Cold In-Place Recycling and Full-Depth Reclamation Literature Review

By: Ben C. Cox and Isaac L. Howard

In the last several decades, in-place recycling techniques have seen increased use for rehabilitating low-volume roads. Depending on the milling depth, these techniques (when absent heat) are generally classified as either cold in-place recycling (CIR) or full-depth reclamation (FDR). CIR often refers to reclaiming and recycling the majority of the existing asphalt concrete layer(s); whereas, FDR often refers to recycling all existing asphalt concrete layer(s) as well as a significant portion of the underlying layers. Recently, the distinction between these two definitions has become clearer, but cross-use of the terms has been observed (Berthelot et al. 2000). Primarily for this reason, a literature review which reports both CIR and FDR properties (e.g. binder dosages and recycling thicknesses) was performed.

This document presents properties compiled from 81 CIR references and 18 FDR references, respectively, as a part of Mississippi Department of Transportation State Study 250. The goal of this document is to provide an extensive list of reference values that can be quickly viewed to gain a broad understanding of the current state of practice of CIR and FDR. It should be noted that the included references were published from 1982 to 2013; in that time, terminology and methods changed as the state of the practice evolved. To compile these references into a consistent form, minor interpretation was required in some instances, which should be noted but should not affect the overall significance of the information.

References often differed in terms of format and content. For instance, one reference may have documented a field in-place recycling project and reported pertinent properties (e.g. bulk reclaimed asphalt pavement (RAP) gradation); whereas, another reference may have performed laboratory testing to determine the effect of bulk gradation on performance. In a case such as this, all of the laboratory-tested gradations were reported within sound reason. For references that reported ranges of values, the average was typically reported (e.g. for a mixing moisture content of 3.5 to 4.5, reported value would be 4.0). Judgment was required to filter extreme outliers so as to obtain a database that is most representative of construction and research. In general, values are listed in ascending order to facilitate data analysis (e.g. construction of histograms). Information is compiled in five parts:

- **Part 1** – In-place Recycling Traffic Levels (pp. 2-4)
- **Part 2** – In-Place Recycling Layer Thicknesses (pp. 4-6)
- **Part 3** – In-Place Recycling Moisture Contents (pp. 6-8)
- **Part 4 –** In-Place Recycling Binders (pp. 9-14)
- **Part 5** – In-Place Recycling Gradations (pp. 15-16)

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Mississippi State University
Construction Materials Research Center
Ph: 662-325-3050

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Part 1: In-Place Recycling Traffic Levels

Average annual daily traffic (AADT) values are shown below for CIR and FDR. This list is composed of values from 30 CIR references and 7 FDR references. The distribution of AADT for 196 CIR values and 9 FDR values is similar. The mean values for CIR and FDR are 2,567 and 2,248, respectively.

CIR Reference	AADT
Morian et al. (2004)	124
Kim et al. (2010)	130
Anderson (1985)	150
Anderson (1985)	150
Scholz et al. (1991b)	180
Cross and Ramaya (1995)	183
Kim et al. (2010)	190
Anderson (1985)	200
Scholz et al. (1991b)	200
Scholz et al. (1991b)	220
Morian et al. (2004)	225
Scholz et al. (1991b)	260
Kim and Lee (2008)	260
Cross and Ramaya (1995)	283
Jahren et al. (1998)	290
Morian et al. (2004)	299
Jahren et al. (1998)	300
Steward (1987)	320
Jahren et al. (1998)	340
Kim et al. (2010)	340
Larsen et al. (1983)	350
Jahren et al. (1999)	360
Cross and Ramaya (1995)	370
Scholz et al. (1991b)	390
Kim et al. (2010)	390

CIR Reference	AADT
Anderson (1985)	400
Anderson (1985)	400
Charmot and Romero (2010)	400
Charmot and Romero (2010)	400
Kim et al. (2010)	400
Cross et al. (2002)	440
Cross and Ramaya (1995)	443
Cross and Ramaya (1995)	448
Scholz et al. (1991b)	450
Kim et al. (2010)	450
Cross and Ramaya (1995)	470
Jahren et al. (1998)	470
Cross and Ramaya (1995)	473
Cross et al. (2010)	480
Cohen et al. (1989)	500
Scholz et al. (1991b)	520
Scholz et al. (1991b)	520
Jahren et al. (1998)	520
Kim et al. (2010)	540
Scholz et al. (1991b)	550
Jahren et al. (1998)	550
Kim et al. (2010)	550
Jahren et al. (1998)	570
Kim et al. (2010)	570
Cross and Ramaya (1995)	573
Forsberg et al. (2002)	580
Scholz et al. (1991b)	600
Scholz et al. (1991b)	600
Scholz et al. (1991b)	600
Jahren et al. (1998)	600
Kim et al. (2010)	610
Jahren et al. (1998)	620
Cross and Ramaya (1995)	638
Cross et al. (2002)	640
Jahren et al. (1998)	665

CIR Reference	AADT
Kim and Lee (2008)	710
Kim et al. (2010)	740
Kim et al. (2010)	770
Scholz et al. (1991b)	800
Scholz et al. (1991b)	800
Loria et al. (2008)	800
Cross et al. (2010)	810
Scholz et al. (1991b)	820
Jahren et al. (1998)	820
Jahren et al. (1998)	850
Scholz et al. (1991b)	880
Kim et al. (2010)	890
Scholz et al. (1991b)	900
Scholz et al. (1991b)	900
Kim et al. (2010)	900
Kim et al. (2010)	930
Charmot and Romero (2010)	932
Jahren et al. (1998)	940
Jahren et al. (1998)	950
Charmot and Romero (2010)	978
Scholz et al. (1991b)	980
Cross and Ramaya (1995)	980
Jahren et al. (1998)	990
Scholz et al. (1991b)	1000
Scholz et al. (1991b)	1000
Scholz et al. (1991b)	1000
Kim et al. (2010)	1000
Cross et al. (2002)	1033
Jahren et al. (1998)	1080
Scholz et al. (1991b)	1100
Loria et al. (2008)	1100
Kim et al. (2010)	1100
Jahren et al. (1998)	1110
Cross and Ramaya (1995)	1135
Kim et al. (2010)	1140

