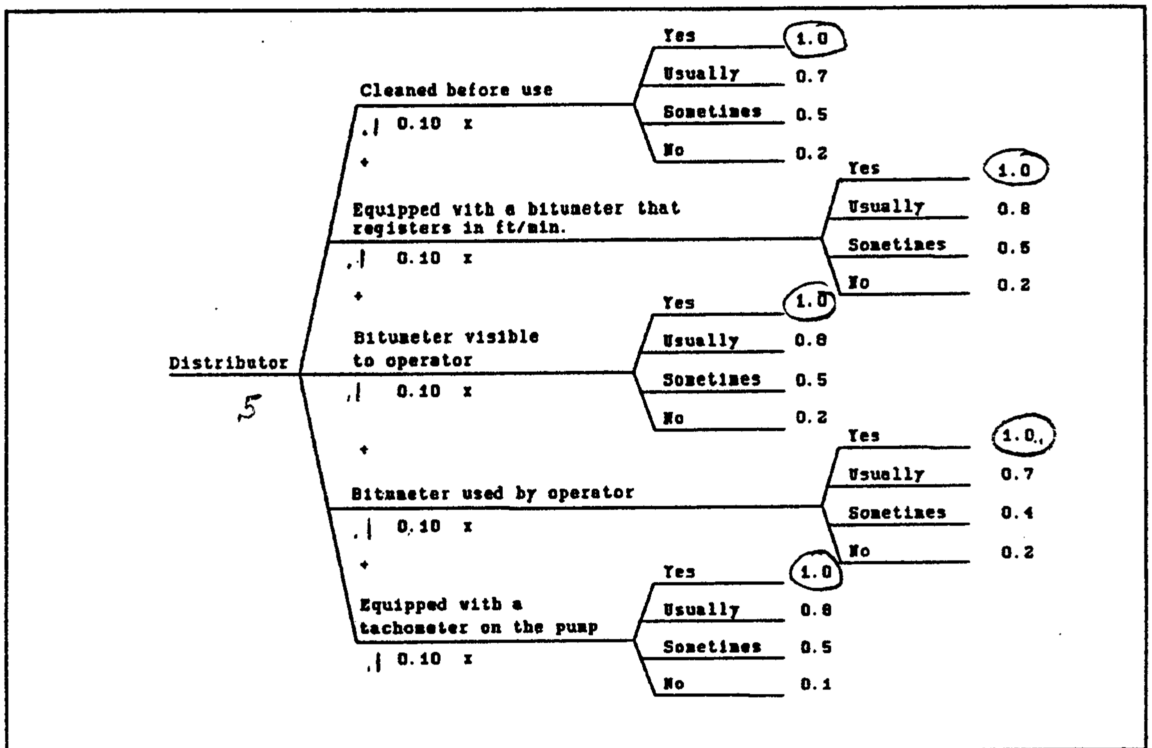


Figure 6. Chip Seal Distributor Attribute Branch (part 1 of 2)

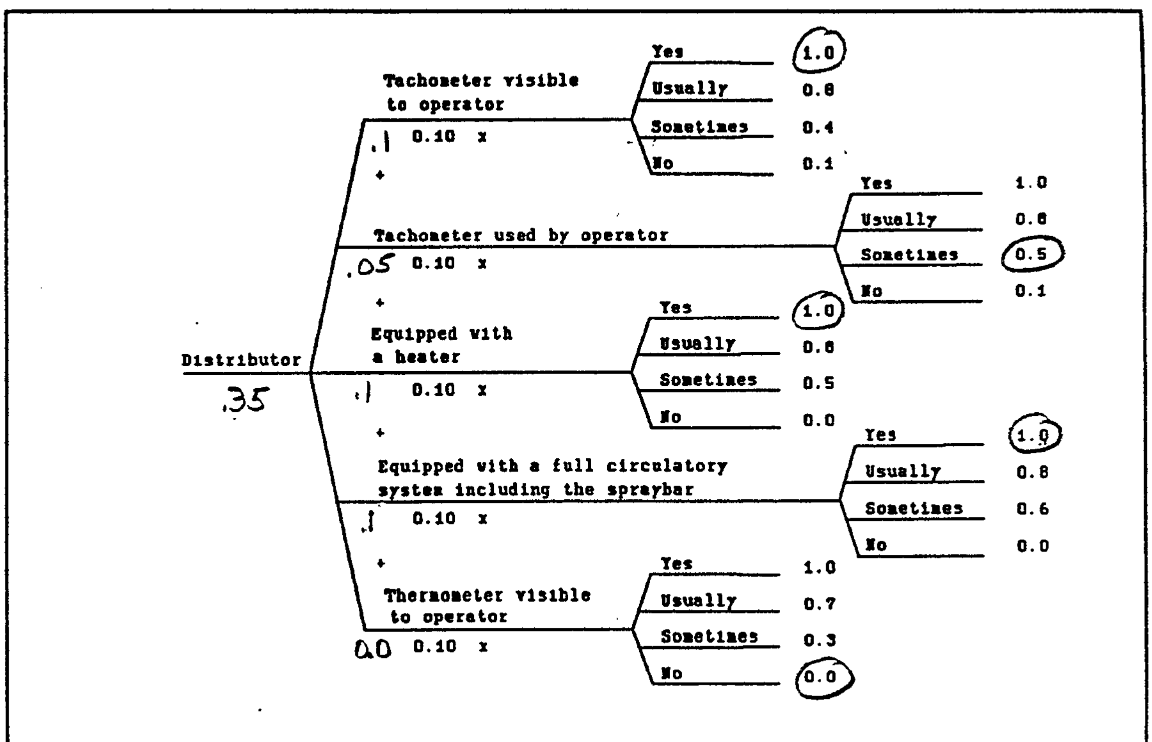


Figure 7. Chip Seal Distributor Attribute Branch (part 2 of 2)

