DEVELOPMENT OF MIX DESIGN PROCEDURES FOR GAP-GRADED ASPHALT-RUBBER ASPHALT CONCRETE

Final Report 524

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16. Abstract

A research project was conducted to identify and document current modifications to ARIZONA 815c (75-blow Marshall method) used to develop gap-graded asphalt rubber asphalt concrete (GG AR AC) mix designs, and to develop and test improvements to provide a standard mix design method for use by contractors and consultants. Based on field performance data provided by the Arizona Department of Transportation (ADOT), the existing mix design method was successful and should serve as the standard for comparison of proposed improvements. Best practices were synthesized to develop proposed improvements. Three aggregate sources and two asphalt-rubber (AR) binders were used for initial testing of the existing (control) mix design method and of the proposed changes. Rebound of compacted AR AC specimens was evaluated, as were Rice test results at 6% and 7% AR binder by weight of mix. The composition of the AR binders (rubber gradation and content) had more effect on the results than which mix design method was used. Additional replicate testing was performed by MACTEC and ADOT to confirm these findings. Changes to the AR AC mix design method consist primarily of making and curing Rice specimens in the same manner as Marshall specimens, tighter temperature ranges for mixing and compaction, incorporating Asphalt Institute calculations in a "User's Guide", and improving presentation. An ADOT construction project was used as an "acid test" to pilot the proposed mix design method and provide materials for a four-laboratory round robin to evaluate the precision of testing AR AC materials. The precision of round robin testing appears very similar to that of conventional asphalt concrete mixtures based on data from Proficiency Sample Programs of the AASHTO Materials Reference Laboratory and ADOT. The results indicate that the mix design method developed can be used by qualified laboratories to provide suitable AR AC mix designs.

17. Key Words
Asphalt-rubber, asphalt-rubber asphalt concrete, AR AC, Gap-graded asphalt concrete mixtures, Marshall mixture design, rubber-modified asphalt concrete

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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	Square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	Square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	Square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	Cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	Cubic meters	1.308	cubic yards	yd^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.								
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000lb)	0.907	megagrams (or “metric ton”)	mg (or “t”)	mg	megagrams (or “metric ton”)	1.102	short tons (2000lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION					**ILLUMINATION**		
fc	foot candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS					**FORCE AND PRESSURE OR STRESS**		
lbf	poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

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EXECUTIVE SUMMARY

The purpose of this study was to develop a standard mix design method for the Arizona Department of Transportation (ADOT) gap-graded asphalt-rubber asphaltic concrete (AR-AC) mixtures that can be used by contractors and consultants. The Department is seeking to transfer AR-AC mix design responsibilities to industry, similar to the current practice for standard Marshall and Superpave asphaltic concrete mixtures.

The first task was to review and document ADOT's existing Marshall-based mix design procedure for AR-AC, based on interviews with ADOT personnel, and a review of ADOT's AR-AC performance data. Field performance data provided by ADOT indicated that more than 96% of AR-AC pavements provided generally good performance. Therefore, the ADOT mix design method was considered a successful standard for comparison of proposed improvements.

Methods and practices for AR-AC mix design used by industry and other agencies were reviewed and synthesized to develop proposed improvements to the existing ADOT procedure. Rice testing according to ARIZ 806[1] was evaluated at two asphalt-rubber (AR) binder contents, 6% and 7% by total weight of AR-AC mixture, to determine whether the binder content should be increased to 7% for testing. Findings indicated that results for samples at both binder contents fall within the precision of the test procedure; either may be used, as the level of precision is equivalent.

Rebound of mix specimens after compaction was also measured and evaluated, with and without constraining weights. Rebound has been a concern for AR-AC mix designers, but no documentation of actual measurements of this anecdotal phenomenon could be found. This may be the only study to address specimen rebound. Findings indicated that most mixes exhibit some slight shrinkage as they cool which appears to be normal volume change. Few mixes rebound. A failed mix design trial for another project provided a mix which did visibly rebound, but the measurements were small. It was decided that mixes that rebound should be discarded and redesigned.

As directed by the Technical Advisory Committee (TAC), MACTEC developed new mix designs for initial testing, using three different sources of aggregate and two different AR binders. The same source of rubber was used in both AR binders. Gradation was varied so that one binder used a rubber gradation on the coarse side, and the other used a gradation on the fine side of the allowable rubber gradation limits. Rubber content was varied to meet the required AR properties. The quantity of rubber required is a function of the rubber gradation and the source and grade of the base asphalt cement.

ADOT's original mix design procedure (newly documented) was used to develop "control" AR-AC mix designs, which established aggregate gradation targets. The Version 1 modified mix design procedure was then applied to the established aggregate gradations for the respective sources. These initial designs performed for Task 1 are referred to as "Round 1" in this report.

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[1] Arizona Department of Transportation. (ADOT) *Materials Testing Manual*. 1985. Section 806.

The Version 1 designs seemed to highlight differences in the effects of the two AR binders on resulting volumetric properties. It appeared that the different binders had more effect on the results than the choice of mix design procedure. However, two of the aggregate sources had relatively high water absorption and yielded more variable test results than the third. The question arose as to whether the Version 1 method better distinguished AR-related differences in volumetric results or was the cause of these differences. Therefore to better distinguish the effects of binder and mix design method, additional testing was focused on mixes using less absorptive and less variable Salt River aggregates.

As work with the Version 1 Marshall mix design method proceeded and the need for additional replicate testing was identified, the project TAC decided to waive the planned gyratory portion of the study to allow full evaluation of the Marshall approach. It appeared that appropriate modifications to the Marshall method could be established to provide a readily useable standard mix design procedure. It also appeared that more resources would be required to thoroughly research the application of gyratory compaction to AR-AC materials, while it was not clear if it would be possible to develop a gyratory mix design method.

The next step was to further explore the relative effects of binder versus mix design method using the relatively consistent Salt River aggregate source, and whether these effects could be reproduced by other laboratories. MACTEC batched aggregate and provided prepared binder to ADOT for "shadow" or replicate testing of control and Version 1 mixes, which is referred to as "Round 2" in this report. Extensive analysis of the results of Round 2 testing supported the initial findings that the AR binders had more effect on volumetric results than the differences between the control and Version 1 mix design procedures. ADOT's results generally fell within the range of MACTEC's results for Rounds 1 and 2. The relatively close conformance of the results indicated that both methods (control and Version 1) could be reproduced by another laboratory.

Presentations of preliminary results were delivered at meetings of the Pacific Coast Conference on Asphalt Specifications and at the Arizona State University Paving and Materials Conference, rather than in workshop format. Comments were solicited. In addition, the test results and the proposed Version 1 mix design procedure were distributed for review and comment among the project team (which also included Speedie & Associates (Speedie) and Rinker Materials Corporation Arizona (Rinker) and two others experienced with these materials including Western Technologies Inc. (WTI)). Results indicated that any of the modifications could be adopted but some were not needed; Version 2 incorporated selected changes to clarify and streamline lab procedures.

ADOT offered an opportunity to use a 2004 AR-AC construction project to pilot the proposed Version 2 AR-AC Marshall mix design method and provide materials for round robin testing by the project team. The project selected provided an "acid test" as the subject "Big Bug" aggregate materials have high water absorption and corresponding increased testing variability. MACTEC performed the original mix design, and developed an alternate AR binder for subsequent round robin testing. ADOT personnel sampled the aggregate stockpiles and delivered these materials to MACTEC for distribution among the participating laboratories.

Round robin testing was performed by four laboratories: ADOT, Speedie, Rinker and MACTEC. These labs batched the aggregates and used prepared AR binder as would normally be done for a new mix design or a verification of an existing design. MACTEC compiled and analyzed the test results, which consist of a limited number of physical tests (which are also possible sources of variability) and calculated the volumetric properties of interest. One of the participating laboratories experienced some equipment problems that affected its results. To remove inaccuracies contributed by variability of other tests, results were normalized by using overall averages of aggregate specific gravity and Rice results to recalculate volumetric properties for each laboratory.