CIR Reference	AADT
Cross et al. (2002)	1150
Kim et al. (2010)	1170
Morian et al. (2004)	1172
Kim et al. (2010)	1250
Morian et al. (2004)	1400
McDaniel (1988)	1430
Morian et al. (2004)	1470
Kim et al. (2010)	1490
Loria et al. (2008)	1500
Cross et al. (2010)	1500
Cross et al. (2010)	1500
Cross et al. (2010)	1500
Kim et al. (2010)	1560
Morian et al. (2004)	1581
Cross et al. (2010)	1620
Morian et al. (2004)	1624
Morian et al. (2004)	1661
Cross and Jakatimath (2007)	1700
Scholz et al. (1991a)	1750
Morian et al. (2004)	1766
Kim et al. (2010)	1770
Scholz et al. (1991b)	1800
Mottola and Chmiel (1990)	1820
Kim et al. (2010)	1850
Badaruddin and McDaniel (1992)	1900
Jahren et al. (1998)	1920
Kim et al. (2010)	1980
Morian et al. (2004)	1982
Scholz et al. (1991b)	2000
Scholz et al. (1991b)	2000
Loria et al. (2008)	2000
Cross et al. (2010)	2120
Scholz et al. (1991b)	2200
Scholz et al. (1991b)	2200
Cross et al. (2010)	2220

CIR Reference	AADT
Cross et al. (2010)	2270
Morian et al. (2004)	2334
Scholz et al. (1991b)	2350
Rogge et al. (1992)	2350
Cross et al. (2010)	2390
Morian et al. (2004)	2426
Morian et al. (2004)	2481
Babaei and Walter (1989)	2500
Lauter and Corbett (1998)	2500
Henault and Kilpatrick (2009)	2515
Morian et al. (2004)	2623
Morian et al. (2004)	2645
Scholz et al. (1991b)	2700
Morian et al. (2004)	2700
Morian et al. (2004)	2735
Cross et al. (2010)	2780
Morian et al. (2004)	2834
Scholz et al. (1991a)	2850
Morian et al. (2004)	2883
Morian et al. (2004)	2901
Morian et al. (2004)	2921
Morian et al. (2004)	2950
Loria et al. (2008)	2950
Cross et al. (2002)	2985
Babaei and Walter (1989)	3050
Scholz et al. (1991b)	3100
Morian et al. (2004)	3109
Morian et al. (2004)	3150
Morian et al. (2004)	3194
Charmot and Romero (2010)	3200
Lee and Kim (2006)	3250
Kim and Lee (2008)	3250
Scholz et al. (1991b)	3350
Scholz et al. (1991b)	3400
Scholz et al. (1991b)	3400

CIR Reference	AADT
Morian et al. (2004)	3422
Morian et al. (2004)	3532
Scholz et al. (1991b)	3600
Scholz et al. (1991b)	3600
Babaei and Walter (1989)	3650
Cross et al. (2010)	3720
Cross et al. (2010)	3840
Morian et al. (2004)	3856
Cross et al. (2010)	4220
Babaei and Walter (1989)	4750
Scholz et al. (1991b)	4800
Cross et al. (2010)	4820
Loria et al. (2008)	5000
Morian et al. (2004)	5054
Morian et al. (2004)	5424
Loria et al. (2008)	5550
Morian et al. (2004)	5956
Kim et al. (2010)	6200
Morian et al. (2004)	6325
Cross et al. (2002)	7100
Charmot and Romero (2010)	8000
Scholz et al. (1991b)	8300
Chan et al. (2010b)	8994
Morian et al. (2004)	13138
Morian et al. (2004)	13414
Loria et al. (2008)	14500
Charmot and Romero (2010)	18200
Charmot and Romero (2010)	22000
Scholz et al. (1991b)	23000
Diefenderfer et al. (2012)	23000
Loizos et al. (2007)	40000

FDR Reference	AADT
Nantung et al. (2011)	600
Johnson et al. (2006)	1100
Diefenderfer and Apeagyei (2010)	1500
Diefenderfer and Apeagyei (2010)	1800
Mallick et al. (2002)	1900
Pickett (1991)	2000
Lewis et al. (2006)	3375
Diefenderfer and Apeagyei (2010)	3700
Kroge et al. (2009)	4260

Part 2: In-Place Recycling Layer Thicknesses

Recycled layer thicknesses ($t_{recycled}$) in mm are shown below for CIR and FDR. This list is composed of values from 35 CIR references and 10 FDR references. Thicknesses for the 185 CIR values are generally much less than that of the 16 FDR values. The mean values for CIR and FDR are 83 and 216, respectively.

