Evaluation of the Specification for Flat and Elongated Particles for Use in Hot Mix Asphalt In Connecticut

Prepared by: Scott Zinke, James Mahoney, Kelly Morison, Stephen Clement

April 23, 2014

Report No. CT-2305-F-13-10

FINAL REPORT

Research Project – SPR 2305

Submitted to the Connecticut Department of Transportation

Connecticut Advanced Pavement Laboratory
Connecticut Transportation Institute
School of Engineering
University of Connecticut

Prepared for:
Connecticut Dpartment of Transportation
Bureau of Engineering and Construction
AEC Applications and Research Section

James A. Fallon, P.E.
Manager of Facilities and Transit

Disclaimer

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Connecticut, the Connecticut Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

Technical Report Documentation Page

1. Report No. CT-2305-F-13-10	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of the Specification for Flat and Elongated Particles for Use in Hot Mix Asphalt in Connecticut - Final Report		5. Report Date April 23, 2014 6. Performing Organization Code
7. Author(s) Scott Zinke, Kelly Morison, Stephen Clement, James Mahoney		8. Performing Organization Report No. CAPLAB 3-2014
9. Performing Organization Name and Address University of Connecticut Connecticut Transportation Institute 270 Middle Turnpike, U-5202 Storrs, Connecticut 06269-5202		10 Work Unit No. (TRIS) N/A 11. Contract or Grant No. N/A 13. Type of Report and Period Covered Final Report
12. Sponsoring Agency Name and Address Connecticut Department of Transportation 2800 Berlin Turnpike Newington, CT 06131-7546		14. Sponsoring Agency Code SPR-2305
15. Supplementary Notes Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration		

16. Abstract
This research was conducted to determine if the specification for flat and elongated aggregates for use in Hot-Mix Asphalt (HMA) in Connecticut can be reasonably achieved. Currently, the ConnDOT specification allows for no more than 10 percent flat and elongated particles utilizing a 3:1 ratio. It has been speculated that this specification may not be achievable by most HMA producers in Connecticut. The research team evaluated specifications from numerous regional state agencies for comparison with the ConnDOT specification. The research team also sampled aggregates from 15 sources which produce HMA for ConnDOT. 3/8-inch and 1/2-inch aggregates were sampled from each source, and flat and elongated tests were conducted on both size aggregates from all 15 sources. This totaled 30 aggregate samples tested from which only six passed the 10 percent maximum at the 3:1 ratio. Recommendations are made to change the specification to reflect achievable percentages of aggregates which are not flat and elongated. It is the opinion of the research team that this percentage should be not more than 10 percent flat and elongated particles by weight utilizing a 5:1 caliper ratio, ASTM D4791, Method B.

17. Key Words Superpave Mix Design, HMA Aggregate Requirements	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161. The report is available on-line from National Transportation Library at http://ntl.bts.gov.

19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 18	21. Price
Form DOT F 1700.7 (8-72)	Reproduction of completed page authorized		

Acknowledgments

This report was prepared by the University of Connecticut, in cooperation with the Connecticut Department of Transportation and the United States Department of Transportation, Federal Highway Administration. The opinions, findings and conclusions expressed in the publication are those of the author(s) and not necessarily those of the Connecticut Department of Transportation or the Federal Highway Administration. This publication is based upon publicly supported research and is copyrighted. It may be reproduced in part or in full, but it is requested that there be customary crediting of the source.

The research team would like to acknowledge and thank the following agencies for information provided regarding their specification for flat & elongated particles:

Massachusetts Department of Transportation
New York State Department of Transportation
Rhode Island Department of Transportation
Vermont Agency of Transportation
New Hampshire Department of Transportation
Maine Department of Transportation
New Jersey Department of Transportation
Pennsylvania Department of Transportation

The research team would also like to acknowledge and thank the following producers for their contributions of materials for testing on this research project:

Tilcon Connecticut Inc.
O&G Industries Inc.
AEN Asphalt Inc.
All States Asphalt Inc.
American Industries Inc.
Galasso Materials Inc.
JSL Asphalt Inc.
Palmer Paving Corporation
Suzio York Hill Companies

Standard Metric Conversions

SI CONVERSION FACTORS				
SYMBOL	**GIVEN**	**MULTIPLY BY**	**CONVERT TO**	**SYMBOL**
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
	NOTE: volumes greater than 1000L shall be shown in m^3			
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or metric ton)	1.103	short tons (2000 lb)	T
		TEMPERATURE		
°C	Celsius	1.8C + 32	Farenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