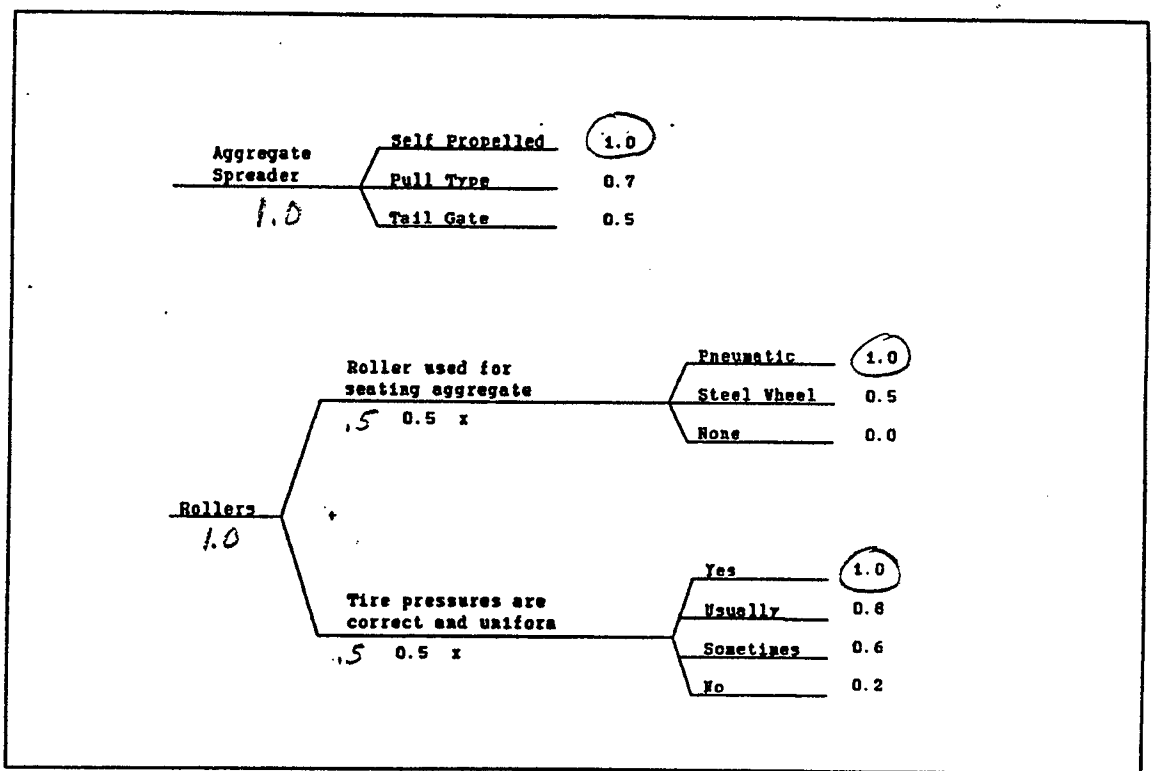


Figure 8. Chip Seal Aggregate Spreader and Roller Attribute Branches

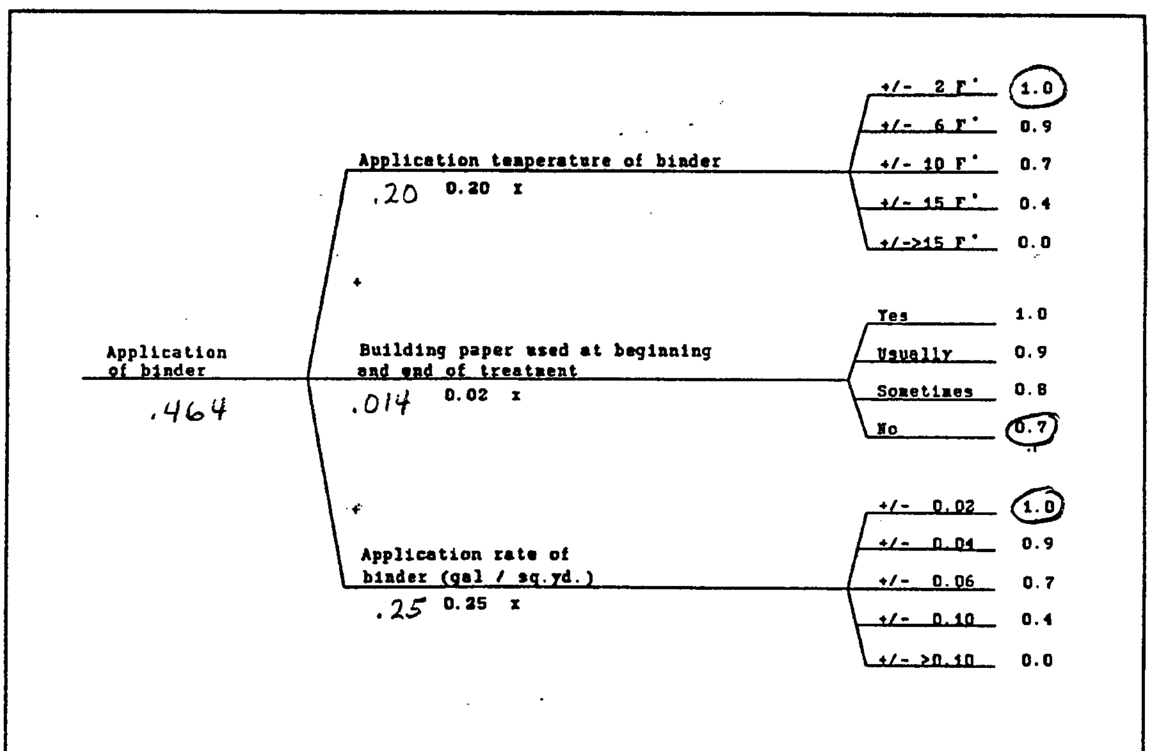


Figure 9. Chip Seal Application of Binder Attribute Branch (part 1 of 2)

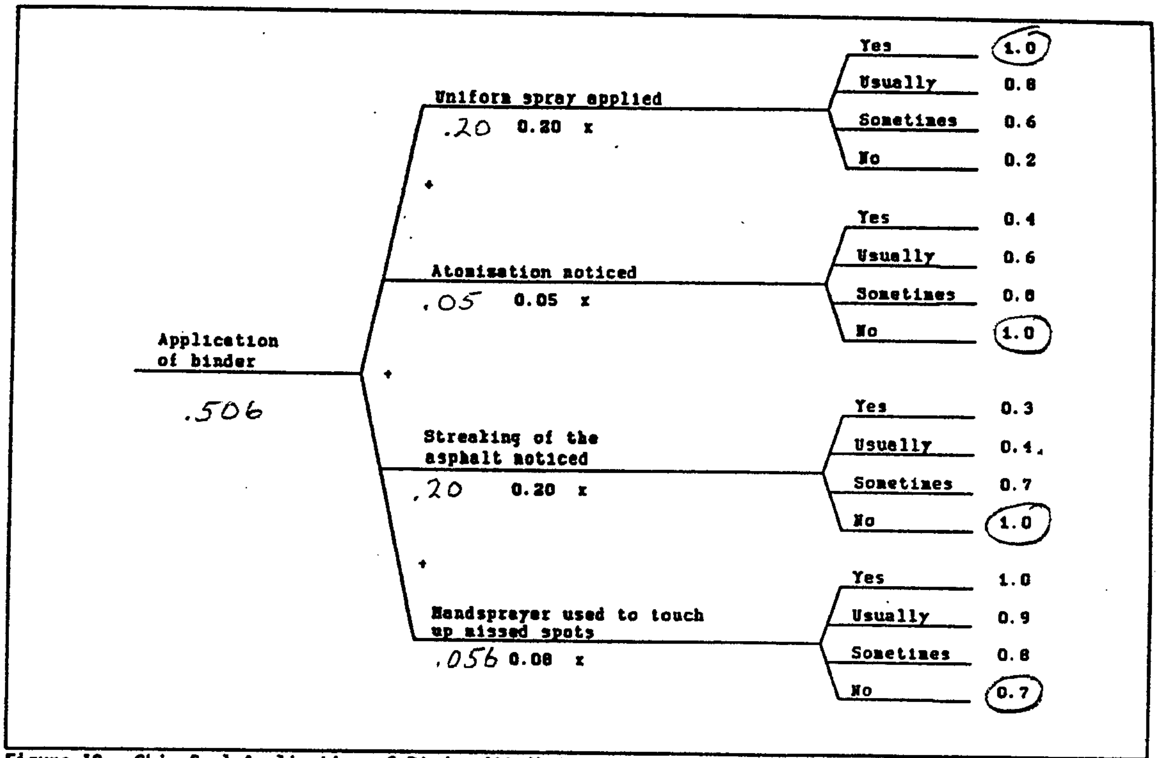


Figure 10. Chip Seal Application of Binder Attribute Branch (part 2 of 2)