MACTEC performed statistical analyses to determine whether the mean results of the respective laboratories for the properties of interest were statistically similar, and to group and rank statistically different means. Precision of the proposed Version 2 mix design procedure was evaluated with respect to results of Marshall asphaltic concrete proficiency sample programs of the AASHTO Materials Reference Laboratory (AMRL) and ADOT, and ASTM precision statements for bulk and maximum theoretical specific gravities. Although the normalized round robin results for some of the volumetric properties did show significant differences among the respective laboratories, the precision of the round robin testing performed by the individual laboratories is generally within the ranges established for conventional asphaltic concrete materials.

The results of this study indicate that the proposed Version 2 AR-AC mix design procedure is generally as repeatable and reproducible as a 75-blow Marshall mix design for conventional asphalt concrete. Version 2 is presented in Appendix H as ARIZ 832[2], Marshall Mix Design for Asphaltic Concrete (Asphalt-Rubber) [AR-AC]. It has been used for ADOT AR-AC projects in 2006. Some refinements may be made with continuing use, but major procedural changes are not expected.

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[2] ADOT *Materials Testing Manual*. 1985. Section 832.

1. INTRODUCTION

The purpose of this study was to develop standard mix design methods for gap-graded asphalt-rubber asphaltic concrete (AR-AC) mixtures that can be used by contractors and consultants. The AR-AC aggregate gradation is gapped on the coarse side of the maximum density line to provide sufficient void space to accommodate the rubber particles in the asphalt-rubber (AR) and high AR binder contents. To date, ADOT's Central Laboratory has been responsible for performing the mix designs for these materials which has at times been a strain on ADOT's limited resources. The Department is seeking to transfer AR-AC mix design responsibilities to industry, similar to the current practice for standard Marshall and Superpave asphaltic concrete mixtures.

The scope of the study was originally divided into three tasks as follows:

- Task One: Review and Documentation of Current Methods
  - Review Marshall mix design criteria
  - Interview ADOT personnel
  - Review industry standards and practices
  - Compare various methods and procedures
  - Synthesize best practices
  - Look for correlations with field performance
  - Develop and test proposed mix design improvements
    - Select three AR-AC mixes
    - Apply recommended improvements to the same materials
    - Check for rebound
    - Evaluate the effects of recommended changes to the mix design procedure

- Task Two: Development of Superpave Gyratory Methods
  - Development of mix design procedures using the Standard Highway Research Program (SHRP) gyratory compactor

- Task Three: Testing Round Robins, Validation, and Presentation of Work
  - Compare results of minimum of 3 mixes (Round 1)
  - Analyze results and conduct workshop
  - Prepare formatted Arizona Test Method
  - Preparation of Final Report, Technical and Project Presentations

The Technical Advisory Committee (TAC) redirected some efforts as deemed appropriate based on ADOT's needs and on the results of each phase of testing. The original work plan was to focus on the mixture properties of the material, and not on the properties of the asphalt-rubber binder. However at ADOT's request, the effects of rubber gradation and rubber content of the AR binder on AR-AC mixture volumetrics were incorporated. The impacts on mixture volumetrics were found to be significant.

The Executive Summary summarizes the work performed. ADOT provided AR-AC performance data, the original formatted mix design method ARIZ 815c[3], and ADOT's Proficiency Sample Program data for 75-blow Marshall testing performed over the last ten years. The performance data showed the original ADOT mix design method was a successful standard for comparison of proposed improvements.

Task One also included a review of various industry methods and practices for AR-AC mix design, synthesis of best practices to develop proposed improvements, and laboratory evaluation of the proposed improvements. As one of the proposed improvements, Rice testing ARIZ 806[4] was evaluated at two AR contents, 6% and 7% by total weight of AR-AC mixture, to determine whether the AR content should be increased to 7% for Rice testing. Rebound of mix specimens after compaction was also measured and evaluated, with and without constraining weights.

For Task One, instead of using three existing AR-AC mix designs as planned, the TAC tasked MACTEC to develop new mix designs using three different sources of aggregate and two different AR binders. This created some overlap between Tasks One and Three.

The second planned task was to develop AR-AC mix design procedures using the SHRP (Superpave) Gyratory Compactor. As work with the Marshall-based method proceeded and the need for additional replicate testing was identified, the project TAC decided to waive the gyratory work to allow full evaluation of the Marshall approach. It appeared that appropriate modifications to the Marshall-based method could be established to provide a readily useable standard mix design procedure. It also appeared that more resources would be required to thoroughly research application of gyratory compaction to AR-AC materials, while it was not clear if the desired result could be achieved.

Task Three was redirected by the TAC to further explore the relative effects of AR binder versus mix design method using the relatively consistent Salt River aggregate source, and whether these effects could be reproduced by other laboratories.

Workshop presentations were deferred and will likely be used to present the results of this study along with the proposed AR-AC mix design method and new end result specifications being implemented for AR-AC in accordance with ADOT 415[5].

For Task Three, ADOT offered an opportunity to use a 2004 ADOT AR-AC construction project to pilot the proposed standard ADOT mix design method and to provide materials for round robin testing by the project team. The parties involved believed this would be a superior way to conclude this study. The project selected provided an "acid test" as the subject aggregate materials have high water absorption and corresponding increased testing variability.

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[3] Ibid. Section 815c.

[4] Ibid. Section 806.

[5] Arizona Department of Transportation (ADOT). *Standard Specifications for Road and Bridge Construction*. 2000. Section 415.

Round robin testing was performed by four laboratories: ADOT, Speedie, Rinker, and MACTEC. MACTEC compiled and analyzed the results. The precision of the round robin testing performed by the individual laboratories is generally within the ranges established for conventional asphaltic concrete materials.

The results of this study indicate that the proposed AR-AC mix design procedure is generally as repeatable and reproducible as a 75-blow Marshall mix design for conventional asphaltic concrete.

1.1 ORGANIZATION OF THE REPORT

Chapter 1 is this Introduction.

Chapter 2 presents the development of the AR-AC mix design procedure from documentation of the existing ADOT Marshall-based AR-AC method to development and testing of the proposed Version 1modifications. It includes discussions of the respective specifications and materials, findings of the analyses of Rounds 1 and 2 test data, and the list of changes included in Versions 1 and 2 of the proposed AR-AC mix design procedure. Test results and corresponding compilations, plots, and statistical analyses are presented in Appendices A through E.

Chapter 3 covers the round robin testing of the Version 2 mix design method and analyses in detail, including materials selection, AR binder preparation, instructions for handling and testing, data reported, considerations regarding volumetric calculations, and findings of the analyses. Test results and corresponding compilations, plots, and statistical analyses are presented in Appendices F and G.

Chapter 4 presents the conclusions of this study.

The current version of the mix design procedure is in Appendix H.

2. DEVELOPMENT OF A MIX DESIGN PROCEDURE

2.1 DOCUMENT EXISTING MODIFICATIONS TO ARIZONA 815c

The first task of this study was to determine and document any modifications to the ARIZ 815c[6] Marshall Mix Design Method that ADOT has been using to design mixes to meet the requirements of Section 413[7] Asphaltic Concrete (Asphalt-Rubber). A meeting was held with ADOT materials managers and laboratory personnel to go through the ARIZ 815c procedure line by line to identify and describe in detail the modifications used for designing gap-graded AR-AC mixes. ADOT provided an electronic copy of ARIZ 815c for a technical review of drafts. ARIZ 815c Modified for Asphaltic Concrete (Asphalt-Rubber) Version 5-28-03 was submitted as the first scheduled deliverable for this project, and is presented in Appendix A.

2.2 MATERIALS SELECTION

Materials selection was a critical part of the experimental plan. The mix design method to be developed must be applicable to the full range of aggregate, asphalt, and asphalt-rubber materials available throughout Arizona that are suitable for use in AR-AC mixtures. The project TAC took an active role in determining what materials should be included in the study.