Table of Contents

List of Tables

List of Figures

Background & Problem Statement

Aggregates used in the production of Hot-Mix Asphalt (HMA) account for approximately 95% of the mixture by weight. These aggregates are intended to withstand significant loading over the expected service life of the roadway. When a vehicle tire travels over the roadway it imposes a force/load onto the wearing surface, which is transmitted to the underlying HMA layers and is ultimately diffused through the road base. In order for this to take place, there needs to be a significant level of quality and structural integrity in the aggregate matrix in each HMA layer. The individual pieces of aggregate are required to resist damage and degradation when subjected to traffic loading.

One of the many requirements for the coarse aggregates is to pass a test known as the Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate, ASTM D4791. (Flat and Elongated Test , Method B – calculated by weight is used). ASTM D4791, Method A – Flat or Elongated particles is not typically used for characterizing aggregates used in HMA as it tends to allow a much higher percentage of undesirably shaped particles to be used. This test is intended to ensure that the weakest and most vulnerable dimension of any aggregate particle is capable of withstanding shear forces when subjected to loading during construction and during its service life. Additionally, an abundance of flat and elongated particles may make it very difficult to compact the HMA during construction.

It is not possible to ensure that 100 percent of all coarse aggregates used for roadway construction are not flat and elongated. Most agencies specify a maximum allowable percentage of flat and elongated particles, which may be present in a source, for use in HMA production. ConnDOT currently specifies that not more than 10 percent flat and elongated particles in the final blend of coarse aggregates are permissible for use in HMA production. This range is based on a flat and elongated ratio of 3:1 (the longest dimension may be no more than 3 times the smallest dimension of the particle). It has been hypothesized that the specified tolerance for flat and elongated particles could be eased without compromising the structural integrity of HMA pavements in Connecticut.

Objectives

This research is intended to establish typical values for flat and elongated particles in aggregates being used for HMA production in Connecticut, and if the current ConnDOT specification of 3:1, 10 percent maximum is beneficial. The research team intends to provide ConnDOT with a recommendation as to any changes that could be made to the specification without compromising the integrity of the pavement structure.

Regional Specification Review

The research team conducted a review of state agency specifications in the northeast for flat and elongated particles, to gain an idea of what is specified regionally. These specifications were used to compare with the ConnDOT specification. State agency specifications state that any stones with a ratio of more than 5:1, 4:1 or 3:1 (depending

on the state) longest dimension to smallest dimension are flat and elongated. States set a maximum acceptable percentage of flat and elongated particles that a coarse aggregate blend may have before being ruled out as an acceptable source. Regional state requirements for flat and elongated particles are shown in Table 1.

Table 1. Regional States Flat and Elongated Specifications

State	Specification ASTM D4791, Method B
Connecticut	10% by weight maximum, 3:1 ratio
Maine	10% by weight maximum, 5:1 ratio
Massachusetts	15% by weight maximum, 4:1 ratio
New Hampshire	10% by weight maximum, 5:1 ratio
New Jersey	10% by weight maximum, 5:1 ratio
New York	10% by weight maximum, 5:1 ratio
Pennsylvania	15% by weight maximum, 5:1 ratio
Rhode Island	10% by weight maximum, 5:1 ratio
Vermont	10% by weight maximum, 5:1 ratio

Sampling Aggregates

The research team collected aggregate samples from 15 different aggregate sources used in the production of HMA for ConnDOT projects. These samples were obtained by CAP Lab personnel at random times throughout the 2012 construction season. These aggregates were sampled from production stockpiles at each of the 15 facilities. Material was collected by taking a random sample of aggregate from hot mix aggregate production piles of both 3/8-inch and 1/2-inch stone following the AASHTO T2 requirements for sampling of aggregate stockpiles. Samples were then tagged and

returned to the CAP Lab for testing. Sources that were sampled and tested are shown in Table 2.