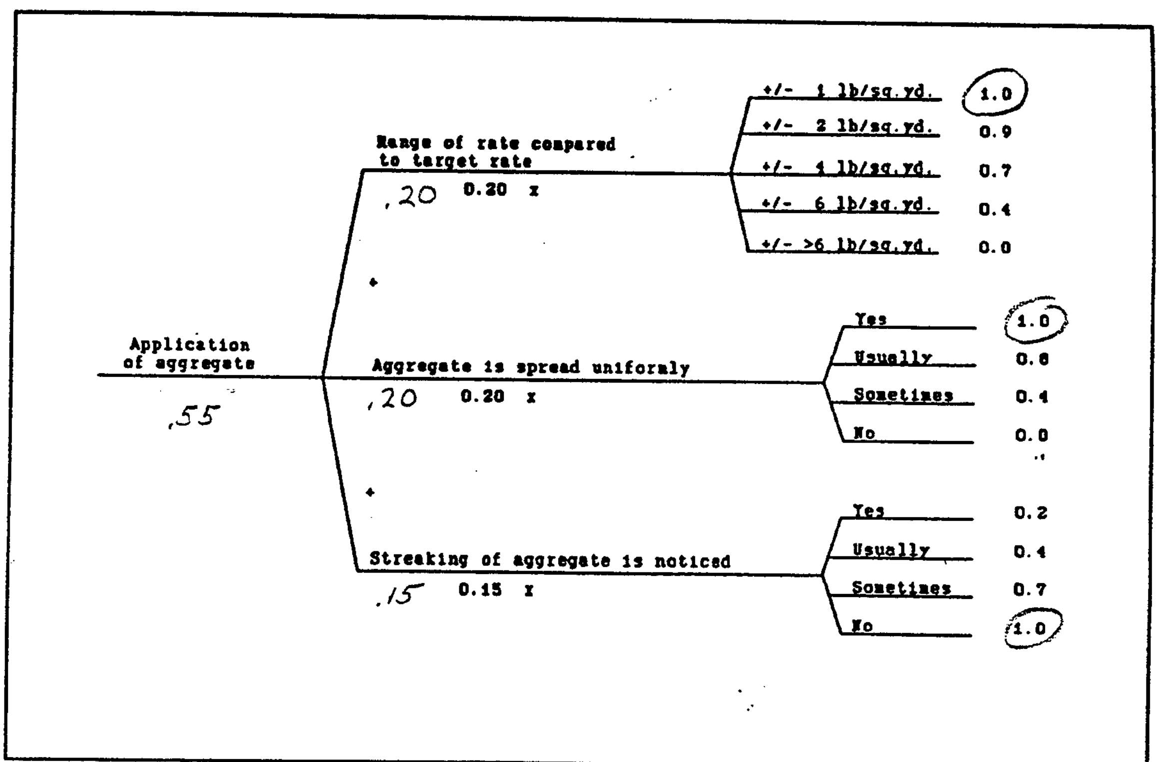


Figure 11. Chip Seal Application of Aggregate Attribute Branch (part 1 of 2)

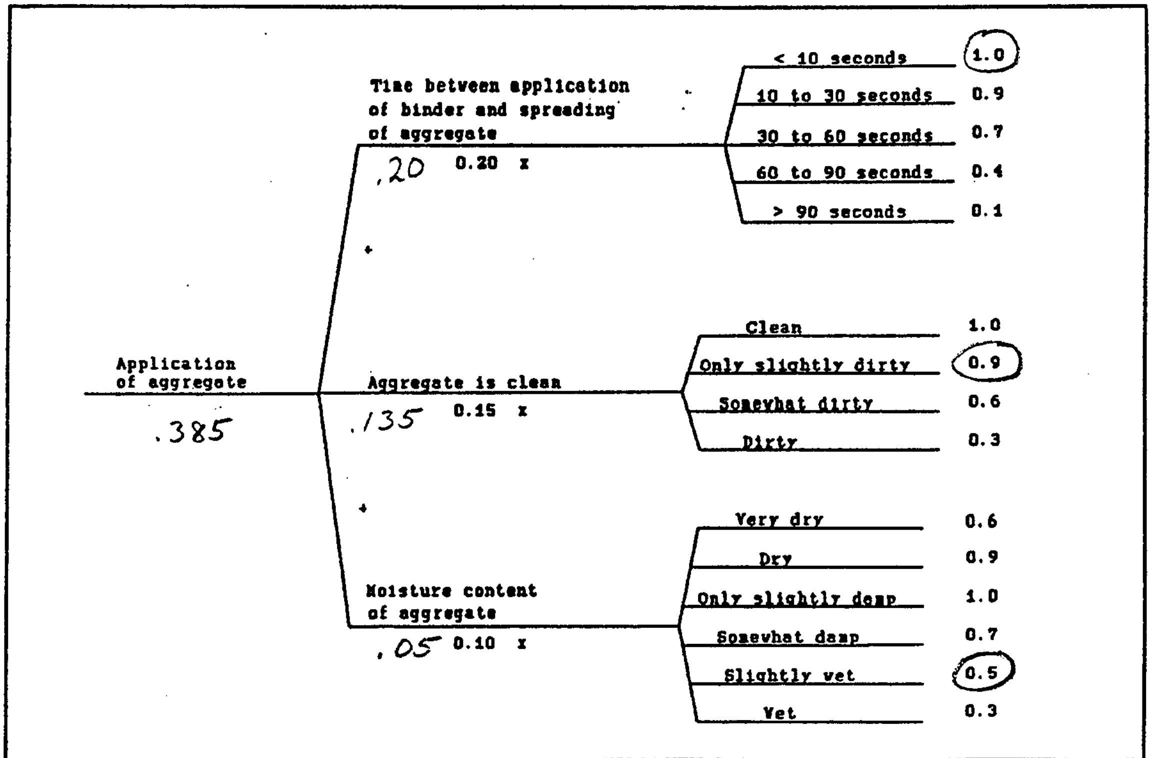


Figure 12. Chip Seal Application of Aggregate Attribute Branch (part 2 of 2)

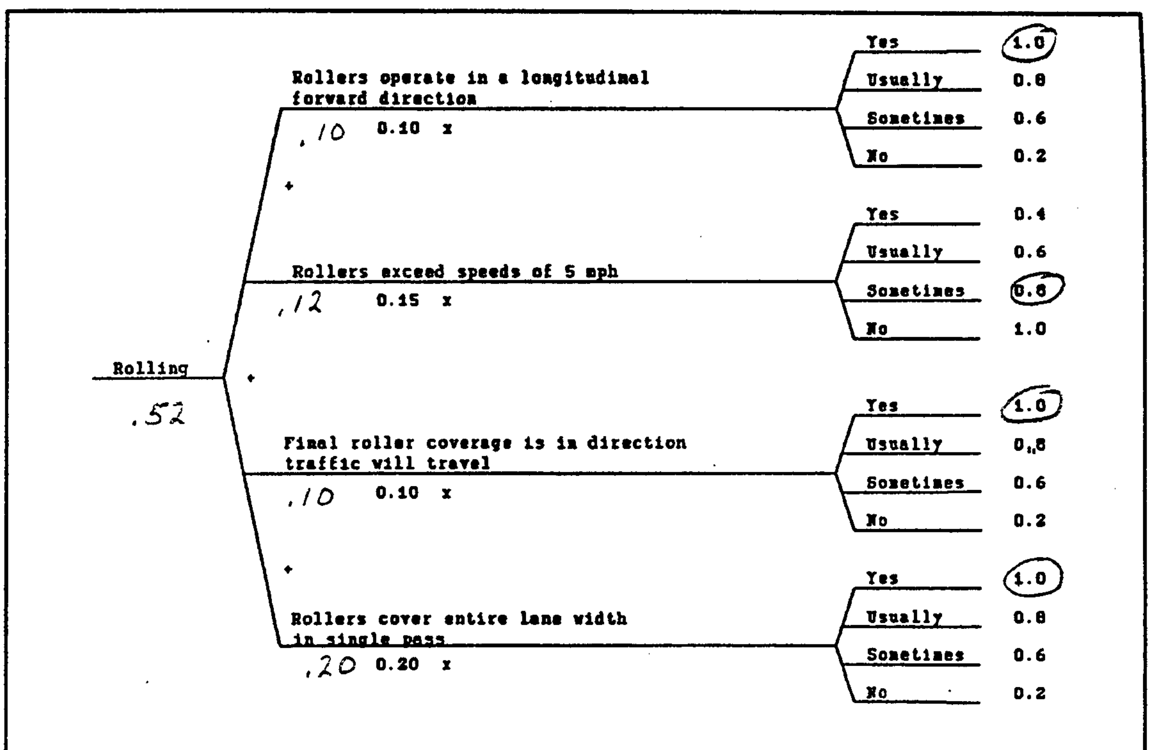


Figure 13. Chip Seal Rolling Attribute Branch (part 1 of 2)