CIR Reference	$t_{recycled}$ (mm)
Scholz et al. (1991b)	25
Scholz et al. (1991b)	38
Scholz et al. (1991b)	38
Scholz et al. (1991b)	38
Scholz et al. (1991b)	38
Rogge et al. (1992)	38
Kim et al. (2010)	446
Scholz et al. (1991b)	50
Scholz et al. (1991b)	50
Scholz et al. (1991b)	50
Kim et al. (2010)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51

CIR Reference	$t_{recycled}$ (mm)
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Scholz et al. (1991b)	51
Rogge et al. (1992)	51
Rogge et al. (1992)	51
Sebaaly et al. (2004)	51
Sebaaly et al. (2004)	51
Loria et al. (2008)	51
Loria et al. (2008)	51
Loria et al. (2008)	51
Loria et al. (2008)	51
Loria et al. (2008)	51
Scholz et al. (1991b)	60
Scholz et al. (1991b)	60
Babaei and Walter (1989)	63
Bradbury et al. (1991)	75
Gumbert and Harris (1993)	75
Kim and Lee (2008)	75
Yan et al. (2009)	75
Yan et al. (2009)	75

CIR Reference	$t_{recycled}$ (mm)	CIR Reference	$t_{recycled}$ (mm)	CIR Reference	$t_{recycled}$ (mm)
Yan et al. (2009)	75	Morian et al. (2004)	76	Kim et al. (2010)	102
Charmot and Romero (2010)	75	Morian et al. (2004)	76	Kim et al. (2010)	102
Charmot and Romero (2010)	75	Morian et al. (2004)	76	Kim et al. (2010)	102
Kandhal and Koehler (1987)	76	Morian et al. (2004)	76	Kim et al. (2010)	102
Kandhal and Koehler (1987)	76	Morian et al. (2004)	76	Kim et al. (2010)	102
Scholz et al. (1991b)	76	Sebaaly et al. (2004)	76	Kim et al. (2010)	102
Jahren et al. (1998)	76	Loria et al. (2008)	76	Kim et al. (2010)	102
Jahren et al. (1998)	76	Loria et al. (2008)	76	Kim et al. (2010)	102
Cross et al. (2002)	76	Loria et al. (2008)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Henault and Kilpatrick (2009)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Johnston (2011)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Kim et al. (2010)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Kim et al. (2010)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Kim et al. (2010)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Kim et al. (2010)	76	Kim et al. (2010)	102
Morian et al. (2004)	76	Martinez et al. (2007)	80	Anderson (1985)	102
Morian et al. (2004)	76	Kim et al. (2010)	81	HWYS (1986)	102
Morian et al. (2004)	76	Cross et al. (2002)	87	Dudley et al. (1987)	102
Morian et al. (2004)	76	Bandyopadhyay et al. (1982)	88	Babaei and Walter (1989)	102
Morian et al. (2004)	76	Charmot and Romero (2010)	89	Jahren et al. (1998)	102
Morian et al. (2004)	76	Kim et al. (2010)	91	Jahren et al. (1998)	102
Morian et al. (2004)	76	Kim et al. (2010)	91	Jahren et al. (1998)	102
Morian et al. (2004)	76	Kim and Lee (2008)	100	Jahren et al. (1998)	102
Morian et al. (2004)	76	Charmot and Romero (2010)	100	Jahren et al. (1998)	102
Morian et al. (2004)	76	Charmot and Romero (2010)	100	Jahren et al. (1998)	102
Morian et al. (2004)	76	Charmot and Romero (2010)	100	Jahren et al. (1998)	102
Morian et al. (2004)	76	Charmot and Romero (2010)	100	Jahren et al. (1998)	102
Morian et al. (2004)	76	Kim and Lee (2011)	100	Jahren et al. (1998)	102
Morian et al. (2004)	76	Steward (1987)	101	Jahren et al. (1998)	102
Morian et al. (2004)	76	Babaei and Walter (1989)	101	Jahren et al. (1998)	102
Morian et al. (2004)	76	Scholz et al. (1991a)	101	Jahren et al. (1998)	102
Morian et al. (2004)	76	Scholz et al. (1991a)	101	Jahren et al. (1998)	102
Morian et al. (2004)	76	Kim et al. (2010)	102	Jahren et al. (1998)	102
Morian et al. (2004)	76	Kim et al. (2010)	102	Jahren et al. (1998)	102

CIR Reference	$t_{recycled}$ (mm)
Jahren et al. (1998)	102
Jahren et al. (1999)	102
Cross et al. (2002)	102
Cross et al. (2002)	102
Cross et al. (2002)	102
Cross et al. (2002)	102
Morian et al. (2004)	102
Morian et al. (2004)	102
Morian et al. (2004)	102
Morian et al. (2004)	102
Babaei and Walter (1989)	107
Chan et al. (2010b)	110
Babaei and Walter (1989)	112
Dudley et al. (1987)	115
Kandhal and Koehler (1987)	125
Babaei and Walter (1989)	125
McDaniel (1988)	127
Forsberg et al. (2002)	127
Diefenderfer et al. (2012)	127
Spelman (1983)	150
Badaruddin and McDaniel (1992)	150
Kim and Lee (2008)	150
Mottola and Chmiel (1990)	152
Spelman (1983)	200
Charmot and Romero (2010)	200
HWYS (1986)	229

FDR Reference	$t_{recycled}$ (mm)
Lewis et al. (2006)	150
Dai and Thomas (2011)	150
Pickett (1991)	152
Shepard et al. (1991)	152
Johnson et al. (2006)	152
Wolfe et al. (2009)	200
Miller et al. (2010)	200
Dai and Thomas (2011)	200
Nantung et al. (2011)	200
Diefenderfer and Apeagyei (2010)	250
Diefenderfer and Apeagyei (2010)	250
Diefenderfer and Apeagyei (2010)	250
Diefenderfer and Apeagyei (2010)	250
Wolfe et al. (2009)	300
Dai and Thomas (2011)	300
Pickett (1991)	305

Part 3: In-Place Recycling Moisture Contents

Recycled layer moisture contents are shown below for CIR and FDR. For CIR, ω_{mix} (%) is reported which corresponds to the mixing moisture content reported by the source. For FDR, *OMC* is reported which corresponds to the optimum moisture content reported by the source. ω_{mix} and *OMC* refer to total moisture content including add water, RAP moisture, and water present in emulsion. For practical purposes, the significance of these two values as it relates to this information is the same. This list is composed of values from 43 CIR references and 8 FDR references. Moisture contents for the 108 CIR values are generally much less than that of the 103 FDR values. The mean values for CIR and FDR are 3.5 and 7.2, respectively.