Table 2. Aggregate Sources

Sources
AEN - North Franklin, CT
All-States – Killingly, CT
American - Jewett City, CT
Galasso Materials – Granby, CT
JSL – Westfield, MA
O&G – Southbury, CT
O&G – Torrington, CT
O&G – Waterbury, CT
Palmer Paving – Palmer, MA
Suzio York Hill – Meriden, CT
Tilcon – Griswold, CT
Tilcon - New Britain, CT
Tilcon – Newington, CT
Tilcon - North Branford, CT
Tilcon – Wallingford, CT

Summary of Testing

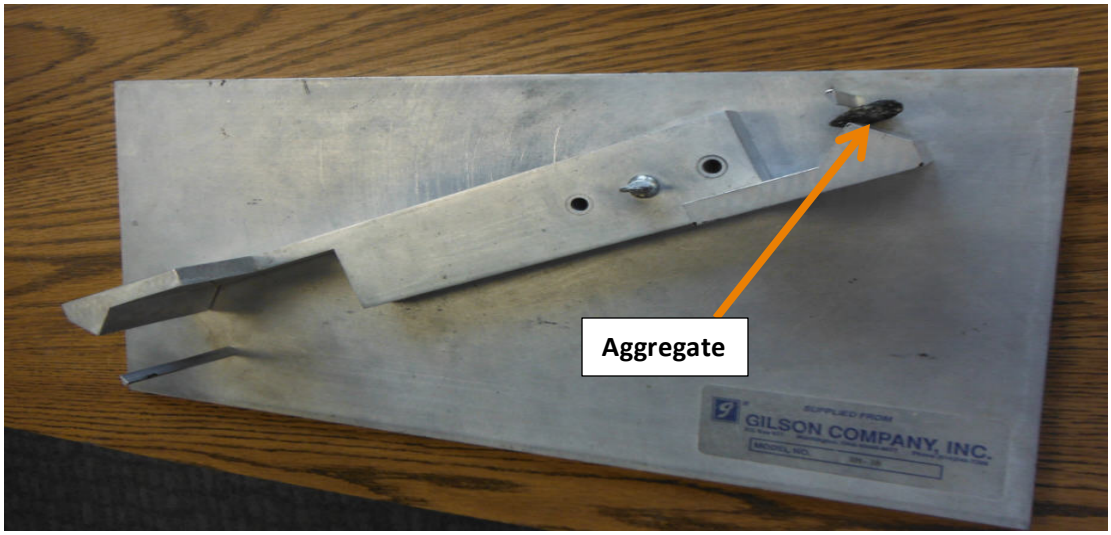
The samples were first placed in an oven and dried to a constant mass. They were then broken down into more manageable sizes using a splitter to obtain a random sample of approximately 2000 grams for 1/2-inch material and 1000 grams for 3/8-inch material. The exact weight of each sample was recorded. The aggregate was then washed and dried to a constant mass. The samples were then split down to sizes of

approximately 100 pieces, in accordance with ASTM D4791. The Flat and Elongated caliper was used to test the samples at a 5:1 ratio and then a 3:1 ratio. This was done by placing each piece of aggregate between the fixed post and the swinging arm on the larger end of the caliper to measure the length, as seen in Figure 1.

Figure 1. Flat and Elongated Test (Longest Dimension)

Once this length was measured, the caliper was kept in place and the specimen was attempted to be passed through the smaller opening, as seen in Figure 2. If the sample fit through the smaller opening with the measured length at the set ratio, it failed the test at that ratio, per ASTM Standard D4791, Method B.

Figure 2. Flat and Elongated Test (Smallest Dimension)



This process was repeated with the entire split sample. The pieces were separated into 'passed' and 'failed' categories. Once this was complete, the masses were recorded and the percentage of flat and elongated particles was calculated.

Results of Testing

The results included in this report were 'blinded' so no results can be attached to the respective producer.

Table 3 shows the vast majority of samples tested at the 3:1 ratio exceeded 10 percent by weight. None of the fifteen sources passed at the 3:1 ratio for both aggregate sizes, and only five managed to pass for even one size. The average for all the 3/8-inch samples tested at a 3:1 ratio was18.3 percent (above the maximum allowable state specification of 10 percent by 8.3 percent.) The average for all the 1/2-inch samples tested at the 3:1 ratio was 16.8 percent (above the maximum state specification of 10

percent by 6.8 percent.) It is also shown in Table 3 that all sources would pass the 10 percent maximum at 5:1 ratio required by AASHTO M323 – Superpave Volumetric Mix Design. The average percentage of flat and elongated particles for all of the 3/8-inch aggregates with the 5:1 ratio was 2.9 percent. The overall average percentage of 1/2-inch flat and elongated particles with the 5:1 ratio was 2.5 percent. When tested at a 5:1 ratio, 7 different samples recorded a flat and elongated percentage of less than 1 percent.