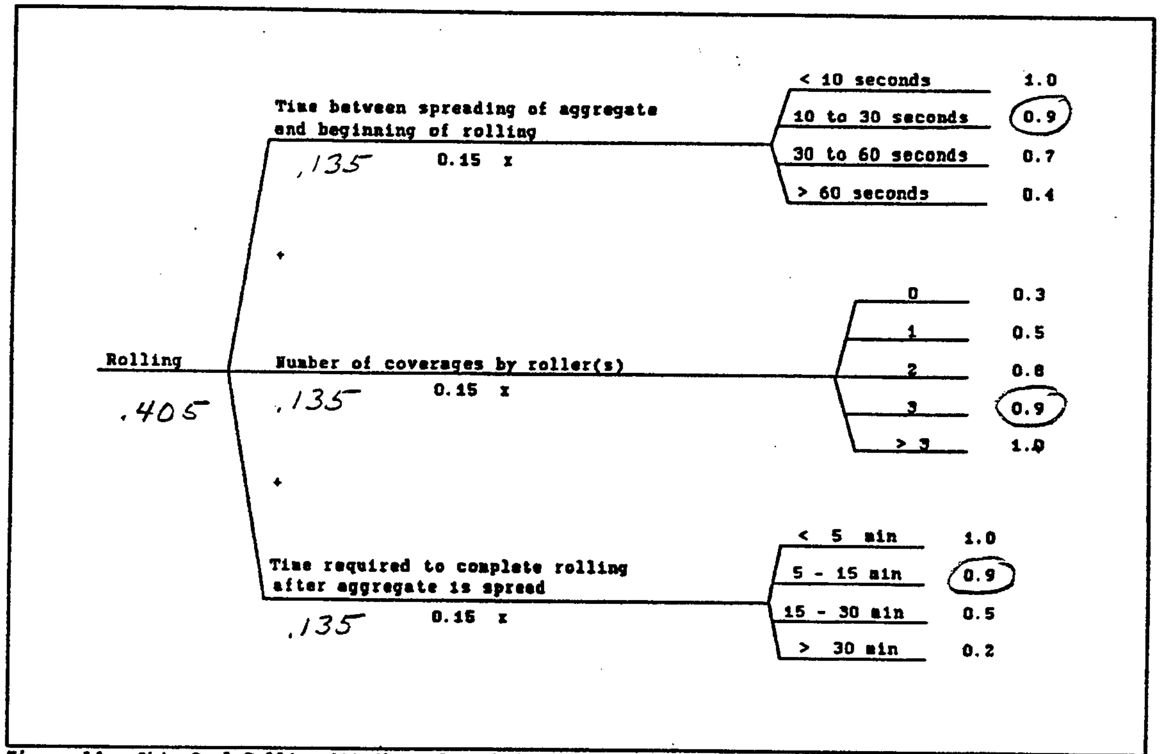


Figure 14. Chip Seal Rolling Attribute Branch (part 2 of 2)

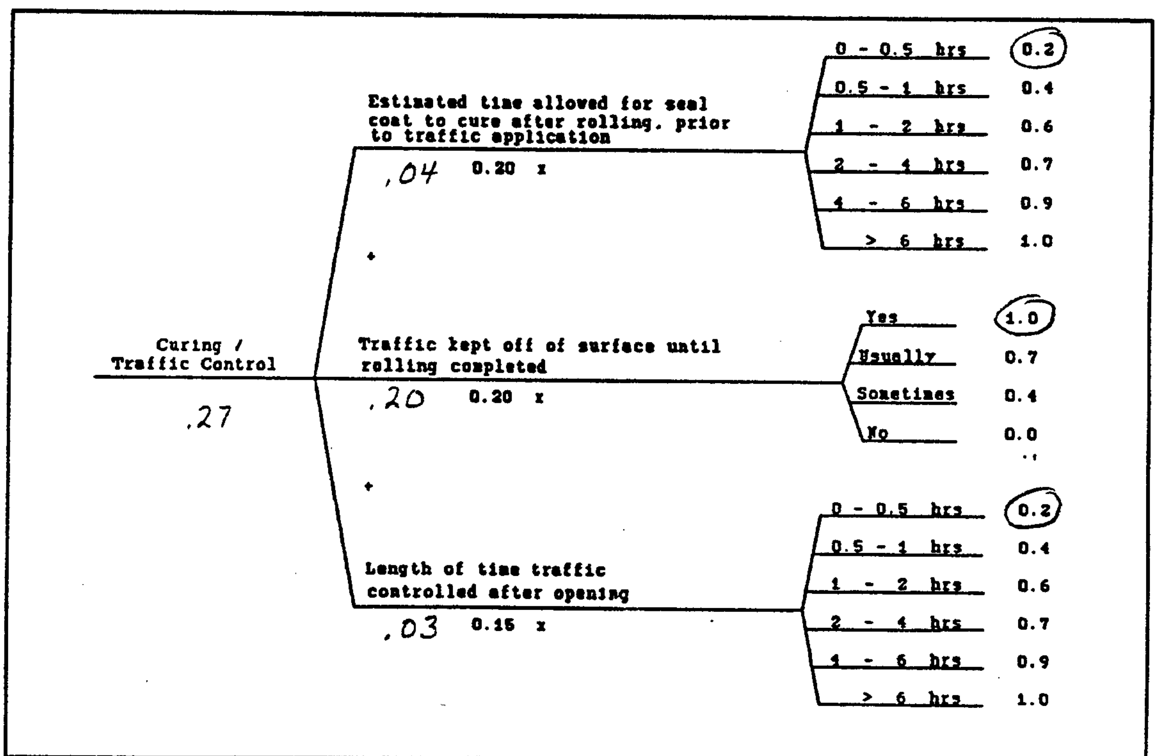


Figure 15. Chip Seal Curing / Traffic Control Main Attribute Branch (part 1 of 2)

