Discussion of the following Blending Chart Examples;

The following blending charts and accompanying calculations follow examples in Chapter 11 of MS-2 Asphalt Mix Design Methods (7th Edition) by the Asphalt Institute, and are dependent on the following variables:

- a.) JMF binder content (tot wt. of the mix)
- b.) RAP binder content (tot wt. of rap)
- c.) Percent RAP (belt feed %'g)= Wt of (RAP AGG + RAP Binder)/(RAP AGG + RAP Binder + Virg Agg)x100%
- d.) The Projects Specified PG Binder Grade
- e.) The contractor proposed grade of the virgin binder
- f.) Critical Temperatures of the virgin binder and binder extracted from RAP

The upper portion of the spreadsheet calculates the "<u>RAP Agg in Agg Blend</u>", and the "<u>RAP Pavement Binder Ratio (RPBR)</u>" based on JMF info (i.e. variables a.), b.) and c.) above.

The lower portion calculates the <u>maximum RAP Agg in the Agg Blend</u> and the <u>maximum</u> <u>RPBR</u> as a function of the projects specified binder and the true grades of the virgin and binder extracted from RAP (i.e. variables d.), e.) and f.) above.

Two primary checks are performed:

"Proposed RPBR" must be < "the lowest maximum RPBR from the four blending charts"

and " must be < either 0.40 or 0.25 (dependent on

"%RAP Agg in the Agg Blend" **must be <** "maximum RAP Agg in the Agg Blend"

and **must be <u><</u> 25%**

Strikethrough text and red text are used to indicate when one or both conditions are not met.

See next sheet for a summary of the example blending charts.

Example 1: An existing JMF using a project specified PG70-10 binder and greater than 15% RAP is examined per CPD 16-___. The JMF must be analyzed to determine if the blended binder (virgin and rap binder) when combined at the percentages defined in the JMF meets the specifications for the projects specified binder. Critical temps (i.e. true grades) of the virgin and RAP binder are determined and entered on the spreadsheet with the JMF info (yellow cells). The virgin and extracted RAP binder grades and the projects specified binder grades are plotted on the blending charts. The max RAP pavement binder ratio (i.e. binder replacement ratio) is determined to be 0.1266 (12.66%) which is less the current design RPBR of 0.28. Therefore this JMF needs to be revised. (See examples #2a, 2b and 2c for options).

Example 2a: Here we determine potential options to revise the JMF in Ex#1 where the RPBR exceeded the maximum determined from the blending charts. In this example, the virgin binder is bumped down a grade from PG 70-10 to PG 64-16. Under the initial assumption that true grading will be used during production, we select NO in cell B2, and enter the true grades for the virgin PG 64-16, leaving the 70-10 grades unmodified (same RAP stockpile). Using the same JMF BC (which may change) indicates that "Max RAP agg in the Agg Blend" is 18.57%. With this value, the %RAP (belt feed %) is lowered from 25% to 19.5% which lowers the RAP Agg in Agg Blend to 18.42% (less than 18.57% max shown to its right).

Example 2b: In this example, we use the same RAP true grades, and the same virgin binder as in example 2a, but under the assumption that we will use the "Certification Program for Suppliers of Asphalt" to establish the critical temps of the virgin binder. Selecting YES in cell B2 automatically populates the virgin binder true grade based on the selected virgin binder grade of PG 64-16. Note the virgin binder true grade cells are no longer "yellow" and are populated with vertical lookup equations from tables elsewhere on the spreadsheet. *Entering a value in these cells overwrites the equations that automatically populate the cells. These equations can be automatically re-populated by clicking the button immediately to the right.* Using the previous examples RAP Binder critical temps, limits the RAP Agg in Agg Blend to 14.35% (less than 15%). In this example, per specifications, the contractor could use 15.2% percent RAP (% belt feed) which corresponds to 14.35% RAP aggregate in the aggregate blend (which is less than 15%). Summarizing this example, as the contractor is choosing to rely on the "Certification Program for Suppliers of Asphalt" to determine the true grades of the virgin binder (rather than weekly testing discussed in example 2a), the blending charts indicate that they cannot use more than 15% RAP aggregate in the aggregate blend.