Table 3. Flat and Elongated Testing Results, ASTM D4791, Method B

Aggregate Source	3/8" 3:1 (%)	3/8" 5:1 (%)	1/2" 3:1 (%)	1/2" 5:1 (%)
A	13.2	1.1	15.8	3.0
B	16.6	0.8	12.8	1.6
C	13.2	1.7	11.7	0.4
D	18.2	2.7	9.8	1.2
E	7.6	2.0	36.0	5.7
F	44.2	9.5	25.6	5.2
G	5.3	0.0	14.6	0.0
H	23.5	5.0	15.8	1.7
I	20.7	4.6	21.0	3.8
J	15.0	3.4	24.8	5.3
K	10.5	2.5	9.5	0.8
L	24.6	3.5	19.8	2.6
M	22.3	3.7	17.9	4.1
N	20.8	0.5	13.2	1.8
O	18.3	2.6	3.0	0.0
Average:	**18.3**	**2.9**	**16.8**	**2.5**

The results from Table 3 are shown graphically in Figures 3 and 4, along with a reference line illustrating the current ConnDOT specification limit of 10 percent at the 3:1 ratio.

Figure 3. Flat and Elongated Percentages (3/8" Stone), ASTM D4791, Method B

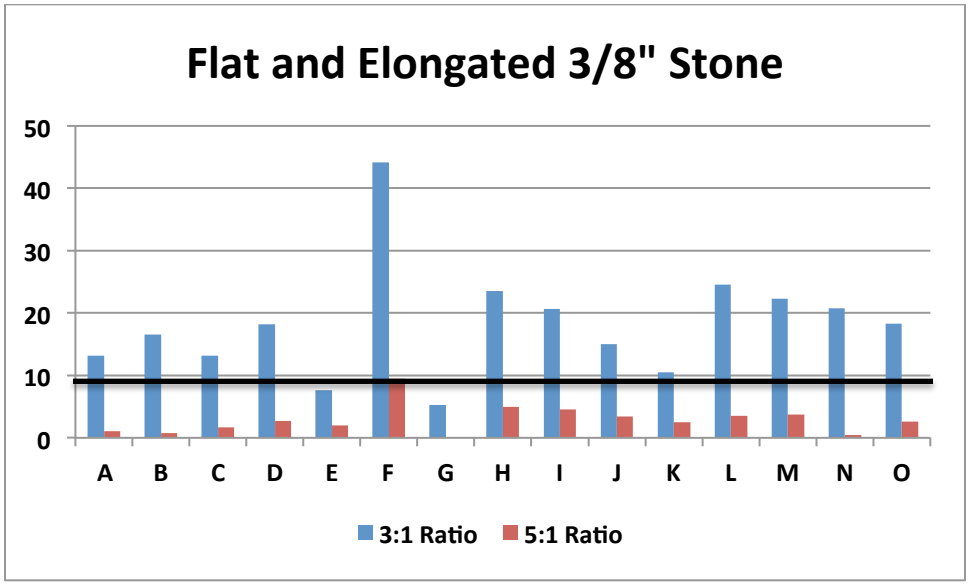
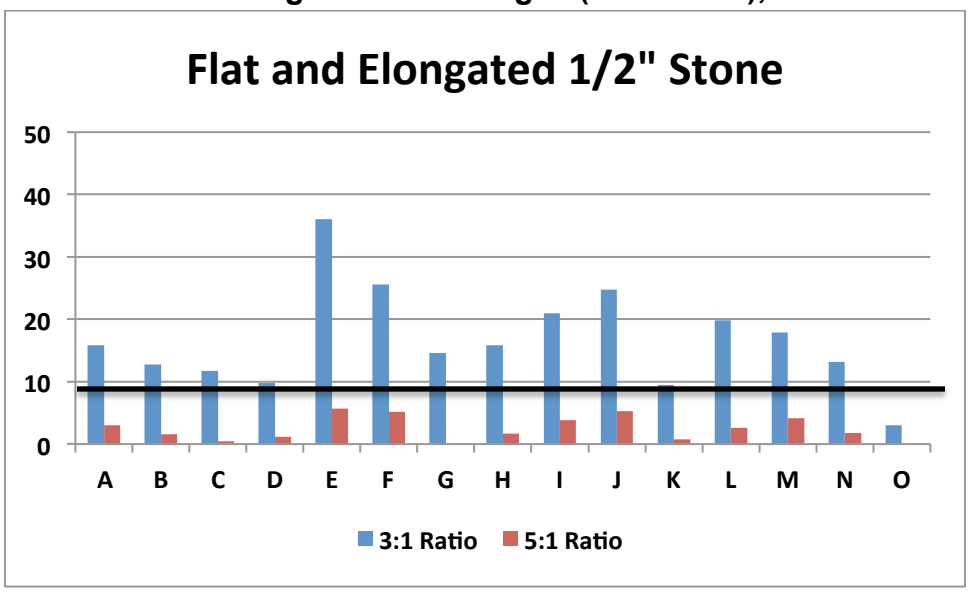