CIR Reference	ω_{mix} (%)
Steward (1987)	0.5
Mamlouk (1983)	1.0
Babaei and Walter (1989)	1.0
Cohen et al. (1989)	1.0
Epps (1990)	1.0
Khosla and Bienvenu (1996)	1.0
Mallela et al. (2006)	1.5
Mallela et al. (2006)	1.8
Mallela et al. (2006)	1.8
Mallela et al. (2006)	1.9
Mallela et al. (2006)	1.9
Mallela et al. (2006)	1.9
Mallela et al. (2006)	1.9
Mallela et al. (2006)	1.9

CIR Reference	ω_{mix} (%)
Mallela et al. (2006)	1.9
Babaei and Walter (1989)	2.0
Epps (1990)	2.0
Cross et al. (2002)	2.0
Mallela et al. (2006)	2.0
Mallela et al. (2006)	2.0
Dai et al. (2008)	2.0
Cross et al. (2002)	2.1
Lee et al. (2000)	2.2
Yan et al. (2009)	2.4
Yan et al. (2009)	2.4
Babaei and Walter (1989)	2.5
Bradbury et al. (1991)	2.5
Kim and Lee (2008)	2.5
Santagata et al. (2010)	2.5
Cross et al. (2002)	2.6
Yan et al. (2009)	2.6
Green and Fini (2011)	2.7
Wood et al. (1988)	3.0
Cross and Fager (1995)	3.0
Cross (1999)	3.0
Cross (2000)	3.0
Cross (2000)	3.0
Cross (2000)	3.0
Lee et al. (2000)	3.0
Lee et al. (2000)	3.0
Lee et al. (2000)	3.0
Cross and Jakatimath (2007)	3.0
Martinez et al. (2007)	3.0
Kim et al. (2011)	3.0
Cross and Jakatimath (2007)	3.1
Cross and Jakatimath (2007)	3.1
Cross et al. (2002)	3.2
Cross et al. (2002)	3.4
Yao et al. (2011)	3.4
Babaei and Walter (1989)	3.5
Lee et al. (2000)	3.5
Cross et al. (2002)	3.5
Cross and Jakatimath (2007)	3.6
Pasetto et al. (2004)	3.9
Kim and Lee (2006)	3.9
Kandhal and Koehler (1987)	4.0
Babaei and Walter (1989)	4.0
Scholz et al. (1991a)	4.0
Salomon and Newcomb (2000)	4.0
Salomon and Newcomb (2000)	4.0
Salomon and Newcomb (2000)	4.0
Salomon and Newcomb (2000)	4.0
Pasetto et al. (2004)	4.0
Sebaaly et al. (2004)	4.0
Sebaaly et al. (2004)	4.0
Sebaaly et al. (2004)	4.0
Du and Cross (2006)	4.0
Du and Cross (2006)	4.0
Lee and Kim (2006)	4.0
Kim and Lee (2007)	4.0
Kim et al. (2007)	4.0
Kim et al. (2007)	4.0
Kim et al. (2007)	4.0
Kim et al. (2007)	4.0
Kim et al. (2007)	4.0
Kim et al. (2007)	4.0
Kim et al. (2007)	4.0
Lee et al. (2007)	4.0
Dai et al. (2008)	4.0
Kim and Lee (2008)	4.0
Lee and Im (2008)	4.0
Loria et al. (2008)	4.0
Benson et al. (2009)	4.0
Henault and Kilpatrick (2009)	4.0
Jenkins and Yu (2009)	4.0
Kim et al. (2011)	4.0
Mallela et al. (2006)	4.3
McDaniel (1968)	4.4
Babaei and Walter (1989)	4.4
Scholz et al. (1991a)	4.5
Lee and Kim (2003)	4.5
Pasetto et al. (2004)	4.5
Du and Cross (2006)	4.5
Cross and Jakatimath (2007)	4.7
Pasetto et al. (2004)	5.0
Pasetto et al. (2004)	5.0
Kim and Lee (2006)	5.0
Carter et al. (2010)	5.0
Kim and Lee (2006)	5.1
Babaei and Walter (1989)	6.0
Pasetto et al. (2004)	6.0
Yao et al. (2011)	6.4
Carter et al. (2010)	6.5
Carter et al. (2010)	6.5
Carter et al. (2010)	6.5
Crispino and Brovelli (2011)	7.0
Cross and Fager (1995)	8.0
Cross and Fager (1995)	8.0

FDR Reference	*OMC* (%)
Bang et al. (2011)	4.5
Johnson et al. (2006)	4.8
Bang et al. (2011)	5.0
Mallick et al. (2002)	5.0
Mallick et al. (2002)	5.0
Mallick et al. (2002)	5.0
Bang et al. (2011)	5.1
Bang et al. (2011)	5.2
Bang et al. (2011)	5.2
Bang et al. (2011)	5.2
Bang et al. (2011)	5.3
Johnson et al. (2006)	5.3
Bang et al. (2011)	5.5
Johnson et al. (2006)	5.6
Bang et al. (2011)	5.8
Bang et al. (2011)	5.8
Bang et al. (2011)	5.9
Johnson et al. (2006)	6.0
Johnson et al. (2006)	6.0
Bang et al. (2011)	6.0
Bang et al. (2011)	6.1
Bang et al. (2011)	6.1
Besseche et al. (2009)	6.2
Bang et al. (2011)	6.3
Bang et al. (2011)	6.3
Bang et al. (2011)	6.3
Yuan et al. (2011)	6.3
Bang et al. (2011)	6.5
Bang et al. (2011)	6.5
Bang et al. (2011)	6.5
Bang et al. (2011)	6.5
Bang et al. (2011)	6.6
Bang et al. (2011)	6.6
Bang et al. (2011)	6.7
Bang et al. (2011)	6.7