2.2.1 Aggregates

The TAC identified three sources of aggregate for the bulk of the mix design testing that represented a wide range of physical properties such as specific gravity and water absorption. The aggregate sources designated were:

- Salt River (Rinker 19th Avenue plant, Phoenix metropolitan area)
- Grey Mountain (US 189 Milepost 454, northern Arizona)
- CKC Construction (1234 E. Airport Rd. Safford, Arizona)

Details of properties of aggregates from these respective sources are included in the corresponding mix design summaries presented in Appendix B.

2.2.2 Rubber

The project proposal excluded evaluation of the effects of rubber gradation and content on the resulting AR binders due to funding constraints. However, ADOT expressed great interest in the effects of these factors on mixture volumetrics. It was thus decided to deviate from the project proposal and develop and use AR binders that incorporated, respectively, relatively coarse or fine rubber gradations within the relatively broad gradation limits for Type B rubber in ADOT Section 1009[8], Asphalt-Rubber Material. Type B rubber is used in AR binders for gap- and open-graded asphaltic concrete mixes, and the specified gradation limits are shown in Table 2.

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[6] ADOT. *Materials Testing Manual*. 1985. Section 815c.

[7] ADOT *Standard Specifications for Road and Bridge Construction 2000* Section 413

[8] Ibid. Section 1009

ADOT's and MACTEC's experience with AR materials indicated that rubber gradation would affect the rubber content of the binder and volumetric properties of AR-AC, particularly the arrangement of the mixture voids. For example, coarsening the rubber gradation would typically increase the amount of rubber required to achieve the specified AR binder properties, and would tend to increase Voids in the Mineral Aggregate (VMA) of AR-AC mixes.

2.2.3 Asphalt Cement

Most of the AR binders used by ADOT are classified as Type 2, which requires a Performance Grade (PG) binder 58-22 (ideal for climates with temperatures ranging from 58° Celsius down to -22° Celsius) for the base asphalt cement.[9] Type 1 AR binders require a stiffer grade of base asphalt cement, PG 64-16, for areas with higher pavement operating temperatures and heavy traffic. Type 3 AR binders require a softer PG 58-28 and are used where enhanced resistance to low temperature cracking is needed.

2.2.4 Asphalt-Rubber Binders

MACTEC compiled a number of existing AR binder design profiles for consideration by the TAC, and TAC members also suggested specific AR binders for use in this study. Two Type 2 AR formulations were selected and designated Binder 1 and Binder 2. The selected binders were produced and tested by MACTEC using the designated component sources and grades. However, due to variations in the physical properties of the asphalt and rubber materials since design, some of the selected formulations required adjustments in rubber content, or a different source or grade of asphalt to meet specifications. Binder 1 used Para-mount PG 58-22. The source of the base asphalt cement for Binder 1 was changed from Chevron to Paramount. Binder 2 used Ergon Snowflake PG 58-22. The Ergon Snowflake asphalt cement available at that time for use in Binder 2 actually graded as a PG 58-28 rather than PG 58-22, but since the resulting AR binder properties met requirements for and conformed to the original Type 2 design, it was used as a Type 2.

The design profiles, components, and rubber gradations for Binder 1 and Binder 2 are presented in Tables 1 through 4. Crumb Rubber Manufacturers (CRM) was the source of rubber for both AR binders.

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[9] Ibid

Table 1 Binder 1 Design Profile

Test Performed	Minutes of Reaction					Specified Limits
	60	90	240	360	1440	
Viscosity, Haake at 177°C, cP	2000	2300	2800	2900	2700	1500-4000
Resilience at 25°C, % Rebound (ASTM D5329)	37		37		37	20 Minimum
Ring & Ball Softening Point, °F (ASTM D36)	135.5	137	140	140	138	130 Minimum
Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)	32		30		31	15 Minimum
Rubber source and type: CRM Type B (coarse gradation) Rubber content: 24.2% by weight of asphalt cement, 19.5 % by weight of total binder Asphalt cement source and grade: Paramount PG 58-22						

Table 2 Binder 1 Rubber Gradation, Percent Passing (ARIZ 714[10])

Sieve Size	Result (%)	Specified Limits (%)
No. 8	100	
No. 10	100	100
No. 16	69.5	65 – 100
No. 30	30.4	20 – 100
No. 50	10.7	0 – 45
No. 200	0.4	0 – 5

Table 3 Binder 2 Design Profile

Test Performed	Minutes of Reaction					Specified Limits
	60	90	240	360	1440	
Viscosity, Haake at 177°C, cP	2000	2100	2600	2400	2300	1500-4000
Resilience at 25°C, % Rebound (ASTM D5329)	39		42		42	20 Minimum
Ring & Ball Softening Point, °F (ASTM D36)	143	140	145	144.5	139.5	130 Minimum
Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)	29		30		34	15 Minimum
Rubber source and type: CRM Type B (fine gradation) Rubber content: 22.7 % by weight of asphalt cement, 18.5 % by weight of total binder Asphalt cement source and grade: Ergon Snowflake PG 58-28						

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[10] ADOT. *Materials Testing Manual*. 1985. Section 714

Table 4 Binder 2 Rubber Gradation, Percent Passing (ARIZ 714[11])

Sieve Size	Result	Specified Limits
No. 8	100	
No. 10	100	100
No. 16	93.7	65 – 100
No. 30	40.6	20 – 100
No. 50	9.6	0 – 45
No. 200	0.7	0 – 5

Binder 1 did require a somewhat higher content of the coarser-graded rubber (24.2% vs. 22.7%) to provide properties similar to Binder 2 made with the finer-graded rubber.

2.3 PILOT AR-AC MIX DESIGNS – CONTROL MIXES

Field performance data provided by ADOT indicated that approximately 104 AR-AC mixes were designed and placed from August 1989 through March 2001. Of these AR-AC mixes, bleeding was reported for three that were used as urban arterial pavements in the Phoenix metropolitan area, and rutting (believed to be due to structural issues) occurred in one mix placed on I-8 near Yuma. Based on this information, as of April 2001, less than four percent of ADOT's AR-AC pavements had exhibited severe distress during a time period of over eleven years. Based on the historically good performance of AR-AC mixes placed throughout Arizona, the existing mix design method was considered to be successful. Therefore it was designated as the control method for this study, the standard to which the results of the proposed improvements would be compared. The method to be developed needs to provide at least the same quality AR-AC material as the existing method, including adequate AR binder content to promote long term durability and compliance with specifications.

ADOT AR-AC specifications at the time of this research were limited to requirements for physical properties of aggregate (gradation, sand equivalent, fractured faces and abrasion); effective voids content (5.5 ± 1.0%); minimum VMA (19.0%); maximum binder absorption (1.0%); and use of 1.0% portland cement or hydrated lime by aggregate weight as a mineral admixture.

The testing plan allowed for a total of six mix designs to be performed according to the newly documented existing ADOT AR-AC mix design method to serve as the controls for this part of the study. AR Binder 1 was used to establish AR-AC control mix designs with aggregates from each of the three designated sources. In some cases, appropriate mix designs that met volumetric requirements could not be developed using Binder 1; the related data for these are identified as "Trial Summaries." Design binder contents were then determined for Binder 2 using similar gradations. The control AR-AC mix design summaries and trial summaries are presented in Appendix B, along with compilations of the properties of interest (effective binder volume, VMA, voids filled with asphalt (VFA), effective air voids, Marshall stability and flow) for each.

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[11] Ibid

2.3.1 Issues with CKC and Grey Mountain AR-AC Control Mixes

The TAC members selected the CKC and Grey Mountain aggregates to represent types of aggregate materials present in the respective southern and northern parts of Arizona that may present challenges to mix designers.