Figure 4. Flat and Elongated Percentages (1/2" Stone), ASTM D4791, Method B



Conclusions

Out of a total fifteen different tested sources, (30 tested samples), only five samples (or 17 percent) actually met the 3:1 requirements at 10 percent. Taking this information into consideration, the current specification is not generally met, and the current levels of flat and elongated particles do not seem to be having a detrimental effect on the pavements being placed in Connecticut. Additionally, strict enforcement of the current Flat and Elongated specification requirement would require the aggregate producers to perform additional processing of the aggregate to meet the specification, which, inevitably, would increase the price of their products with minimal or no long-term benefit. As Connecticut has a stringent in-place density specification for HMA, it is in the producers' best interest to minimize the flat and elongated particles to make it easier for them to achieve compaction.

Recommendations

After analyzing the results obtained, as well as the specifications from regional states, it can be stated that a less stringent specification would be more attainable. Most surrounding states are using the 5:1 ratio with 10 percent maximum allowable flat and elongated particles. Per the results shown above, it would be quite reasonable in Connecticut to return the specification values to the AASHTO M323 Superpave Volumetric Mix Design requirement of 10 percent maximum using a ratio of 5:1 for the coarse aggregate blend.

References

American Association of State Highway and Transportation Officials, *Standard Specifications for Transportation Materials and Testing,* 32nd Edition, 2012.

ASTM, *Annual Book of ASTM Standards Road and Paving Materials; Vehicle-Pavement Systems*, Volume 04.03, 2012.

Maine Department of Transportation. Materials Testing. *Standard Specifications*. State of Maine, Dec. 2002. Web. 7 Nov. 2012. <http://www.maine.gov/mdot/contractor-consultant-information/ss_division_700.pdf>.

Rhode Island Department of Transportation. Telephone discussion with Mike Byrne regarding Flat and Elongated Particles Specification. April, 2013.

Massachusetts Department of Transportation. Research and Materials Department. *Division III Materials Specifications*. State of Massachusetts, n.d. Web. 7 Nov. 2012. <http://www.mhd.state.ma.us/downloads/manuals/88specs/division3.pdf>.

New Hampshire Department of Transportation. Materials and Research Department. *Standard Specifications*. State of New Hampshire, 2010. Web. 3 Jun. 2013. <http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/specifications/documents/2010_Division_400.pdf >.

New Jersey Department of Transportation. Road and Bridge Construction. *Standard Specifications*. State of New Jersey, 2007. Web. 7 Nov. 2012. <http://www.state.nj.us/transportation/eng/specs/2007/spec900.shtm#s901>.

New York State Department of Transportation. Engineering Department. *New York State Speficications*. New York State, 2 Jan. 2002. Web. 3 Jun. 2013. <https://www.dot.ny.gov/main/business-center/engineering/specifications/english-spec-repository/espec5-2-13english_0.pdf>.

Pennsylvania Department of Transportation. *Standard Specs*. State of Pennsylvania, n.d. Web. 07 Nov. 2012. <http://www.dot.state.pa.us/Penndot/reginfo.nsf/416a55d4cc3b28c38525674a004b66f9/187666f98d5f3863852567a10073af29>.

Vermont Agency of Transportation. Materials Testing Department. *Agency Standard Specifications*. State of Vermont, n.d. Web. 7 Nov. 2012. <http://www.aot.state.vt.us/conadmin/Documents/2011%20Spec%20Book%20for%20Construction/2011Division700.pdf>.