FDR Reference	*OMC* (%)
Bang et al. (2011)	6.7
Bang et al. (2011)	6.8
Bang et al. (2011)	6.8
Bang et al. (2011)	6.9
Mallick et al. (2002)	7.0
Bang et al. (2011)	7.0
Bang et al. (2011)	7.0
Bang et al. (2011)	7.0
Bang et al. (2011)	7.1
Bang et al. (2011)	7.1
Bang et al. (2011)	7.1
Bang et al. (2011)	7.2
Bang et al. (2011)	7.2
Bang et al. (2011)	7.2
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.3
Bang et al. (2011)	7.4
Bang et al. (2011)	7.4
Bang et al. (2011)	7.4
Bang et al. (2011)	7.4
Hilbrich and Scullion (2008)	7.5
Bang et al. (2011)	7.5
Bang et al. (2011)	7.5
Bang et al. (2011)	7.5
Bang et al. (2011)	7.6
Bang et al. (2011)	7.6
Bang et al. (2011)	7.6
Bang et al. (2011)	7.7
Bang et al. (2011)	7.7

FDR Reference	*OMC* (%)
Bang et al. (2011)	7.7
Bang et al. (2011)	7.8
Bang et al. (2011)	7.8
Bang et al. (2011)	7.8
Bang et al. (2011)	7.9
Bang et al. (2011)	7.9
Bang et al. (2011)	7.9
Bang et al. (2011)	8.1
Thomas and May (2007)	8.1
Bang et al. (2011)	8.1
Bang et al. (2011)	8.1
Yuan et al. (2011)	8.2
Bang et al. (2011)	8.3
Bang et al. (2011)	8.3
Bang et al. (2011)	8.6
Bang et al. (2011)	8.6
Bang et al. (2011)	8.6
Bang et al. (2011)	8.6
Bang et al. (2011)	8.9
Bang et al. (2011)	8.9
Bang et al. (2011)	9.0
Bang et al. (2011)	9.0
Bang et al. (2011)	9.2
Bang et al. (2011)	9.2
Bang et al. (2011)	9.2
Bang et al. (2011)	9.3
Bang et al. (2011)	9.5
Bang et al. (2011)	9.8
Lewis et al. (2006)	9.8
Bang et al. (2011)	9.8
Liu and Nie (2010)	10.2
Bang et al. (2011)	10.3
Bang et al. (2011)	10.3

Part 4: In-Place Recycling Binders

Recycled layer binder dosages are shown below for CIR and FDR. This list is composed of values from 61 CIR references and 16 FDR references. Dosages of any binder for the 198 CIR values are generally less than that of the 117 FDR values. Emulsion use is observed more in CIR while cement and fly ash are observed more in FDR. Approximately 18% and 15% of CIR and FDR mixtures used combination binders, but these blends were typically dominated by a primary binder with a small dosage of a secondary binder as opposed to a balanced blend of both binders (e.g. 2.7% emulsion plus 1% cement). FAC refers to foamed asphalt cement, and Hyd. Lime refers to hydrated lime. Dosages are reported as a percentage of RAP mass.

CIR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Scholz et al. (1991b)	0.3	---	---	---	---
Scholz et al. (1991b)	0.5	---	---	---	---
Scholz et al. (1991b)	0.5	---	---	---	---
Rogge et al. (1992)	0.5	---	---	---	---
Scholz et al. (1991b)	0.6	---	---	---	---
Babaei and Walter (1989)	0.8	---	---	---	---
Cross and Fager (1995)	0.9	---	---	---	5.0
Scholz et al. (1991b)	0.9	---	---	---	---
Cross and Young (1997)	1.0	---	---	1.5	---
Sebaaly et al. (2004)	1.0	---	---	1.5	---
Cross and Fager (1995)	1.0	---	---	---	5.0
Scholz et al. (1991a)	1.0	---	---	---	---
Scholz et al. (1991b)	1.0	---	---	---	---
Scholz et al. (1991b)	1.0	---	---	---	---
Scholz et al. (1991b)	1.0	---	---	---	---
Scholz et al. (1991b)	1.0	---	---	---	---

CIR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Scholz et al. (1991b)	1.0	---	---	---	---
Scholz et al. (1991b)	1.0	---	---	---	---
Rogge et al. (1992)	1.0	---	---	---	---
Rogge et al. (1992)	1.0	---	---	---	---
Rogge et al. (1992)	1.0	---	---	---	---
Cross and Fager (1995)	1.0	---	---	---	---
Cross and Ramaya (1995)	1.0	---	---	---	---
Cross and Young (1997)	1.0	---	---	---	---
Cross (1999)	1.0	---	---	---	---
Mallela et al. (2006)	1.0	---	---	---	---
Mallela et al. (2006)	1.0	---	---	---	---
Kim and Lee (2010)	1.0	---	---	---	---
Kim and Lee (2010)	1.0	---	---	---	---
Scholz et al. (1991b)	1.1	---	---	---	---
Rogge et al. (1992)	1.1	---	---	---	---
Cross et al. (2002)	1.1	---	---	---	---
Mallela et al. (2006)	1.1	---	---	---	---
Mallela et al. (2006)	1.1	---	---	---	---
Mallela et al. (2006)	1.1	---	---	---	---
Dai et al. (2008)	1.2	---	---	---	---
Scholz et al. (1991b)	1.2	---	---	---	---
Scholz et al. (1991b)	1.2	---	---	---	---
Scholz et al. (1991b)	1.2	---	---	---	---
Scholz et al. (1991b)	1.2	---	---	---	---
Lee et al. (2000)	1.2	---	---	---	---
Lee et al. (2000)	1.2	---	---	---	---
Lee et al. (2000)	1.2	---	---	---	---
Mallela et al. (2006)	1.2	---	---	---	---
Bradbury et al. (1991)	1.3	---	---	---	---
Scholz et al. (1991b)	1.3	---	---	---	---
Scholz et al. (1991b)	1.3	---	---	---	---