2.3.1.1 CKC Aggregates

The CKC source was selected specifically because ADOT's Central Lab had experienced problems in developing acceptable volumetric AR-AC mix designs when combining these aggregate materials with an AR binder made with relatively coarse-graded rubber, like Binder 1. It was necessary for ADOT to request an alternate AR binder made with a finer gradation of rubber to obtain an appropriate mix design. The CKC aggregate exhibited high water absorption which historically increases variability in laboratory mix testing.

As shown on the CKC AR-AC design and trial summaries, MACTEC experienced the same problems as ADOT when mixing the CKC aggregate with Binder 1. Increasing the content of Binder 1 increased the mix VMA, and the mixture voids remained excessive (7.9%) even with 8.5% binder by total mix weight. It seemed as if the coarser rubber particles in the binder were not allowing the aggregate matrix to consolidate and interlock.

The aggregate blend was modified to provide a slightly denser matrix, but the gradations of the available stockpiled materials did not allow a significant change in the composite gradation. None of the stockpiles provided sufficient fines to close up the mix voids while remaining within ADOT 413[12] aggregate gradation limits. Therefore a suitable mix design could not be developed for the combination of Binder 1 and the available CKC aggregate materials.

However, when Binder 2 was substituted for Binder 1 the mixture voids dropped into an acceptable range of 6.1% at 7.5% AR binder content, and 5.4% at 8.5% AR binder. This also mirrored ADOT's experience.

2.3.1.2 Grey Mountain Aggregates

The combination of Grey Mountain aggregates and Binder 1 exhibited a trend of increased VMA with increased AR binder content similar to that of the CKC materials, but less pronounced. It was possible to develop an AR-AC mix design with Gradation Trial A and Binder 1. However the resulting combination of high VMA and high binder content caused decreased Marshall stability and increased Marshall flow, which indicated that properties were somewhat marginal. Such a design would not be recommended.

A wider range of stockpile gradations was available from the Grey Mountain source which made it possible to evaluate the effects on the voids structure of either substituting

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[12] ADOT. *Standard Specifications for Road and Bridge Construction. 2000*. Section 413

or blending in a "dirtier," i.e., finer, crusher fines material with the clean crusher fines. The change in gradation due to blending these two fine aggregate materials was small enough to fall within production tolerances from Gradation A mix design targets (see Appendix B). Limited trials indicated that this small change in gradation resulted in a drop from 7.5% to 6.9% effective air voids at 7.5% Binder 1 content by mix weight. Substituting the finer crusher fines to further densify the gradation (Gradation B with crusher fines) had a profound effect on the voids content, dropping it down to 4.0% at 7.5% Binder 1 by mix weight.

No difficulties were encountered with developing suitable AR-AC mix designs using Binder 2 with trial aggregate Gradation A. The finer rubber gradation produced an acceptable mix design.

2.3.1.3 Discussion

The voids structure of asphaltic concrete and AR-AC mixtures depends on a number of factors including, but not limited to:

- Aggregate particle size – gradation.
- Aggregate particle shape – examples include cubical, flat, angular.
- Aggregate surface texture – fine or coarse grains, glassy or rough, size and number of surface voids, etc.

These factors affect how aggregates pack together when compacted. The Uncompacted Void Content (ARIZ 247[13]) used for Superpave mixes may be considered as an index of such factors.

In AR-AC mixes, the discrete swollen rubber particles that remain in the AR binder after interaction with the asphalt cement may also affect how aggregates pack together. The rubber particles must also be accommodated within the aggregate matrix and may fill some voids. However if the voids are too small to accommodate them, the rubber particles may interfere with stone-to-stone contact and force the aggregate particles apart, which increases VMA and mixture voids. In such cases, increasing the AR binder content increases the number of interfering rubber particles and consequently increases VMA and mixture voids. Finer rubber particles do not take up as much space as coarser rubber and are more likely to fit within the aggregate matrix.

ADOT AR-AC mixes are limited to very low fines content in order to promote stone-on-stone contact in the aggregate matrix and to provide sufficient void space to accommodate a relatively high content of AR binder that includes discrete rubber particles. ADOT specifications limit the amount of minus No. 200 material in any of the component stockpiles to a maximum of 6.0%. Although design AR binder contents are high compared to conventional mixes, AR-AC mixes do not require high contents of fine aggregate particles in the mix to avoid drain down or minimize potential for bleeding.

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[13] ADOT. *Materials Testing Manual*. 1985. Section 247

The lack of allowable fines leaves the mix designer with few options for closing up high voids AR-AC mixes. If changing the aggregate stockpile or bin blend proportions and AR binder content cannot reduce the voids enough, then it may not be possible to develop a suitable mix design with a specific AR binder that fully complies with binder specification requirements and includes relatively coarse-graded rubber. This situation is both illustrated in Appendix B in MACTEC's control mix design trials with CKC aggregate and Binder 1, and supported by ADOT's experience with this source.

The control mix design trials performed with the Grey Mountain aggregate (also presented in Appendix B) indicate that adding a relatively small proportion of fines can have major impacts on reducing effective voids contents of gap-graded mixes. However the crusher fines material used to adjust the Grey Mountain mixes with Binder 1 does not meet ADOT limits for maximum 6% minus No. 200 material and could not be used without waiving these requirements.

Although the relative impact of adding fines would be material-specific, mix designers must have some means to adjust mixture voids. The first option would be to seek a finer crumb rubber material to use in the AR binder. In cases where finer rubber is not available and an acceptable AR-AC mix design cannot be developed otherwise, consideration should be given to allowing use of aggregate stockpiles that include more than 6.0% passing the No. 200 sieve, raising the upper gradation limit for the composite aggregate blend including admixture to three or four percent passing the No. 200, or both.

2.3.2 Salt River Control Mixes

No problems were encountered in developing control mixes for the Salt River aggregates. The mix design data for the control mixes with Binder 1 and Binder 2 are included in Appendix B. As requested by the project TAC, MACTEC performed two additional replicate designs for the Salt River control mixes with each binder using the established target gradation. Results were relatively consistent and are summarized in Table 5. The limited replicate data show design contents of Binder 2 (finer rubber) are slightly lower than those for Binder 1 (coarser gradation) at corresponding air voids contents.

Table 5 Design Binder and Air Voids Contents, Salt River Aggregate Control Mixes

Mix ID*	Binder 1 % by mix weight	Air Voids, %	Binder 2 % by mix weight	Air Voids, %
B1C1	7.5	5.6	--	
B1C2	7.3	5.5	--	
B1C3	7.3	5.4	--	
B2C1			7.1	5.6
B2C2			7.1	5.5
B2C3			6.8	5.4
Average	7.37%	5.5%	7.0%	5.5%
* Mix ID Example: B1 C1 = Binder 1 Control Mix Trial 1				

2.4 MODIFICATIONS TO EXISTING ADOT AR-AC MIX DESIGN PROCEDURE

Development of the Version 1 modifications to the mix design procedure began during initial documentation of the existing AR-AC mix design method. MACTEC solicited input from the ADOT Materials staff, the project team and TAC, and other local consultants who design AR-AC mixes for counties and municipalities.

The primary procedural changes considered included making and treating the Rice specimens in the same manner as the loose Marshall specimens, and adding weights to the surface of compacted Marshall specimens to prevent rebound while cooling prior to extrusion from the molds. Rice tests of AR-AC mixes have customarily been performed at 6.0% AR binder content, although AR binder content is rarely less than 7.0% by weight of mix. Thus, a comparison of results of Rice testing at 6.0% and at 7.0% AR binder was deemed necessary. A complete list of the modifications proposed is presented in Section 2.4.1.