Example 2c: To allow a higher percentage RAP be used than in the previous examples 2a and 2b, in this example, the virgin binder is dropped two grades from a PG 70-10 to a PG 58-22. "YES" was selected in cell B2 to indicate that the "Certification Program for Suppliers of Asphalt" will be used to control the virgin binder (i.e. weekly true grading of the virgin binder not required). Selecting "YES" replaces the virgin binder true grades with the most conservative values for a PG 58-22. Using these values, the max RPBR pulled from the blending charts is 25.32%, which exceeds 25% maximum covered by the specifications, therefore the 25% maximum controls. The Percent RAP (percentage of belt feed) is lowered until the RAP aggregate in the agg blend is less than 25%. In this example the Percent RAP (percentage of belt feed) is lowered to 26%, given the JMF OBC and RAP BC, equates to a RAP Aggregate in the Aggregate blend amount of 24.67% (less than the 25% max). RPBR values up to 0.40 are allowed by specification in lifts below the upper 0.20' of the layer, but only up to 0.25 in the upper 0.20 of the layer. As the corresponding RPBR is 0.292, this HMA with RAP to be placed below the upper 0.20' of the HMA layer. To use this material in the upper 0.20 of the layer, the RAP (percentage belt feed) has to be reduced from 26% to 22.3% or less to prevent the RPBR from exceeding 0.25.

Example 1: An existing JMF using a project specified PG70-10 binder and greater than 15% RAP is examined per CPD 16-___. The JMF must be analyzed to determine if the blended binder (virgin and rap binder) when combined at the percentages defined in the JMF meets the specifications for the projects specified binder. Critical temps (i.e. true grades) of the virgin and RAP binder are determined and entered on the spreadsheet with the JMF info (yellow cells). The virgin and extracted RAP binder grades and the projects specified binder grades are plotted on the blending charts. The max RAP pavement binder ratio (i.e. binder replacement ratio) is determined to be 0.15 which is less the current design RPBR of 0.28. Therefore this JMF needs to be revised. (See examples #2a, 2b and 2c for options). The resulting 23.7% RAP Agg Blend must also be less than the 12.66% Max RAP Agg Blend.

rans	Blendi	ng Chart for blendi	ing V	/irgin ar	nd RAP Binders	(>15%	RAP)			
NO	Select YES performin using the i to be "bur also produ	ntractor using the COC program if the contractor plans to use the "C g weekly true grade testing of the viry nost conservative values that corresp uped down" one grade when using R ction. If the RAP pile gets augmente if the contractor plans to perform tr	Certification gin binde pond to the AP Aggrea ed, new t	ion Program for er. Selecting Y the chosen virg egate %g's exce true grades of f	r Suppliers of Asphalt" as a cor ES, auto populates the Virgin E in binder. These assumed valu eding 15%. These assumed vii the extracted RAP binder must	ntrol check of Binder critical Jes typically r rgin binder cr t be determir	f the virgin b I temperatur require the p ritical temp v ned and usec	inder critical t res in the "True proposed virgin values must be d from that po	emperatures, rat e Grade Test Data n binder grade (in e used during the int forward.	a table" 04/21/16 a cell E36) © 2016 Califor JMF and Department of Transportation
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nforma		Gray cells are general	info in	nput	Yellow cells are Us	<mark>er requir</mark>	ed value	es that dri	ve blending	; charts
	or Project ID): JMF No.	Rte 247 Rehab near Mythical Valley 08-123454 1922-28c-3cxxx 08-SBD-247-PM12.3/45.6					HMA Plant:	HMA Builders Hot Mix w/ R/ John Smith		
	HMA Type:	3/4" HMA Type A w/ xx%RAP	Striket		through indicates JM	hrough indicates JMF			Business, Inc.	
		Binder Source:		needs	to be revised			Bid Item #	55	
		% JMF OBC (xta)=>	5	5.80%	*Xta, total asphalt content of weight of the mix	HMA from JM	IF, expressed]
		% RAP BC (xra)=>		5.80%	*Xra, asphalt content of RAP	expressed as	a percentag	e of the total w		
Pe	ercent RAP	(percentage of belt feed) =>		5.00%	where RAP% = [(Wt of RAF	P)/(Wt of Virg	gin Agg + W	t of RAP)]x10	0%	
	ons limit this to	the lesser of 25% or as determined from 23.70%		function of the above 3 variables when RAP Agg% = [(1 /xra)-1]/[((1 /xra)/RAI Strikethrough Red font indicates value	P%)-1)	eds cell 116)	12.66%		<= Minimum of 25% or "Max RAP Agg Agg Blend as based on Lowest Max RPI value from blending charts"(Calc'd bek in cell H53)	
					<=A function of JMF OBC, RAP BC and RAP Agg in Agg%, where; RPBR=[([RAP Agg%)/(1-Xra)]x(Xra)x(1-Xta)]/Xta Red text is a reminder when this value exceeds 0.25, and that specifications limit material placed in the upper 0.2' to 0.25 (or 25% 0.2'.					
Ma	aximum allo	wed in the upper 0.2 feet of HMA e of OGFC) is 25% and 40% below.		0.280	Red text is a reminder when this value					to 0.25 (or 25%), 0.40 (40%) in areas
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Xta, total asphalt content of HMA from JMF, expressed as a percentage of the total weight of the mix=>	5.80%	% <= % JMF OBC (x _{ta})	
Xra, asphalt content of RAP expressed as a percentage of the total weight of the RAP=>	6.80%	% <= % RAP BC (x _{ra})	
Lowest Max RPBR from 4 blending Charts=>	0.15	<= a function of the true grades of virgin and reclaimed rap binder	
Max RAP Agg in Agg Blend corresponding to Lowest Max RPBR	12.66%	a function of the above 3 variables	