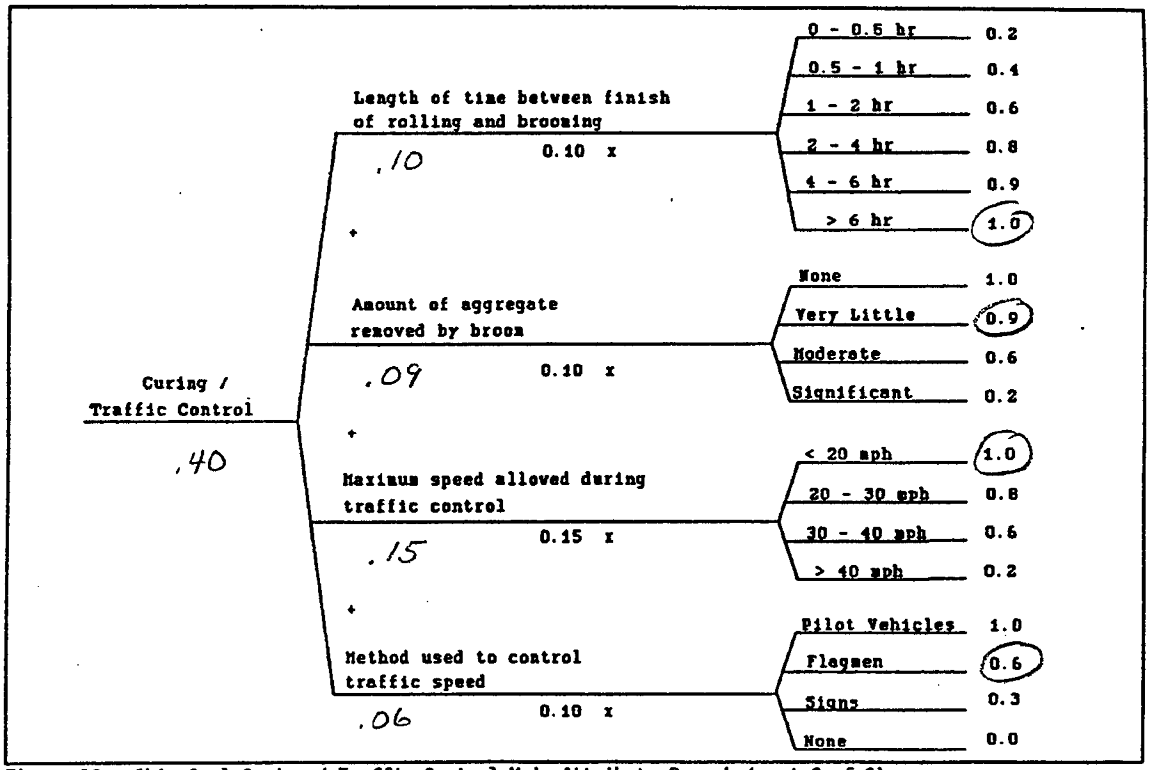
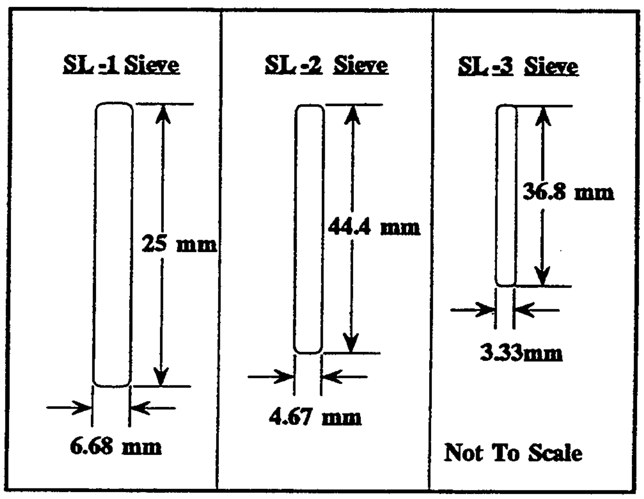


Figure 16. Chip Seal Curing / Traffic Control Main Attribute Branch (part 2 of 2)

Table 1. Slotted-sieve dimensions.

Slotted Sieve Designation	Aggregate Size To Be Used For	Opening Width	Opening Length	Total Openings in 200 mm Sieve Collar
SL-1	12.5 to 9.5 mm (½ to ⅜")	6.68 mm (0.263")	50.0 mm (2.00")	31
SL-2	9.5 to 6.3 mm (⅜ to ¼")	4.67 mm (0.184")	44.4 mm (1.75")	41
SL-3	6.3 to 4.75 mm (¼" to No. 4)	3.33 mm (0.131")	31.8 mm (1.25")	51

Figure 1. Slotted-sieve openings.



Individual sieves can be made by punching out openings on a 1 mm thick circular metal sheet, and then continuously welding that sheet onto the collar of an old 200 mm (8-in.) sieve.

Note: where the 1ST aggregate has been obtained from a NYSDOT-approved source, Slotted Sieve SL-3 will not be needed.

APPENDIX B. PROPOSED STANDARD TEST METHOD FOR DETERMINING AVERAGE LEAST DIMENSION (ALD) OF 1ST AGGREGATE

This appendix presents a new testing procedure proposed for the NYSDOT specifications, needed because the values calculated are essential for the rational design method (Appendix C) and expert system. The text was prepared in the format of NYSDOT and AASHTO testing specifications to facilitate its implementation.

1. SCOPE

This method describes a simplified procedure be followed for 1ST aggregate (after its approval and designation for use as a bituminous surface treatment), furnishing information necessary for design of a surface treatment. (The method was originally developed by Norman W. McLeod and the Country Roads Board of the State of Victoria, Australia.)

2. REFERENCE DOCUMENTS

2.1 AASHTO Standard M 92: Wire Cloth Sieves for Testing Purposes

2.2 ASTM Standard E 11: Wire Cloth Sieves for Testing Purposes

2.3 New York State DOT Materials Method 9.1, Appendix A: Sampling of Aggregates

2.4 Asphalt Institute Manual Series 19, Appendix D: Method for Determining the Average Least Dimension of Cover Aggregates for Biituminous Surface Treatments and Seal Coats

3. APPARATUS

3.1 Square Sieves: with square openings of the following sizes conforming to AASHTO M-92 or ASTM E 11, for sieving samples in accordance with Section 5.1.1: 12.5 mm (1/2-in.), 6.3 mm (1/4-in.), 9.5 mm (3/8-in.), or 4.75 mm (No. 4).

3.2 Slotted Sieves: with rounded rectangular openings of the dimensions given in Table 1 and shown in Figure 1 for sieving samples in accordance with Section 5.2.1.

3.3 Balance: this must conform to AASHTO M-231, Class G2.

4. TEST SAMPLE

4.1 Sample aggregate from stockpile after delivery, extracting material that will be used on the surface treatment.

4.2 Obtain a minimum 2.5 kg (5.5-lb) sample from the stockpile according to Appendix A of Materials Method 9.1. This sample taken must be in a free-flowing condition, with no visible film of water (surface-dry).

5. PROCEDURE

5.1 Median Size Test

5.1.1 Shake the sample through a nest of square sieves for at least 7 minutes.

5.1.2 Weigh each sample retained on each sieve using the balance, keeping individual aggregate sizes separated.

5.1.3 Determine the percentages passing each sieve and record them on the Aggregate Grading Chart (Fig. 2). Connect the data points with a continuous line.

5.1.4 Median size is where the line intersects "50 total percent passng."

5.2 Flakiness Index Test

5.2.1 Separate individual aggregate sizes into portions of 600 g (1⅓ lb) or less. If any gradation is less than 5 percent of the total sample, delete it in determining the flakiness index. Shake each portion through its designated slotted sieve for at least 5 minutes.

5.2.2 Weigh each portion passing through each slotted sieve.

5.2.3 Total the mass of the portion passing and the total tested. The percent passing of the total sample is the aggregate's flakiness index.

5.3 Determination of Average Least Dimension (ALD)

Find this using the Chart For Determining Average Least Dimension (Fig. 3). Match median size to the flakiness index and move left to find ALD. (Note: This procedure can be performed using the software for the NYSDOT Chip Seal Expert System.)