ARIZ 815c[14] includes considerable explanation and exposition of calculations which makes its presentation lengthy and cumbersome. ADOT Materials staff requested changes in the presentation format to clarify the method and make it easier to use, and modification of the volumetric calculations to conform to those used by the Asphalt Institute for design of Marshall and Superpave mixes.[15,16]

2.4.1 List of Considered Procedural Changes to AR-AC Mix Design Method

1. Include mineral admixture in the mix as part of the aggregate.
2. Use "Wet Prep" method of admixture addition – mix dry admixture thoroughly with dry aggregate to distribute uniformly throughout, then blend, then add 3% water by aggregate weight and mix thoroughly to wet.
3. Batch aggregates in oven dry condition.
4. Fabricate Rice specimens at 7.0 % AR binder by total mix weight instead of 6.0 %, and include the required 1% admixture by dry aggregate weight (added and wet prepped as in step 2 above) but omit liquid anti-strip.
5. Cure Rice specimens at the same temperature (325ºF ± 10ºF) and for the same amount of time (2 hours) as for the loose mixture for Marshall specimens.
6. Mixing temperature: AR binder at 350ºF, aggregate at 325ºF
7. Compaction temperature: 325ºF to 335ºF
8. Cool the compacted AR-AC specimens vertically in the molds (with base plate underneath and 2000grams ± 10 gram steel disc on top of specimen) to less than or equal to 90ºF before extruding them.

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[14] Ibid, Section 815c

[15] The Asphalt Institute. "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types", Chapter 4

[16] The Asphalt Institute. "Superpave Mix Design", Chapter 4

The changes listed were incorporated to develop "Version 1" mix designs for each aggregate source, using the composite aggregate gradations developed for the respective control mix designs with Binder 1 and Binder 2.

2.4.2 Mix Designs – Version 1 Mixes

2.4.2.1 Salt River Aggregate Version 1 Mixes

No problems were encountered in developing Version 1 mix designs for the Salt River aggregates. As requested by the project TAC, MACTEC performed two additional replicate designs for the Salt River aggregate Version 1 mixes with each binder using the established control gradation. The Version 1 mix designs with AR Binders 1 and 2 are included in Appendix C. Results were relatively consistent and are summarized in Table 6.

Table 6 **Design Binder and Air Voids Contents for Salt River Aggregate Version 1 Mixes**

Mix ID*	Binder 1 % by mix weight	Air Voids, %	Binder 2 % by mix weight	Air Voids, %
B1PC1	8.0	5.6		
B1PC2	8.1	5.6		
B1PC3	8.2	5.6		
B2PC1			6.9	5.4
B2PC2			6.7	5.5
B2PC3			6.7	5.4
Average	8.10	5.60	6.77	5.43
*Mix ID Example: B1PC1 = Binder 1, Version 1 Mix Design Trial 1				

The limited data show Version 1 mix design contents of Binder 2 (finer rubber) are 1.1% to 1.5% lower than those for Binder 1 (coarser gradation) at similar air voids contents.

Compared to the results listed in Table 5, design contents for Binder 1 Version 1 mix designs increased by 0.5% to 0.9% (average content 8.1%) over the range of Binder 1 contents determined for the control mix designs (range 7.3%-7.5%, average 7.37%). However the Version 1 design contents of Binder 2 showed very little difference from the control mix design value range of 6.8%-7.1% with average of 7.0%. The effects of the difference in AR binder composition, rubber gradation, and content, appeared to be accentuated by the Version 1 method.

2.4.2.2 CKC Aggregate Version 1Mix Designs

Work on Version 1 designs was limited to a trial using 7.5% and 8.5% Binder 2 by weight of the modified composite aggregate gradation used in the control mix. The data are summarized in Appendix C. Effective air voids of the Version 1 mix were higher than the control, but no conclusions can be drawn from the limited data.

2.4.2.3 Grey Mountain Aggregate Version 1 Mix Designs

Work on Version 1 designs was limited to a trial using 7.5% and 8.5% Binder 2 by weight of the original aggregate gradation (A) used in the control mix design. The data are summarized in Appendix C. Effective air voids of the Version 1 mix were lower than the control design with Binder 2, but no conclusions can be drawn from the limited data.

2.4.2.4 Discussion of Results

The purpose of the additional mix testing with the Salt River aggregates was to permit evaluation of the variability of both the control and Version 1 design methods and of the materials being used. The Salt River aggregate has proved to be a good, sound, durable material for use in asphaltic concrete, with low water absorption and relatively consistent physical properties. It has historically proven to be less variable than the CKC or Grey Mountain aggregates and thus was the best choice for replicate testing to evaluate the effects of binder and mix design method on the results. Volumetric properties evaluated included effective binder volume, VMA, VFA, and effective air voids content.

Some volumetric differences due to binder composition were expected and occurred. In plots of the control mix data, the data tend to group by binder but there is some overlap. However the plots of the Version 1 mixes show very distinct differences between volumetric properties of mixes made with Binder 1 and those made with Binder 2 at corresponding binder contents.[17] The magnitudes of these differences are greater than would be expected for the relatively minor changes to the mix design procedure and represent significant practical differences in the results as follows:

- Air Voids – more than 2% difference between Binder 1 and Binder 2 mixes
- VMA – up to 2% difference
- Voids Filled – up to 10% difference

These large differences do follow expected trends for the rubber gradations and relative contents, but raised the following questions:

1. Did the changes to the mix design method cause these differences in volumetric results, or simply better distinguish binder related differences in mixture properties that had been occurring but had not been recognized?

2. Are the differences repeatable and reproducible?
    a. With these same materials?
    b. With other materials?

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[17] Referenced plots are included in compiled data plotted for MACTEC-ADOT Rounds 1 and 2 that is presented in Appendix E, but are presented with other results and not alone due to the large number of plots included with this report.

A program of replicate testing by ADOT and MACTEC was implemented as Round 2 of this study to answer these questions. Repeatability typically refers to the precision of testing expected, i.e., the acceptable range of results, for a single test operator or laboratory. Reproducibility typically refers to the precision of testing expected for two or more different laboratories. Round 2 activities and findings are discussed in Section 2.5 of this report.

2.4.3 Analysis of Rice Results at 6.0% and 7.0% AR Binder Content

While performing the control and Version 1 mix designs with aggregate materials from the respective sources, MACTEC prepared and tested corresponding sets of Rice specimens at AR binder contents of 6.0% and 7.0% by total mix weight. Additional replicate Rice testing of control and Version 1 mixes was also performed during Round 2. The dry back procedure was used because it is the referee method, although it incorporates more possible sources of variation. The increased variability is reflected in the precision and bias statements for the corresponding ASTM D 2041, Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures, developed from AMRL Proficiency Sample Program data with and without dry back.[18] Results and statistical analyses of Rice testing are presented in Appendix D.

To validate the data, the measured Rice value at one binder content was used to calculate the effective specific gravity of the aggregate, G_{se}, using Equation 1. The calculated G_{se} value was used in Equation 2 to calculate the Rice value at the other binder content.

$$G_{se} = \frac{P_{mm} - P_b}{\frac{P_{mm}}{G_{mm}} - \frac{P_b}{G_b}} \qquad \textit{Equation 1}$$

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}} \qquad \textit{Equation 2}$$

Where

G_{se} = Effective specific gravity of the aggregate-admixture blend
G_{mm} = Maximum theoretical specific gravity of the AR-AC at AR binder content P_b
P_b = AR binder content at which the Rice test was performed
G_b = Specific gravity of the AR binder
P_s = Aggregate content, percent by total weight of mix (100-Pb)
P_{mm} = Percent by weight of total loose mixture = 100%

Results of the measured and calculated Rice values were then compared. The differences between measured and calculated Rice values at 6.0% and 7.0% AR binder contents are no greater than 0.012, which is at the limit of the acceptable range of two results obtained

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[18] ASTM. “ASTM D 2041-03a, Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures.” ASTM Book of Standards 2005, Volume 4.03, pp. 177-180.

on the same material by a single operator according to ARIZ 417b.[19] The maximum difference was obtained for a control mix made with the Grey Mountain aggregate. Only one of the mixes made with the Salt River aggregate yielded a difference of greater than 0.004 between measured and calculated Rice values at 6% and 7% AR binder contents. Thus the variability of the results for both the control and Version 1 mixes appears to fall within the acceptable range for this test.