For questions or comments on this blending chart, contact pete.spector@dot.ca.gov, 916-227-7306



Example 2a: Here we determine potential options to revise the JMF in Ex#1 where the RPBR exceeded the maximum determined from the blending charts. In this example, the virgin binder is bumped down a grade from PG 70-10 to PG 64-16. Under the initial assumption that true grading will be used during production, we select NO in cell B2, and enter the true grades for the virgin PG 64-16, leaving the 70-10 grades unmodified (same RAP stockpile). Using the same JMF BC (which may change) indicates that "Max RAP agg in the Agg Blend" is 18.57%. With this value, the %RAP (belt feed %) is lowered from 25% to 19.5% which lowers the RAP Agg in Agg Blend to 18.42% (less than 18.57%). In the next example 2b, we will assume the same virgin binder, but use the "Certification Program for Suppliers of Asphalt", which assumes the most conservative critical temps for the virgin PG 64-16.

Cal	trans B	Blendii	ng Chart for blendi	ng Virgin an	d RAP Binders	(>15% RAP)				Ŭ		
	Spread: Select YES if the contractor using the COC program for true grading the virgin binder (rather than performing weekly true grade testing)? Select YES if the contractor plans to use the "Certification Program for Suppliers of Asphalt" as a control check of the virgin binder critical temperatures, rather than performing weekly true grade testing of the virgin binder. Selecting YES, auto populates the Virgin Binder critical temperatures in the "True Grade Test Data table" using the most conservative values that correspond to the chosen virgin binder. These assumed values typically require the proposed virgin binder grade (in cell E36) Dorduction. If the RAP pile gets augmented, new true grades of the extracted RAP binder must be determined and used from that point forward. Transport									preadsheet evision Date 04/21/16 2016 California Oppartment of ransportation Page 1 of 2 California		
JMF	Informat	ion	Gray cells are general i	info input	Yellow cells are Us	er required value	<mark>es that dri</mark>	ve blending	charts			
	EA (oi	r Project ID): JMF No. Co/Rte/PM:	Rte 247 Rehab near Mythical Valley 08-123454 1922-28c-3cxxx 08-SBD-247-PM12.3/45.6 3/4" HMA Type A w/ xx%RAP		Contractor: HMA Builders Inc. HMA Plant: Hot Mix w/ RAP Inc. QC Manager: John Smith Resident Engineer: Jane Doe							
		nima type.				QC Lab.	Quality Is Our					
			Binder Source: % JMF OBC (xta)=>	5.80%	*Xta, total asphalt content of	HMA from JMF, expresse	Bid Item # d as a percenta	55 ge of the tota	1			
			% RAP BC (xra)=>	6.80%	weight of the mix *Xra, asphalt content of RAP	expressed as a percentad	se of the total w	eight of the RAP	-			
	Por	cont PAD	(percentage of belt feed) =>	19.50%	where RAP% = [(Wt of RA			•				
	Specification	RAP Age	pregate in the Aggregate Blend => the lesser of 25% or as determined from mum RPBR value on the blending charts.	18.42%	function of the above 3 variables whe RAP Agg% = [(1 /xra)-1]/[((1 /xra)/RA Strikethrough Red font indicates valu	e; %)-1)		18.57%	<= Minimum of 25% or "Max RAP Agg in Agg Blend as based on Lowest Max RPBR value from blending charts"(Calc'd below in cell H53)			