Figure 2. Aggregate grading chart.

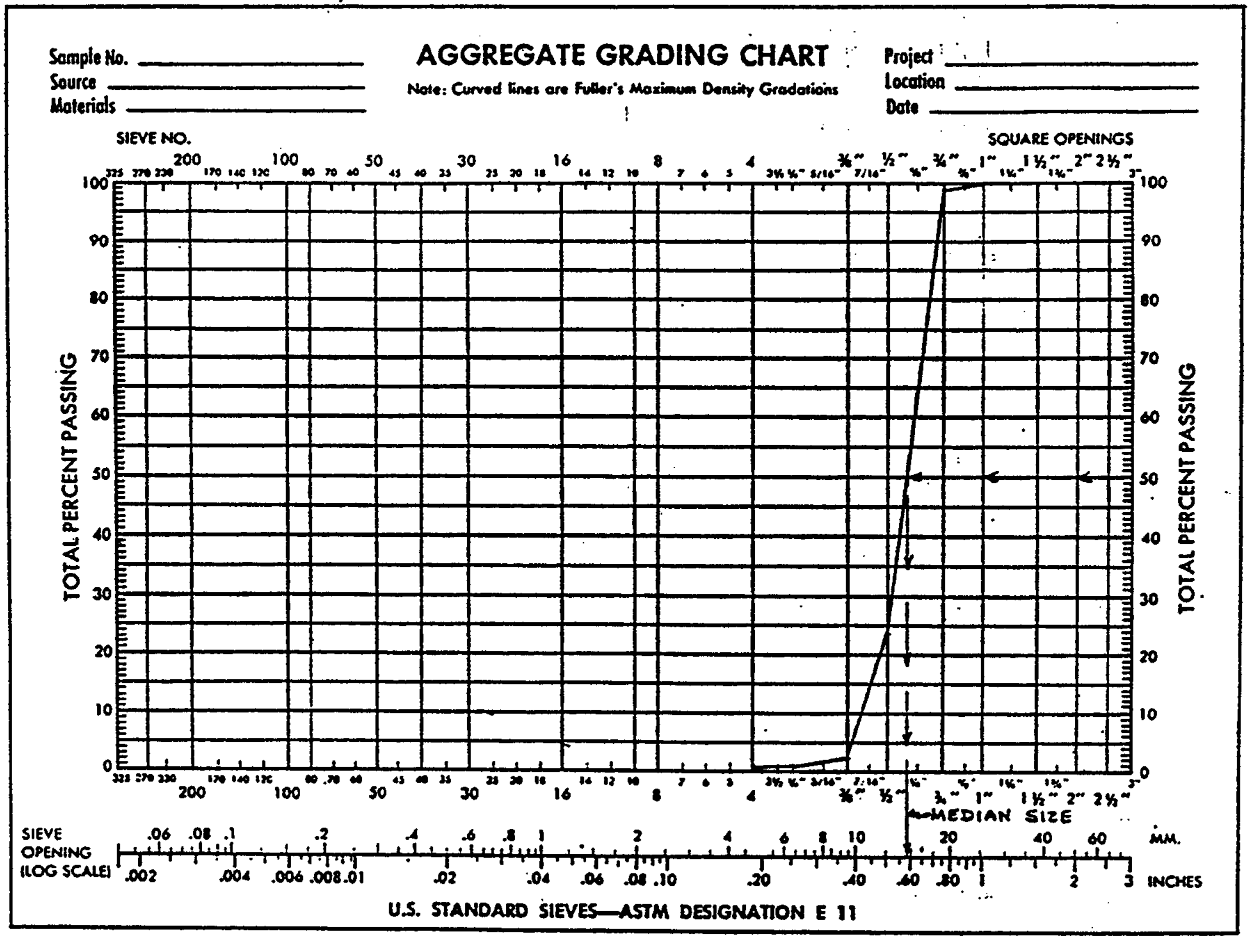


Figure 3. Chart for determining average least dimension (ALD).

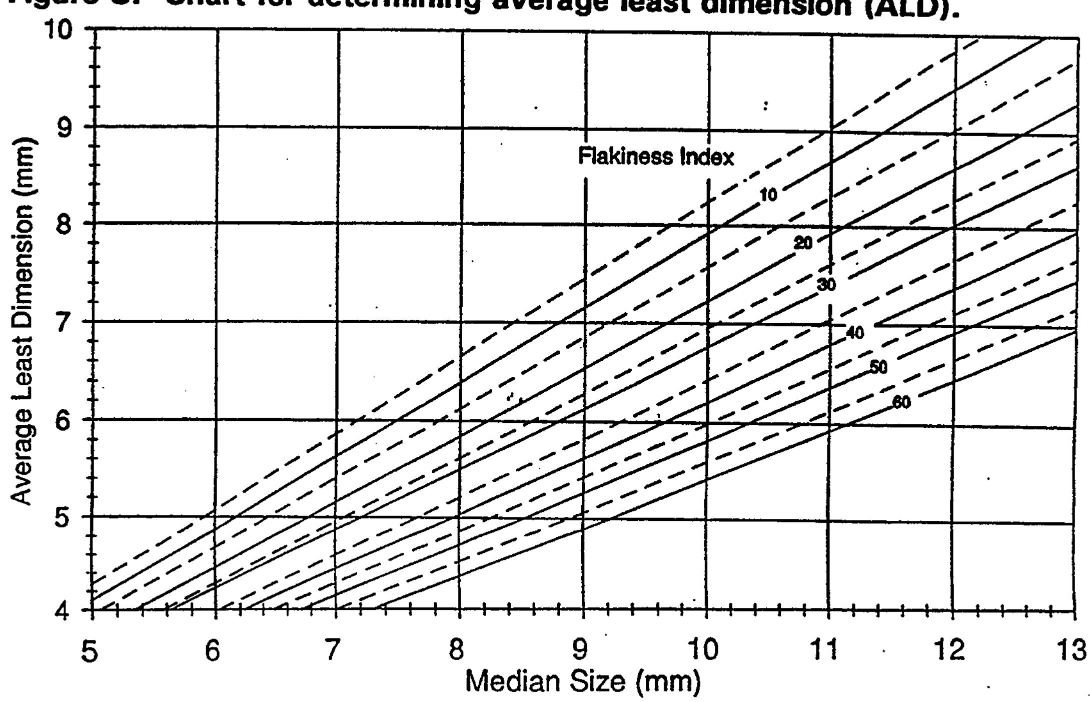


Figure 4. Work sheet.