Analysis of variance (ANOVA) was also used to evaluate the relative effects on Rice results of AR binder (Binder 1 or Binder 2) and design method (control or Version 1). The results of the analysis indicate negligible effects of these factors on the Rice results. The effects of interaction of binder and method were stronger than either factor alone but were still negligible. The analysis indicates that including mineral admixture does not measurably increase variability of Rice test results and is feasible. Including the admixture in the Rice specimens also simplifies calculations.

2.4.3.1 Summary

Rice testing for AR-AC mix design may be performed at either 6.0% or 7.0% AR binder content on mix specimens that include lime as a mineral admixture. Although no testing was done with cement as a mineral admixture, it is expected that these results would apply to cement. Although samples fabricated with 7.0% AR binder were reportedly more difficult to work with, the quality of the results of this study did not appear to be affected. Asphalt-rubber is very sticky, so increasing the binder content can make it more difficult to break up any clumps of fine aggregate particles as required by the test procedure.

The TAC decided to continue using the lower 6.0% AR binder content for AR-AC mix design to facilitate handling and breakup of the Rice specimens, as the analysis of results indicated no need to change. The same type and proportion of mineral admixture included in the Marshall specimens should be included in the Rice specimens.

2.4.4 AR-AC Rebound of Compacted Specimens

For purposes of this study, rebound is defined as a measurable increase in the height of a compacted AR-AC specimen after completion of compaction and prior to extrusion. This phenomenon has been observed occasionally and reported anecdotally during the last 20 years or so, but MACTEC was not able to find any indication that rebound of AR-AC mixes has ever been formally documented.[20]

In the early 1990s, AR-AC mixes were developed for demonstration projects throughout the U.S. in response to the legislative mandate of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) to include scrap tire rubber in asphalt pavements. Rebound was occasionally reported during attempts at mix design verification by

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[19] ARIZ 417b Maximum Theoretical Specific Gravity of Field Produced Bituminous Mixtures (Rice Test), December 1987.

[20] "Use of Scrap Tire Rubber – State of the Technology and Best Practices." Caltrans, 2005

laboratories that had little if any experience in working with asphalt-rubber materials. The Principal Investigator has personal knowledge of four such cases, of which all but one seemed to be generally resolved by substituting hand Marshall compaction (the referee method) for mechanical compaction and improving temperature control during mixing and compaction. In those three cases, it was found that the mechanical Marshall hammers had not been calibrated to the referee hand method; some states did not require it. The exception was a dense-graded mix which exhibited some volumetric issues and likely did not have enough void space to accommodate the rubber particles in the binder.

Although AR-AC specimen rebound is not often observed, most of the local consultants informally surveyed by MACTEC indicate that they routinely take some action to prevent specimen rebound during AR-AC mix design. Several of the laboratories keep base plates on top of the specimen in the Marshall mold during cooling, and others place weights of up to 5,000 grams directly on the top surface of the compacted Marshall specimen. Base plates do not assure uniform contact with the specimen and thus were not considered appropriate for this study.

MACTEC had steel weights with handles ("pucks") fabricated to fit on top of 4-inch diameter AR-AC Marshall specimens inside the compaction mold. Puck weight was 2,000 ± 10 grams. Figure 1 shows a picture of the puck and of the dial indicator that was used to measure vertical displacement of the puck over time.

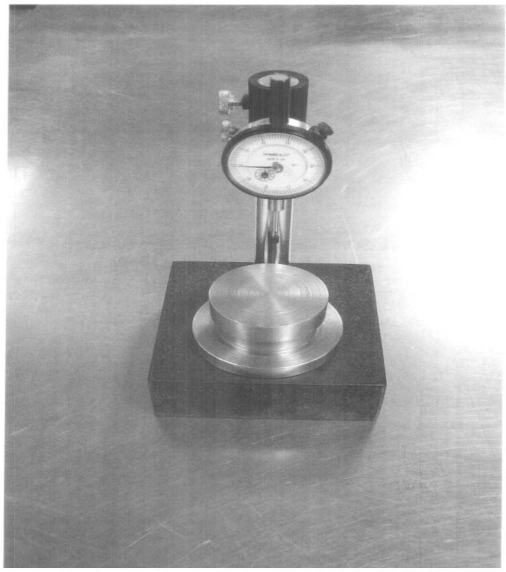

Figure 1: 2,000 gram Rebound "Puck" and Dial Indicator

Results of rebound testing are presented in Appendix D. The results for the Round 1 and Round 2 control and Version 1 mixes show that height change was negligible for most of the specimens tested with or without the 2,000 gram weight. The data indicate that most of the specimens experienced some minor shrinkage upon cooling. The 2,000 gram weight did not appear to make a practical difference in height of compacted specimens of mixes that did not swell.

By chance, a mix design trial for a different project yielded specimens that were observed to puff up like a soufflé in the Marshall molds after compaction. This mixture was duplicated and tested for rebound with and without the 2,000 gram puck. Results for the "soufflé mix" are also included in Appendix D. Although un-weighted specimens did exhibit rebound, increases in height measured no more than 0.014 inch. The pucks did succeed in preventing rebound of the soufflé mix.

2.4.4.1 Summary of Rebound Evaluation

This rebound evaluation may be the first to be documented. Results indicated that changes in AR-AC specimen height after compaction are generally negligible, and that most specimens exhibit minor shrinkage while cooling in the molds. Although weights may be used to prevent rebound, there is no compelling reason to require their use.

It was the consensus of the project team and TAC that AR-AC specimens that exhibit noticeable rebound after compaction should be considered as indicators of mixture volumetric issues. Such specimens should be discarded and the composite aggregate gradation should be adjusted to better accommodate the AR binder.

2.4.5 Round 2 Replicate Testing – ADOT's Central Lab and MACTEC

Review with the TAC of MACTEC's results of replicate tests of control and Version 1 mixes made with Binder 1 and Binder 2, respectively, indicated that more testing was needed to evaluate the effects of the Version 1 modifications, as well as their repeatability.

A focused test plan and handling instructions were developed for both ADOT and MACTEC to evaluate MACTEC's Round 1 results, and Round 2 of testing was initiated. MACTEC presented the instructions for making specimens of Version 1 mixes in the format of the proposed revised mix design procedure as Version 9-26-03, updated 10-29-03. This was an intermediate draft to be applied only to this replicate testing phase of this study and was not intended to be the final version. The control mix replicates were to be made according to the existing ADOT mix design method.

MACTEC batched the Salt River aggregate materials for ADOT to use for "Round 2" replicate testing for control and Version 1 AR-AC mixes. The aggregate samples were delivered to ADOT's Central Laboratory along with lime admixture, batch sheets, six gallons each of Binder 1 and Binder 2, and a 2000-gram rebound "puck" as a template for ADOT to duplicate. MACTEC also prepared and tested three more replicates each of the Salt River control and Version 1 mixtures with Binders 1 and 2, respectively, for Round 2.

When ADOT personnel began to fabricate specimens for the Version 1 mixes, it became apparent that there had been a misunderstanding as to how MACTEC had incorporated the lime admixture in these mixes during the Round 1 testing. MACTEC had reported that the lime was substituted for 1% of the crusher fines in the composite blend, and viewed this simply as a modification of the existing laboratory procedure. However

ADOT was concerned that this approach could be construed as a policy change regarding admixture addition, which was not intended. ADOT therefore instructed MACTEC to incorporate lime in the Version 1 mixes the same as for the control mixes, by determining the composite aggregate blend and then adding 1% lime by total dry weight of aggregate. MACTEC batched new specimens for the Version 1 mixes for Round 2 testing.