CIR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Kazmierowski et al. (1992)	1.3	---	---	---	---
Mallela et al. (2006)	1.3	---	---	---	---
Mallela et al. (2006)	1.3	---	---	---	---
Mallela et al. (2006)	1.3	---	---	---	---
Mallela et al. (2006)	1.3	---	---	---	---
Sebaaly et al. (2004)	1.4	---	---	1.0	---
Scholz et al. (1991b)	1.4	---	---	---	---
Scholz et al. (1991b)	1.4	---	---	---	---
Rogge et al. (1992)	1.4	---	---	---	---
Lee et al. (2000)	1.4	---	---	---	---
Cross (2000)	1.5	---	---	1.0	---
Du and Cross (2006)	1.5	---	---	1.5	---
Thomas et al. (2000)	1.5	---	---	1.5	---
Cross et al. (2002)	1.5	---	---	1.5	---
Du and Cross (2006)	1.5	---	---	---	---
HWYS (1986)	1.5	---	---	---	---
Steward (1987)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Scholz et al. (1991b)	1.5	---	---	---	---
Rogge et al. (1992)	1.5	---	---	---	---
Rogge et al. (1992)	1.5	---	---	---	---
Rogge et al. (1992)	1.5	---	---	---	---
Rogge et al. (1992)	1.5	---	---	---	---
Cross (2000)	1.5	---	---	---	---
Forsberg et al. (2002)	1.5	---	---	---	---
Bemanian et al. (2006)	1.5	---	---	---	---
Du and Cross (2006)	1.5	---	---	---	---
Mallela et al. (2006)	1.5	---	---	---	---
Scholz et al. (1991b)	1.6	---	---	---	---
Scholz et al. (1991b)	1.6	---	---	---	---
Scholz et al. (1991b)	1.6	---	---	---	---
Mallela et al. (2006)	1.6	---	---	---	---
Scholz et al. (1991b)	1.7	---	---	---	---
Scholz et al. (1991b)	1.7	---	---	---	---
Scholz et al. (1991b)	1.7	---	---	---	---
Scholz et al. (1991b)	1.7	---	---	---	---
Moore et al. (2011)	1.8	---	0.8	---	---
Moore et al. (2011)	1.8	---	---	0.8	---
Emery (2006)	1.8	---	---	---	---
Scholz et al. (1991b)	1.8	---	---	---	---
Green and Fini (2011)	1.9	---	---	---	---
Cross and Young (1997)	1.9	---	---	---	7.0
Scholz et al. (1991a)	1.9	---	---	---	---
Anderson (1985)	2.0	---	---	---	---
Kandhal and Koehler (1987)	2.0	---	---	---	---
Kandhal and Koehler (1987)	2.0	---	---	---	---
Babaei and Walter (1989)	2.0	---	---	---	---
Babaei and Walter (1989)	2.0	---	---	---	---
Cross et al. (2002)	2.0	---	---	---	---
Cross and Jakatimath (2007)	2.0	---	---	---	---
Cross et al. (2002)	2.1	---	---	---	---
Cross et al. (2002)	2.2	---	---	1.6	---
Scholz et al. (1991b)	2.2	---	---	---	---
Yao et al. (2011)	2.3	---	1.0	---	---

CIR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Sebaaly et al. (2004)	2.5	---	---	1.0	---
Mamlouk (1983)	2.5	---	---	---	---
McDaniel (1988)	2.5	---	---	---	---
Babaei and Walter (1989)	2.5	---	---	---	---
Cross et al. (2002)	2.5	---	---	---	---
Scholz et al. (1991b)	2.6	---	---	---	---
Carter et al. (2010)	2.7	---	1.0	---	---
Carter et al. (2010)	2.7	---	1.0	---	---
Carter et al. (2010)	2.7	---	1.0	---	---
Carter et al. (2010)	2.7	---	1.0	---	---
Cross and Jakatimath (2007)	2.7	---	---	---	---
Morian et al. (2004)	2.8	---	---	---	---
Scholz et al. (1991b)	2.8	---	---	---	---
Gamache and Pluta (2005)	3.0	---	1.0	---	---
Crispino and Brovelli (2011)	3.0	---	2.0	---	---
Kim et al. (2011)	3.0	---	---	---	---
Kandhal and Koehler (1987)	3.0	---	---	---	---
Kandhal and Koehler (1987)	3.0	---	---	---	---
Gamache and Pluta (2005)	3.0	---	---	---	---
Cross and Jakatimath (2007)	3.0	---	---	---	---
Babaei and Walter (1989)	3.2	---	---	---	---
Babaei and Walter (1989)	3.3	---	---	---	---
Forsberg et al. (2002)	3.3	---	---	---	---
Yao et al. (2011)	3.5	---	1.0	---	---
Santagata et al. (2010)	3.5	---	2.5	---	---
Babaei and Walter (1989)	3.5	---	---	---	---
Martinez et al. (2007)	3.5	---	---	---	---
Cross and Jakatimath (2007)	3.6	---	---	---	---
Cross and Jakatimath (2007)	3.6	---	---	---	---
Mamlouk (1983)	3.7	---	---	---	---
Yan et al. (2009)	3.8	---	2.0	---	---