	•	kimum allo	Pavement Binder Ratio (RPBR)=> wed in the upper 0.2 feet of HMA e of OGFC) is 25% and 40% below.	0.218 🬾	<=A function of JMF OBC, RAP BC and Red text is a reminder when this value 0.2'.	RAP Agg in Agg%, where; RPBR=[exceeds 0.25, and that specificat	tions limit material p	cent R/	AP (belt	40%) in areas below		
True	Grade Te	est Data	Table				fee	d %) lo\	wered			
	Enter Criti	ical Temp	erature (True Grading) Test I	Results for Virgin B	linder and Extracted b	nder from RAP.		il resulti BR and	•			
				TEMP RANGE	Virgin Binder(°c)	RAP Binder(°C)	Pinde	P Agg i				
		Original	DSR G*/sin(delta), ≥1.00 kPa	High	67	n/a		nd valu				
		RTFO	DSR G*/sin(delta), \geq 2.20 kPa	High	68	103			naximun			
		PAV	DSR G*sin(delta), ≤ 5,000 kPa BBR Stiffness, "S" ≤ 300MPa	Intermediate Low	28 -18	44 5			ιαλιπιμι			
			BBR m-value, m ≥ 0.300	Low	-18	7	and	wed				
			p, enter True Grade values which are 10C te test temperature. The plotted low test	Lowest "High" Highest "Low	-23 · 67 -18	103	-	Date:				
			10C higher than the True Grade.	Actual (True Grade)	PG 67-18	PG 103+7						
			PG	Equivalent M320 grade	PG 64-16	PG 10377	1					
				On M3	20 Table and in CT SS Sec 92							
Spec			le / Blended Binder Grad	e / CHECKS on P	roduction HMA Mi	ture Binder Grad	de against	contract sp	ecs.	r		
	-		cified Binder Grade =>	PG 70-10	<= The PG Grade selected here popula	es the horizontal lines on the bler	nding charts.					
	Prop	posed V	/irgin Binder Grade =>	PG 64-16	<= Per specification, when using RAP exceeding 15%, contractor may bump down one grade. See graphic in cell s19 for "likely cho					imping down a grade.		
	"HMA I	Mixture Bir	nder Grade" at Proposed RPBR =>	PG 75-13	<=For High PG Temp, where For Low PG temp, where "R							
			mination of HMA Mixture Binder here the RPBR (black line) crosses			Lower Spec Upper Spec Limit Limit Temp Temp Binder wi			mps of Blended in Production ances.			
	High Temp Blending Line Crosses Proposed RPBR at Tcrit= 75					75	70	77		ок Ок		
			ng Line Crosses Proposed RPBR at Tcrit=	31 Low Test Temp	Low Grade Temp (-10C)	31 Highest Low Temp	n/a	34	· · · · · ·	JK		
	Low Temp Stiffness (S) Crosses Proposed RPBR at Tcrit= -3 -13 n/a -8 OK Low Temp m-value Crosses Proposed RPBR at Tcrit= -6 -16 -13 n/a -8									ЭК		
Calc'	s for Che	ck on M	ax Allowable RAP Aggreg	ate in the Aggre	gate Blend (aka %R	AP)						
	Xta, total asphalt content of HMA from JMF, expressed as a percentage of the total weight of the mix=> 5.80% <= % JMF OBC (x _{in}) Xra, asphalt content of RAP expressed as a percentage of the total weight of the RAP=> 6.80% <= % RAP BC (x _{in}) Lowest Max RPBR from 4 blending Charts=> 0.22 Max RAP Agg in Agg Blend corresponding to Lowest Max RPBR 0.22											
				50			18.57%	a runction of the	above 3 variables			