MACTEC compiled and plotted test results of Rounds 1 and 2. Microsoft Excel was used to calculate means, standard deviations, and outlier limits (according to the ADOT method for dispute resolution) for the respective data sets. The one-way analysis of variance (ANOVA) feature of the Excel Data Analysis package was used to evaluate the statistical validity of combining MACTEC's data from Rounds 1 and 2, for respective binders and content levels. MACTEC considered this particularly important due to the difference in batching aggregates and admixture for the Version 1 method between rounds. Results of these analyses indicate that MACTEC's data from Rounds 1 and 2 may be combined at levels of confidence ranging from 95% to 99%. Printouts of the ANOVA analysis are included in Appendix E. The results are summarized in the One-way ANOVA Results Matrix also in Appendix E.

Two-way ANOVA was used to evaluate the relative effects of both Binders 1 and 2 as well as the mix design method (existing ADOT versus Version 1) on the results. The results are also presented in Appendix E. These ANOVAs indicate that although there are some effects of mix design method, binder is clearly the primary source of differences among the control and Version 1 mixtures tested by MACTEC.

The ADOT results were provided in two compilations, with voids analyses performed based on Rice values at 6.0% and 7.0% AR binder content, respectively. MACTEC had based voids analyses for the control mixes on Rice at 6.0%, and used Rice at 7.0% for volumetric calculations for the Version 1 mixes. The corresponding ADOT data compilations were used for comparison in the various plots and analyses of variance which are presented in Appendix E.

A full set of 24 plots of MACTEC's and ADOT's combined Rounds 1 and 2 test results for control and Version 1 mixes made with Salt River aggregates and Binder 1 and Binder 2 were generated and are presented in Appendix E of this report. A detailed legend is provided to facilitate review of the plots. Differences between Rounds 1 and 2 in batching and gradation of the Version 1 mixes appear to be reflected in the plots of MACTEC's results, which typically bracket the ADOT Round 2 results.

The plots of VMA, VFA, and effective air voids results versus AR binder content for the replicates from both Rounds 1 and 2 illustrate that the distinctions between binders highlighted in the Round 1 Version 1 mix results still exist. However the differences are smaller. Since one of the Version 1 modifications (approach to adding lime) was eliminated along with the related minor difference in composite gradation, this shift toward the control mix results makes sense. The remaining differences seem most likely to be binder related. The plots also illustrate the two-way ANOVA results. For each binder, results of control and Version 1 mixes tend to overlap. However the volumetric results of Binder 1 mixes generally differ from those of Binder 2 mixes.

After visual examination of the plots with ADOT Round 2 data added indicated similar results, MACTEC performed numerous ANOVAs to evaluate and compare results with respect to design method, binder, and laboratory. It was necessary to tabulate the ANOVA results to look for patterns and correlations.

Two-way ANOVA of the ADOT results were performed to evaluate the relative effects of binder and mix design method. The individual ANOVAs are presented in Appendix E. To facilitate review, these ANOVA results are summarized in the Two-Way ANOVA Results Matrix included in Appendix E along with the results of the corresponding analysis of MACTEC data. The statistical analysis indicates that binder had a very strong effect on test results from both laboratories, and that the design method used (control versus Version 1) had relatively little impact. This finding validates the mix design procedure that ADOT has been using and indicates that only the most useful and practical of Version 1 mix design modifications should be adopted. It also validates a considerable body of experience and anecdotal data that has long indicated that the AR binder is a key factor in AR-AC mixture volumetrics.

The findings of the analyses of Round 1 and 2 results are summarized as follows:

- Review of plots of VMA, VFA, and effective air voids results indicate that both the control (existing ADOT) and Version 1 mix design methods generally distinguish between Binder 1 and Binder 2 for these properties.

- The respective averages of MACTEC and ADOT Round 2 test results are in substantial agreement for both binders and design methods, *except for Marshall stability*.

- ADOT's stability results were systematically higher than MACTEC's.

- Results of Marshall stability and flow tests do not reliably distinguish among binders.

- Effective binder volume appears relatively insensitive to binder type or design method used in this study.

- Analysis of variance indicates that the mixes made with Binder 1 (Paramount PG 58-22 with 24.4% coarse CRM rubber by weight of AC) exhibited greater variability than mixes made with Binder 2 (Ergon PG 58-28 with 22.7% fine CRM rubber by weight of AC). This is best illustrated by comparison and ANOVA of MACTEC's Round 1 and Round 2 test results for control mixes made with the respective binders.

- In spite of the variations in individual mix property values, the agreement between averages of ADOT and MACTEC Round 2 test results remains very good for the binders and procedures used. This indicates that the overall AR-AC mix design results can be reproduced by other laboratories.

- The ANOVA results matrix shows relatively good agreement between MACTEC Round 1 and ADOT Round 2 results, in spite of differences in binder storage time and Version 1 aggregate gradation. This further supports MACTEC's conclusion that the AR-AC design results are reproducible.

- ANOVA of the ADOT and MACTEC data indicates that the effects of the binder are consistently very strong, while mix design method within this study has relatively little if any effect.

- Based on the findings to date, it is not necessary to adopt each of the changes to the existing ADOT mix design method for AR-AC that MACTEC originally proposed. Recommended changes are limited to the following:

    - Use oven-dry batching only when aggregates can not be air-dried to a moisture content of less than 3%.

    - Use "Wet Prep" method of admixture addition – add 1% admixture by aggregate weight and mix thoroughly to distribute, and then thoroughly mix in 3% water by aggregate weight.

    - Fabricate Rice specimens with 1% admixture by weight of aggregate (added by wet prep) and 6% AR binder by total mix weight.

    - Cure Rice specimens at the same temperature (330ºF ± 5ºF) for the same amount of time (2 hours) as the loose AR-AC mixture used to make Marshall specimens.

    - Set mixing temperature: AR binder at 350ºF, aggregate at 325ºF.

    - Set compaction temperature: 330ºF ± 5ºF.

    - Cool the compacted specimens upright in the molds to less than or equal to 90ºF before extruding them. Specimens should not be extruded until just prior to testing.

    - Do not place weights on top of compacted AR-AC specimens while cooling in the mold. Mixes that exhibit rebound in the mold should be discarded and redesigned.

The TAC concurred with the findings of the analyses and the recommended changes to the mix design method, which are relatively minor. These changes were incorporated as Version 2 of the AR-AC mix design procedure.

The results of the Round 2 replicate testing indicated that the control and Version 1 methods were relatively repeatable within a single laboratory and that the resulting mix designs could be substantially reproduced by another laboratory. However the replicate testing was performed on mixes made with a single source of relatively consistent high quality aggregate materials, batched by a single laboratory under tightly controlled conditions, so more evaluation would be useful.

The next task was to use round robin testing to evaluate whether the proposed Version 2 mix design method was robust enough to be used by other qualified laboratories to design AR-AC mixes, using aggregate materials of varying quality that are more challenging to work with than the Salt River materials.

3. ROUND ROBIN TESTING FOR VERIFICATION OF PROPOSED AR-AC MIX DESIGN METHOD

The purpose of the round robin testing was to provide an "acid test" for the proposed mix design procedure. The round robin was intended to simulate real world mix design and/or verification operations. Participants would start with bulk samples of respective aggregate stockpile materials, mineral admixture and prepared AR binder. Each participating laboratory would measure aggregate specific gravity and absorption properties; batch aggregates to meet composite gradation targets and mix with the prepared AR binder; compact, condition, and test mixture specimens fabricated with a range of AR binder contents; and calculate volumetric properties. The results would be used to select a design AR binder content for each of three sets of replicate results.

3.1 PROJECT AND MATERIALS SELECTION

ADOT provided the opportunity to use a 2004 ADOT AR-AC construction project to pilot the proposed standard ADOT AR-AC mix design method and provide materials for round robin testing by the project team (Speedie and Associates, Rinker, ADOT's Central Lab, and MACTEC). In addition, ADOT planned to obtain samples for acceptance testing during construction to characterize the mix as produced and placed (including compaction results) so that the performance of the resulting pavement can be monitored over time by periodic surveys. The parties involved believed this would be the best way to conclude this study.

ADOT selected the following ARAC construction project to pilot the proposed mix design method.