CIR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Yan et al. (2009)	3.8	---	2.0	---	---
Yan et al. (2009)	4.0	---	2.0	---	---
Mallela et al. (2006)	4.0	---	---	---	---
Cohen et al. (1989)	5.0	---	---	---	---
Babaei and Walter (1989)	5.5	---	---	---	---
Dudley et al. (1987)	6.8	---	---	---	---
Dai et al. (2008)	---	1.0	---	---	---
Jenkins and Yu (2009)	---	1.0	---	---	---
Chan et al. (2010a)	---	1.0	---	---	---
Moore et al. (2011)	---	1.3	0.8	---	---
Moore et al. (2011)	---	1.3	---	0.8	---
Kim et al. (2007)	---	1.7	---	---	---
Kim and Lee (2008)	---	1.8	---	---	---
Kim et al. (2007)	---	1.9	---	---	---
Diefenderfer et al. (2012)	---	2.0	1.0	---	---
Kim et al. (2011)	---	2.0	---	---	---
Lee and Kim (2006)	---	2.0	---	---	---
Kim and Lee (2007)	---	2.0	---	---	---
Lee et al. (2007)	---	2.0	---	---	---
Kim and Lee (2008)	---	2.0	---	---	---
Kim and Lee (2008)	---	2.0	---	---	---
Loria et al. (2008)	---	2.0	---	---	---
Henault and Kilpatrick (2009)	---	2.0	---	---	---
Jenkins and Yu (2009)	---	2.0	---	---	---
Kim et al. (2007)	---	2.1	---	---	---
Kim et al. (2007)	---	2.1	---	---	---
Kim et al. (2007)	---	2.1	---	---	---
Plati and Papavasilio (2011)	---	2.3	1.0	---	---
Kim et al. (2007)	---	2.3	---	---	---
Kim et al. (2007)	---	2.3	---	---	---
Loizos et al. (2007)	---	2.5	1.0	---	---

CIR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Pasetto et al. (2004)	---	2.5	1.5	---	---
Lee and Kim (2003)	---	2.5	---	---	---
Kim and Lee (2008)	---	2.5	---	---	---
Lee and Im (2008)	---	2.5	---	---	---
Pasetto et al. (2004)	---	3.0	2.0	---	---
Pasetto et al. (2004)	---	3.0	2.0	---	---
Benson et al. (2009)	---	3.0	---	---	---
Loizos and Papavasiliou (2006)	---	3.2	1.0	---	---
Loizos et al. (2007)	---	3.2	1.0	---	---
Pasetto et al. (2004)	---	3.5	2.0	---	---
Pasetto et al. (2004)	---	3.5	2.5	---	---
Pasetto et al. (2004)	---	4.5	3.0	---	---
Cross et al. (2010)	---	---	0.5	---	---
Yan et al. (2009)	---	---	2.0	---	---
Berthelot et al. (2010)	---	---	2.0	---	---
Diefenderfer et al. (2012)	---	---	3.0	---	---
Cross and Young (1997)	---	---	---	---	3.0
Cross and Fager (1995)	---	---	---	---	5.0
Cross and Fager (1995)	---	---	---	---	7.0
Thomas et al. (2000)	---	---	---	---	10.0
Cross (2000)	---	---	---	---	10.0
Cross and Young (1997)	---	---	---	---	11.0
Cross and Young (1997)	---	---	---	---	15.0
Cross and Young (1997)	---	---	---	---	19.0
Dudley et al. (1987)	---	---	---	---	---
Babaei and Walter (1989)	---	---	---	---	---
Mallela et al. (2006)	---	---	---	---	---

FDR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Dai and Thomas (2011)	1.3	---	---	---	---
Nantung et al. (2011)	1.3	---	3.0	---	---
Wolfe et al. (2009)	1.4	---	---	---	---
Wolfe et al. (2009)	1.6	---	2.0	---	---
Mallick et al. (2002)	2.2	---	---	---	---
Bang et al. (2011)	3.0	---	---	1.0	---
Bang et al. (2011)	3.0	---	---	---	---
Dai and Thomas (2011)	3.0	---	---	---	---
Quick and Guthrie (2011)	3.3	---	---	---	---
Mallick et al. (2002)	3.4	---	---	2.0	---
Mallick et al. (2002)	3.4	---	---	---	---
Diefenderfer and Apeagyei (2010)	3.5	---	1.0	---	---
Thomas and May (2007)	3.7	---	1.0	---	---
Hilbrich and Scullion (2008)	4.0	---	1.0	---	---
Dai and Thomas (2011)	4.0	---	---	---	---
Quick and Guthrie (2011)	4.2	---	---	---	---
Bang et al. (2011)	4.5	---	---	1.0	---
Besseche et al. (2009)	4.5	---	---	---	---
Kroge et al. (2009)	4.5	---	---	---	---
Bang et al. (2011)	4.5	---	---	---	---
Quick and Guthrie (2011)	4.8	---	---	---	---
Thomas and May (2007)	5.5	---	1.0	---	---
Bang et al. (2011)	6.0	---	---	1.0	---
Bang et al. (2011)	6.0	---	---	---	---
Bang et al. (2011)	---	2.5	1.0	---	---
Bang et al. (2011)	---	2.5	---	---	---
Diefenderfer and Apeagyei (2010)	---	2.7	1.0	---	---
Bang et al. (2011)	---	3.0	1.0	---	---
Bang et al. (2011)	---	3.0	---	---	---
Bang et al. (2011)	---	3.5	1.0	---	---

FDR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Bang et al. (2011)	---	3.5	---	---	---
Johnson et al. (2006)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Bang et al. (2011)	---	---	3.0	---	---
Miller et al. (2010)	---	---	4.0	---	---
Yuan et al. (2011)	---	---	4.0	---	---
Mallick et al. (2002)	---	---	5.0	---	---
Wolfe et al. (2009)	---	---	5.0	---	---
Diefenderfer and Apeagyei (2010)	---	---	5.0	---	---
Diefenderfer and Apeagyei (2010)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---
Bang et al. (2011)	---	---	5.0	---	---