NYSDOT Average Least Dimension Work Sheet

Region__________ Date Sample Taken__________
Sample From__________ Today's Date__________
__________ Aggregate Source Designation__________
__________ Project No.__________

Gradation Test			
Sieve Size	Retained (g)	Passing (g)	Percent Passing
12.5mm (½")	0.0		100.00
9.5mm (⅜")			
6.3mm (¼")			
4.75mm (no.4)			
Pan			

Median Size of Sample:__________mm

Slotted Sieve Test					
Aggregate Size	Sieve	Trial	Passing (g)	Retained (g)	Total (g)
12.5 - 9.5mm	Slot-1	1			
		2			
		3			
9.5 - 6.3mm	Slot-2	1			
		2			
		3			
6.3 - 4.8mm	Slot-3	1			
		2			
Total			(A)		(B)

$$\text{Flakiness Index} = \frac{\text{Total Passing}}{\text{Total Aggregate}} = \frac{(A)}{(B)} \_\_\_\_\_\_ \times 100\% = \_\_\_\_ \%$$

AVERAGE LEAST DIMENSION (ALD) of Sample__________mm

6. REPORT

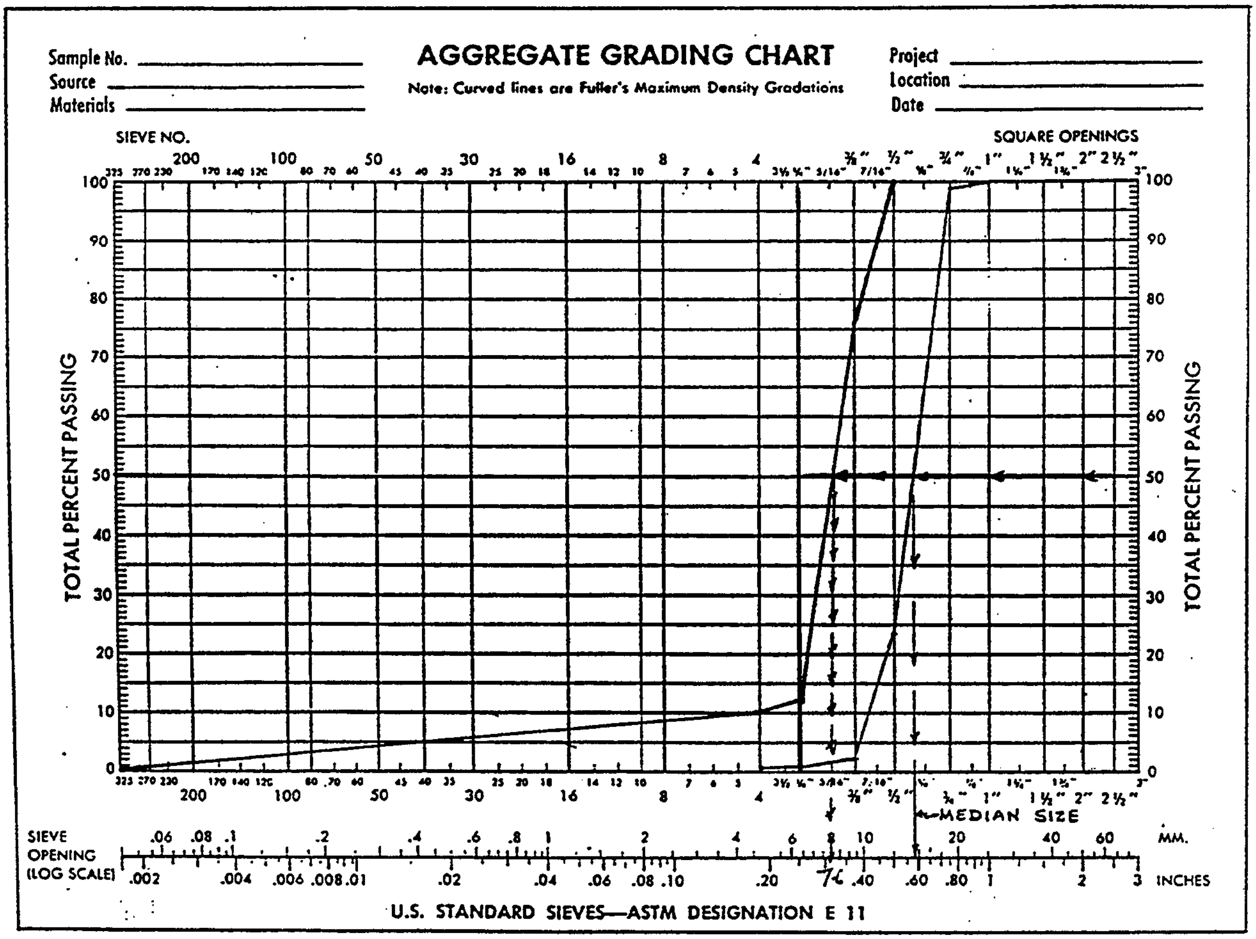
Send the Resident Highway Maintenance Engineer a report stating median size, flakiness index, and ALD, with a copy to the person designated to design the chip seal (who may be an outside contractor). Use the ALD worksheet (Fig. 4) to assist in this procedure.

7. SAMPLE TEST

7.1 Gradation Test Results

Sieve Size	Retained (g)	Passing (g)	Percent Passing
12.5 mm (½")	0.0	2,648.20	100.00
9.5 mm (⅜")	639.2	2,009.00	75.86
6.3 mm (¼")	1,645.5	363.50	13.73
4.75 mm (No.4)	110.4	253.10	9.56
Pan	253.1	0.00	0.00

Figure 5. Example results for grading.



From the Aggregate Grading Chart (Fig. 5), median size is 7.62 mm (0.30 in.).

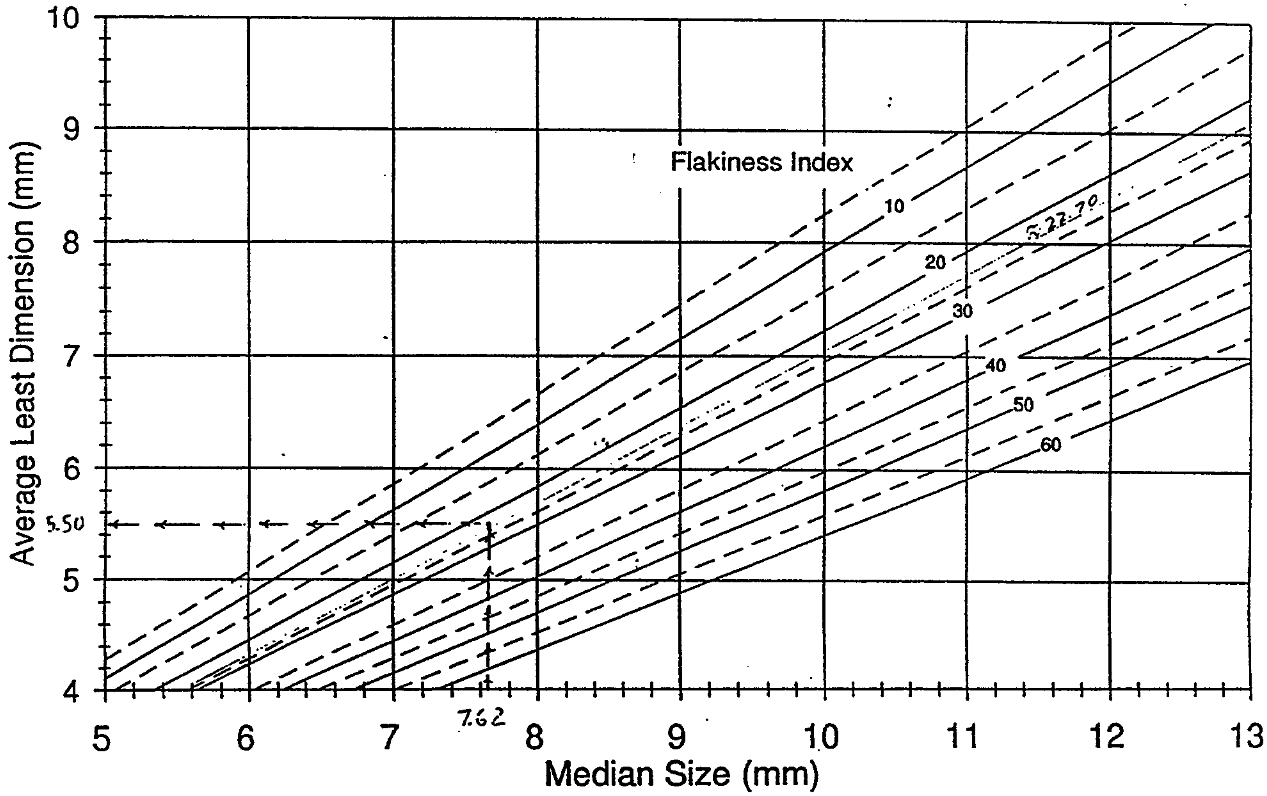
7.2 Slotted-Sieve Test Results

Aggregate Size	Sieve	Trial	Passing (g)	Retained (g)	Total (g)
12.5-9.5 mm	SL-1	1	65.5	240.9	306.40
		2	82	250.7	332.70
9.5-6.3 mm	SL-2	1	114.8	421.7	536.50
		2	124.1	415.2	539.30
		3	133.2	435	568.20
Total			519.60	1,763.50	2,283.10