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Example #2b. In the previous example, when we chose the option to perform true grading of the binder on a weekly basis, the max RAP % was 19.5%. Here we determine the amount under the assumption that we will use the Certification Program for Suppliers of Asphalt to control the virgin binder. Selecting YES in cell B2 populates the virgin binder grade with the most conservative values (note these cells are not yellow, they are populated automatically based on the "Proposed Virgin Binder Grade"). Using the previous examples RAP Binder critical temps, limits the RAP Agg in Agg Blend to 14.35%, which is less than 15%. In this example, per specications, the contractor could use 15.2% percent RAP (%belt feed), which correspon

			egate in the aggregate blend					harts.			
Calt	altrans Blending Chart for blending Virgin and RAP Binders (>15% RAP)										
		Select YES	if the contractor plans to use the "C	ertification Program for	virgin binder (rather than performing weekly true grade testing)? suppliers of Asphalt" as a control check of the virgin binder critical temperatures, rather than , auto populates the Virgin Binder critical temperatures in the "True Grade Test Data table"					Spreadsheet Revision Date	
	YES		most conservative values that corresp							04/21/16 © 2016 California	
			nped down" one grade when using R. Iction. If the RAP pile gets augment			-			JMF and	Department of Transportation	
		Select NO	if the contractor plans to perform tru	ue grading to determine	the critical temperatures of v	rirgin binder. This true	grading must be	e performed duri	-	Page 1 of 2	
			ent of the JMF as well as weekly durin h check the "blended binder grade" approximation of the second second second second second second second second								
		grades fro	m the extracted rap, the check of the	"blended binder" grade	against the specifications in	cells J40:J43.					
										Caltrans	
JMF	Informat		Gray cells are general	info input	Yellow cells are Us	<mark>er required valu</mark>	<mark>les that dr</mark> i	ive blending	<mark>; charts</mark>		
		-	Rte 247 Rehab near Mythical Valley 08-123454			Contracto	r: HMA Builder	rs Inc.			
			1922-28c-3cxxx 08-SBD-247-PM12.3/45.6				t: Hot Mix w/ R r: John Smith	AP Inc.			
						Resident Enginee	r: Jane Doe				
	I	HMA Type:	3/4" HMA Type A w/ xx%RAP			QC La	: Quality Is Ou	r Business, Inc.			
			Binder Source:		Bid Item # 55						
			% JMF OBC (xta)=>	0.0070							
			% RAP BC (xra)=>	6.80%	*Xra, asphalt content of RAP	expressed as a percent	veight of the RAP				
	Per	cent RAP	(percentage of belt feed) =>	15.20%	where RAP% = [(Wt of RAF	P)/(Wt of Virgin Agg +	Wt of RAP)]x10	00%			
		s limit this to	gregate in the Aggregate Blend => o the lesser of 25% or as determined from imum RPBR value on the blending charts.	14.31%	function of the above 3 variables whe RAP Agg% = [(1 /xra)-1]/[((1 /xra)/RA	P%)-1)		14.35%	Agg Blend as b value from ble	f 25% or "Max RAP Agg in ased on Lowest Max RPBR nding charts"(Calc'd below	
			-		Strikethrough Red font indicates value				in cell H53)		
	-	imum allo	Pavement Binder Ratio (RPBR)=> owed in the upper 0.2 feet of HMA e of OGFC) is 25% and 40% below.		<=A function of JMF OBC, RAP BC and RAP Agg in Agg%, where; RPBR=[[(RAP Agg%]/[1-Xra])/[Xra](1-Xra])/[Xta Red text is a reminder when this value exceeds 0.25, and that specifications limit material placed in the upper 0.2' to 0.25 (or 25%), 0.40 (40%) in areas below 0.2'.						