FDR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Bang et al. (2011)	---	---	5.0	---	---
Johnson et al. (2006)	---	---	6.0	---	---
Lewis et al. (2006)	---	---	6.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Bang et al. (2011)	---	---	7.0	---	---
Wolfe et al. (2009)	---	---	---	4.0	6.0
Wolfe et al. (2009)	---	---	---	4.0	6.0
Liu and Nie (2010)	---	---	---	5.9	11.8
Wolfe et al. (2009)	---	---	---	---	5.0
Johnson et al. (2006)	---	---	---	---	9.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	10.0

FDR Reference	Emulsion	FAC	Cement	Hyd. Lime	Fly Ash
Bang et al. (2011)	---	---	---	---	10.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	12.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0
Bang et al. (2011)	---	---	---	---	15.0

Part 5: In-Place Recycling Gradations

Recycled layer gradations (i.e. bulk RAP gradations as opposed to extracted aggregate gradations) are shown below for CIR and FDR. This list is composed of values from 13 CIR references and 4 FDR references. Gradation for the 28 CIR gradations is generally coarser than that of the 10 FDR gradations. Average percent passing the 0.075 mm sieve 0.6% and 7.1% for CIR and FDR, respectively.

CIR Reference		McDaniel (1988)	Scholz et al. (1991a)	Scholz et al. (1991a)	Cross and Young (1997)	Cross (1999)	Lee et al. (2000)	Lee et al. (2000)	Lee et al. (2000)	Lee and Kim (2003)	Lee and Kim (2003)	Lee and Kim (2003)	Lee and Kim (2003)	Du and Cross (2006)	Cross and Jakatimath (2007)
Percent Passing	**25.0 mm**	100	95	92	100	100	100	100	98	100	100	100	100	100	100
	19.0 mm	98	89	89	90	97	90	96	92	97	99	97	94	96	97
	12.5 mm	88	76	82	72	83	76	86	83	86	96	88	77	85	80
	9.5 mm	76	62	73	61	70	66	75	72	76	90	78	64	78	66
	4.75 mm	48	34	45	39	42	43	48	48	51	67	48	30	64	39
	2.36 mm	32	---	---	24	23	23	27	29	32	49	35	22	45	25
	1.18 mm	22	---	---	13	11	16	12	16	20	33	23	15	26	17
	0.60 mm	15	---	---	7	5	9	4	8	10	18	13	8	14	10
	0.30 mm	9	---	---	2	2	4	1	3	3	6	4	3	4	5
	0.15 mm	5.7	---	---	1.0	0.4	1.5	0.3	0.8	0.5	1.0	0.8	0.5	0.7	2.0
	0.075 mm	4.2	0.5	1.9	0.6	0.1	0.4	0.1	0.2	0.1	0.2	0.2	0.1	0.1	0.7

CIR Reference		Kim et al. (2007)	Kim et al. (2007)	Kim et al. (2007)	Kim et al. (2007)	Kim et al. (2007)	Kim et al. (2007)	Kim et al. (2007)	Martinez et al. (2007)	Lee and Im (2008)	Lee and Im (2008)	Yan et al. (2009)	Yan et al. (2009)	Yan et al. (2009)	Charmot et al. (2013)
Percent Passing	**25.0 mm**	100	100	100	100	100	100	100	99	100	100	100	100	100	98
	19.0 mm	94	95	96	94	99	97	95	96	93	93	88	91	93	93
	12.5 mm	80	82	82	80	87	85	82	83	77	78	67	74	73	81
	9.5 mm	68	71	72	68	78	74	71	73	63	67	56	61	61	65
	4.75 mm	37	40	46	40	50	49	42	47	35	40	36	38	39	40
	2.36 mm	22	27	32	27	35	37	29	27	19	22	21	21	23	18
	1.18 mm	8	13	20	14	20	20	15	---	11	12	15	12	17	10
	0.60 mm	3	7	13	7	12	10	8	7	7	6	9	5	10	5
	0.30 mm	2	3	5	3	5	3	3	3	3	2	6	2	4	2
	0.15 mm	1.0	1.2	2.0	1.2	2.0	1.3	1.6	---	1.5	0.7	3.0	1.0	2.0	1.0
	0.075 mm	0.5	0.5	0.7	0.5	0.8	0.7	0.6	0.7	0.8	0.2	1.0	0.5	0.7	0.3

FDR Reference		Shepard et al. (1991)	Shepard et al. (1991)	Shepard et al. (1991)	Shepard et al. (1991)	Mallick et al. (2002)	Johnson et al. (2006)	Johnson et al. (2006)	Johnson et al. (2006)	Johnson et al. (2006)	Besseche et al. (2009)
Percent Passing	**25.0 mm**	100	100	100	100	100	97	99	95	98	100
	19.0 mm	97	100	99	100	100	95	96	91	94	88
	12.5 mm	---	---	---	---	87	80	85	77	81	71
	9.5 mm	---	---	---	---	76	67	71	67	68	61
	4.75 mm	---	---	---	---	58	45	48	47	44	46
	2.36 mm	43	20	34	30	47	32	37	34	32	36
	1.18 mm	---	---	---	---	35	24	27	24	23	29
	0.60 mm	21	12	17	13	22	17	19	17	16	25
	0.30 mm	---	---	---	---	12	12	13	12	12	19
	0.15 mm	---	---	---	---	6.0	9.0	10.0	10.0	9.0	14.0
	0.075 mm	7.0	7.0	7	6.0	3.5	7.9	8.2	8.2	7.4	8.9

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