From this table, calculate flakiness index as follows:

Total Passing/Total Aggregate = (519.6 g/2283.1 g) x 100% = 22.70%

Figure 6. Example results for average least dimension.



7.3 Using the ALD chart (Fig. 6), the sample's ALD thus is 5.5 mm (0.22 in.).

APPENDIX C. PROPOSED "RATIONAL" CHIP-SEAL DESIGN METHOD

This appendix describes the method used in designing the experimental chip seals and in the expert system. (This design method was created by the Australian Country Roads Board using the Hanson Method.)

Step 1: Calculate base rate for the asphalt binder. Match the aggregate type used with the road's AADT in Tables 1 or 2. (For shoulders, AADT is assumed to be <50.) Multiply this percentage by the average least dimension (ALD) of the 1ST aggregate in millimeters and 0.20 L/m^2 x mm. This gives the base binder rate in L/m^2:

$$\text{Percentage of Voids}/100\% \times \text{ALD} \times 0.20(\text{L/m}^2 \times \text{mm}) = \text{Base Rate}$$

Table 1. Percentage of aggregate voids to be filled (single-course).

1ST Aggregate Type	AADT 12-hour Count				
	<50	50-150	150-250	250-500	500-1000
Trap Rock	100%	90%	80%	75%	70%
Granite Ore Tailings Sandstone	100%	90%	85%	75%	75%
Limestone Dolomite	100%	90%	85%	80%	80%

Table 2. Percentage of aggregate voids to be filled (double-course).

1ST Aggregate Type	AADT 12-hour Count				
	<50	50-150	150-250	250-500	500-1000
Trap Rock	60%	60%	60%	60%	60%
Granite Ore Tailings Sandstone	60%	60%	60%	60%	60%
Limestone Dolomite	65%	65%	65%	65%	65%

Step 2: Find the surface texture adjustment. Match existing surface condition to the adjustment in Table 3 using the Appendix D photos as reference.

Step 3: Find the special traffic adjustment. Match the traffic condition that best applies to the adjustment in Table 4.

Table 3. Surface texture adjustment.

Surface	Black	Smooth	Slightly Hungry	Somewhat Hungry	Very Hungry	Extremely Hungry
Adjustment (l/m^2)	None	+ 0.1	+ 0.2	+ 0.3	+ 0.4	+ 0.5

Table 4. Special traffic adjustment.

Traffic Condition	Adjustment (L/m^2)
Shoulders and Breakdown Lanes	+ 0.1
>10% Heavy Truck Traffic	-0.1
Steep and/or Long Grades With Heavy Trucks	-0.2
Fast Lane of Four-Lane Highway	+ 0.1

Table 5. Cubical aggregate adjustment.

Condition	Flakiness Index	Adjustment (L/m^2)
Normally Shaped	> 20	None
Practically Cubical	15 - 20	+ 0.1
Very Cubical	< 15	+ 0.2

Table 6. Emulsion recommendations.

Aggregate Type	Recommended Emulsion
Traprock	Any One
Granite	CRS-2
Ore Tailings	CRS-2
Sandstone	Any One
Limestone	HFRS-2, RS-2, HFMS-2
Dolomite	HFRS-2, RS-2, HFMS-2

Table 7. 1ST aggregate application rate.

ALD (mm)	Application Rate (L/m^2)
0.0 - 3.6	6.25
3.6 - 3.8	6.67
3.8 - 4.0	7.14
4.0 - 4.2	7.40
4.2 - 4.4	7.69
4.4 - 4.6	8.00
4.6 - 4.8	8.33
4.8 - 5.0	8.70
5.0 - 5.4	9.09
5.4 - 5.6	9.52

ALD (mm)	Application Rate (L/m^2)
5.6 - 6.0	10.00
6.0 - 6.4	10.53
6.4 - 7.0	11.11
7.0 - 7.4	11.76
7.4 - 8.0	12.50
8.0 - 8.4	13.33
8.4 - 9.2	14.29
9.2 - 10.0	15.38
10.0 - 11.0	16.67
11.0 - 12.0	18.18

Step 4: Find the cubical aggregate adjustment. Match the flakiness index (found in the ALD test) of the 1ST aggregate to the adjustment in Table 5.

Step 5: Determine the aggregate absorption adjustment. If the 1ST aggregate is a particularly absorbent sandstone, limestone, or dolomite likely to decrease effectiveness of the asphalt, the adjustment is +0.2 L/m^2. If it is not absorbent, no adjustment is needed.

Step 6: Determine the surface penetration adjustment. If the existing surface is particularly soft, and the 1ST aggregate is likely to penetrate into the surface, the adjustment is -0.2 L/m^2. If it is not soft, there is no adjustment.

Step 7: Calculate the binder rate. Add all adjustments from Steps 2 through 6 to the base rate of the asphalt binder to calculate the binder rate.

	Base Rate
	Surface Texture Adjustment
	Special Traffic Adjustment
	Cubical Aggregate Adjustment
	Aggregate Absorption Adjustment
+	Surface Penetration Adjustment
	Binder Rate

Step 8: Select the type of emulsion. Those allowed by New York State specifications for chip sealing are RS-2, CRS-2, and HFRS-2. HFMS-2 is allowed only for shoulder work. Emulsions may "reject"the aggregate if the wrong emulsion is chosen for the type of aggregate. Table 6 lists the recommended types.

Step 9: Calculate the final emulsion rate. This is found by dividing the binder rate by the minimum residue by distillation found in Tables 702-5 and 702-6 of the current NYSDOT specifications. CRS-2 and HFMS-2 emulsions have 65-percent minimum residue specified. RS-2 and HFRS-2 emulsions have 60-percent minimum residue specified:

$$[\text{Binder Rate } (L/m^2)/(\text{Minimum Residue} \div 100\%)] = \text{Final Rate } (L/m^2).$$

This is the emulsion rate to be applied onto the road surface for the 1ST course. To convert to customary units, multiple final rate in L/m^2 by 0.208 to change to gal/yd^2.

Step 10: Find the 1ST aggregate application rate. Using Table 7, match the ALD of the 1ST aggregate with the application rate.

Step 11: If the treatment is double-course, find the top-course emulsion rate. If the 1A aggregate is traprock, granite, ore tailings, or sandstone, use 1.15 L/m^2 of emulsion; if it is limestone or dolomite, use 1.30 L/m^2 of emulsion. It is inadvisable to use a different aggregate sources for the top and bottom courses.

Step 12: If the treatment is double-course, use the top-course aggregate rate. For all aggregate types, use an application rate of 7 L/m^2 for the 1A aggregate.