True	Grade Te	est Data	Table								
							V (* * .	D' - 1 1			
	Enter Criti	cal Temp	perature (True Grading) Test	Results for Virgin I	inder and Extracted binder from RAP. Virgin Binder bumped do Virgin Binder(°c) RAP Binder(°C) one grade.					ed down	
		AGING	PROPERTY	TEMP RANGE	Virgin Binder(°c)	Virgin Binder(°C) RAP Binder(°C)					
		Original	DSR G*/sin(delta), <u>></u> 1.00 kPa	High	69	n/a					
		RTFO	DSR G*/sin(delta), <u>≥</u> 2.20 kPa	High	⁶⁹ 103 YES above uses				es the	e most	
			DSR G*sin(delta), ≤ 5,000 kPa	Intermediate	28	4 4	conservative virgin binder grades. Because YES wa				
		PAV	BBR Stiffness, "S" ≤ 300MPa	Low	-16						
			BBR m-value, m ≥ 0.300	Low	-16		U				
			p, enter True Grade values which are 10C he test temperature. The plotted low test	Lowest "High Highest "Low		7		ed, the p			
		temp will be	10C higher than the True Grade.	Actual (True Grade)	PG 69-16	PG 103+7	tolerar	ice chec	ck bel	ow is not	
			PG	Equivalent M320 grade				essary on a weekly basis.			
				On M	RAP agg			gg bind	g binder properties		
Spec			de / Blended Binder Grad	-	Production HMA Mix	^{ra} unchanged from previous					
	Projec	ts Spe	cified Binder Grade =>	PG 70-10	<= The PG Grade selected here populat	tes the horizontal lines on the bl	examp	•			
	Prop	osed \	/irgin Binder Grade =>	PG 64-16	<= Per specification, when using RAP e	xceeding 15%, contractor may b	слатр	100.			
	"HMA N	"HMA Mixture Binder Grade" at Proposed RPBR => PG 75-12			<=For High PG Temp, where For Low PG temp, where "R	n Temp blending line. hest Low temp blending line. f Production Tolerance Check					
	Determination of HMA Mixture Binder Grades (critical tempe Where the RPBR (black line) crosses the blending line (blue					Lower Spec Limit Temp	Upper Spec Limit Temp	Are Criti	cal Temps of Blended r within Production tolerances.		
	High 1	emp Blendi	ng Line Crosses Proposed RPBR at Tcrit=	75		75	70	77		OK	
	Intermed. Temp Blending Line Crosses Proposed RPBR at Tcrit= 31 Low Test Temp			Low Grade Temp (-10C)	31 Highest Low Temp	n/a	34		OK		
	Low Temp Stiffness (S) Crosses Proposed RPBR at Tcrit= -2 Low Temp m-value Crosses Proposed RPBR at Tcrit= -2				-12 -12	-12	n/a	-8		ОК	
Calc'	s for Che	ck on N	lax Allowable RAP Aggreg	gate in the Aggre	gate Blend (aka %R	AP)					
					, expressed as a percentage of th expressed as a percentage of the	-		5 <= % JMF OBC 5 <= % RAP BC (1	K _{ra})		
						om 4 blending Charts=		<= a function of the binder	true grades o	f virgin and reclaimed rap	
	Max RAP Agg in Agg Blend corresponding to Lowest Max RPBR										

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14.35% a function of the above 3 variables



Example 2c: To allow a higher percentage RAP be used than in the previous examples, in this example, the virgin binder is dropped two grades from a PG 70-10 to a PG 58-22. "YES" was selected in cell B2 to indicate that the COC program will be used to control the virgin binder. Selecting YES replaces the virgin binder true grades with the most conservative values for PG 58-22. As shown in this example, bumping down two grades allows a RAP belt feed % of up to 26%, resulting in an RPBR of 0.292, which exceeds 0.25 limitation for HMA in the upper 0.2' of layer thickness, but is less than the 0.40 limitation for HMA below the upper 0.2'. The RAP belt feed % has to be lowered to 22.3% to prevent the RPBR from exceeding 25% (not shown in this example).



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