Project Name: Badger Springs – Big Bug
Project No.: IM-017-B(005)A
TRACS No.: 017 YV 256 H611501C
Project Location: I-17 NB and SB MP 263-255

The project was called "Big Bug" and the source of the aggregate was the Dugas Pit. ADOT personnel obtained bulk samples of the designated project aggregate materials from the Dugas Pit, including clean crusher fines, 3/8" and 3/4" stockpile materials, for use in the mix design and round robin testing. ADOT delivered the aggregate samples to MACTEC in late June, 2004.

The Dugas aggregate has relatively high water absorption: more than 1.5% for the coarse fraction, and more than 2% for the fine fraction.

3.2 MATERIALS DESIGNS

3.2.1 Asphalt-Rubber Binder Design

A Type 2 AR binder was designed and produced by Speedie and Associates (Speedie) in June 2004 for use in the AR-AC mix design. The AR binder design profile is presented in Table 7. The rubber, CRM, which came from the same source, was included with Binders 1 and 2 for Rounds 1 and 2 of this study. The PG 58-22 asphalt was from Chevron (a different source than used in Rounds 1 and 2). Sieve analysis results in Table 8 show that the rubber gradation was coarse and very similar to that used in Binder 1. ADOT provided samples of this AR binder to MACTEC for use in the mix design.

Table 7 Original Big Bug AR Binder Design Profile

Test Performed	Minutes of Reaction				Specified Limits
	60	120	240	1440	
Viscosity, Haake at 177°C, cP	2100	1900	2300	2700	1500-4000
Resilience at 25°C, % Rebound (ASTM D3407)	31	33	35	34	20 Minimum
Ring & Ball Softening Point, °F (ASTM D36)	139	138	140	143	130 Minimum
Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)	23	22	30	25	15 Minimum
Rubber source and type: CRM Type B (coarse gradation) Rubber content: 25.8% by weight of asphalt cement, 20.5 % by weight of total binder Asphalt cement source and grade: Chevron PG 58-22					

Table 8 Big Bug AR Binder Rubber Gradation, Percent Passing (ARIZ 714[21])

Sieve Size	Results (percent passing	Specified Limits (percent passing)
No. 8	100	
No. 10	100	100
No. 16	78	65 - 100
No. 30	28	20 - 100
No. 50	4	0 - 45
No. 200	0	0 - 5

3.2.2 AR-AC Mix Design

MACTEC performed the AR-AC mix design according to the procedure described. The mix design summary and detailed test results are presented in Appendix F. The design AR binder content of 7.8% yielded a target air voids content of 5.7%.

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[21] ADOT. *Materials Testing Manual*. 1985. Section 714

3.3 PREPARATION OF ASPHALT-RUBBER BINDER SAMPLES FOR ROUND ROBIN TESTING

It was discovered that the amount of AR binder originally prepared and submitted for use in the mix design was not sufficient to complete the planned round robin testing. Therefore MACTEC prepared and tested AR specimens using the source and grade of respective asphalt cement and rubber materials used in the original binder design developed by Speedie and Associates. However, differences in the properties of PG 58-22 asphalt cement samples received by MACTEC's laboratory three months after completion of the original AR binder design required some adjustments to the AR blend. It was necessary to increase the rubber content from 25.8% to 26.6% by weight of asphalt cement to provide an AR binder that fully complied with specifications throughout the 24-hour laboratory interaction period. The updated binder design data is presented in Table 9. MACTEC does not know if any similar adjustments to rubber content were required during field blending of the AR binder for AR-AC construction on the Big Bug project in September 2004.

Table 9 AR Binder Design Profile for Round Robin Testing Version 2 Mix Design

Test Performed	Minutes of Reaction					Specified Limits
	60	90	240	360	1440	
Viscosity, Haake at 177°C, cP	1600	2100	2000		1900	1500-4000
Resilience at 25°C, % Rebound (ASTM D5329)	35		37		35	20 Minimum
Ring & Ball Softening Point, °F (ASTM D36)	152	152	153		147	130 Minimum
Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)	20		22		23	15 Minimum
Rubber source and type: CRM Type B (coarse gradation) Rubber content: 26.6 % by weight of asphalt cement, 21.0 % by weight of total AR binder Asphalt cement source and grade: Chevron PG 58-22						

Since the AR binder is a major factor in mix volumetrics, it was important to assure that there was a sufficient amount of the updated binder for the participating laboratories to complete their testing. MACTEC was tasked to prepare 20 gallons of the AR binder represented by Table 9 in order to provide sufficient material. The change in the binder was expected to cause some changes in volumetric properties compared to the original mix design, but comparisons to the original design were not necessary. Since each of the round robin participants was using the new AR binder material, the conduct and analysis of the round robin testing would not be affected, although the individual test results were expected to differ from the original design parameters.

3.4 INSTRUCTIONS AND DISTRIBUTION OF SAMPLES FOR ROUND ROBIN TESTING

MACTEC prepared instructions for conduct of the round robin testing for the Version 2 mix design method to promote procedural uniformity among the participants, to highlight differences between the revised ADOT AR-AC mix design procedure and current practice, and to list the data items required to complete the round robin. A copy of the sheet of instructions is presented in Figure 2. MACTEC also provided an electronic spreadsheet file for data entry and corresponding hard copy, which clearly showed what test results and data items were required for MACTEC's analysis of the results.

MACTEC delivered copies of these documents, individual and target composite aggregate gradation data, and the revised ADOT AR-AC mix design procedure along with bulk samples of the individual aggregate and admixture materials and five one-gallon cans of asphalt-rubber binder to the participating laboratories during the last week of October and first week of November 2004. Each lab was instructed to determine aggregate specific gravities (bulk oven dry, saturated surface dry (SSD), and apparent) and absorption of the composited coarse and fine fractions, to fabricate and test three replicates of the mix design using the updated AR binder, including one set of Rice tests per replicate, and to report their test results to MACTEC. Each replicate included three AR binder contents.

To provide a better simulation of the entire mix design process, the aggregates for the round robin were not pre-batched as they were in Rounds 1 and 2. Two of the participating laboratories reported some minor departures in their aggregate blends from the target composite gradation due to variations from the overall average gradation within the stockpile samples. They were not instructed to do any artificial blending. The largest difference from the target gradation was a 2% increase on the percentage passing the No. 8 sieve (23% vs. 21%); a few screens showed a plus or minus 1% difference, but percentage passing No. 200 was within 0.4% or less from the target. Such minor departures remain well within production tolerances and make this simulation more realistic, particularly for mix design verification.

3.5 BASICS OF ESTIMATING VARIABILITY OF TEST METHODS AND ACCEPTABLE RANGES OF TEST RESULTS

To facilitate review of the round robin results and analyses presented herein, this section includes a brief summary of how testing variability is estimated, and how acceptable ranges for various numbers of individual test results are established.

The basic statistic for evaluating precision of tests of construction materials is the standard deviation of the population of measurements (test results), which is typically expressed in terms of the one-sigma limit (1s).[22] The one-sigma limit may be established for single-operator precision or multilaboratory precision. Limits for multilaboratory precision are larger due to different test operators, equipment, and laboratory environments that provide more sources of variability or error.

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[22] ASTM. "ASTM C 670-03, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials" *ASTM Book of Standards 2006*

Round Robin testing is required to verify the proposed Marshall mix design procedure for ADOT 413 Asphalt Rubber Asphaltic Concrete (ARAC). To assure that sufficient AR binder is available to complete the testing, MACTEC has prepared 5 one-gallon cans of AR binder for each participating laboratory. These will be distributed with along bulk samples of the respective component aggregate materials and hydrated lime mineral admixture, and copies of these instructions, the mix design procedure, pertinent information from MACTEC's original mix design, and blank Mix Design Data Report Form.

PLEASE READ THESE INSTRUCTIONS BEFORE PROCEEDING

1. Read the entire mix design procedure first and follow it exactly – there are some important differences from the previous procedure for Rice specimens, and temperature control. If you have any questions, contact Anne Stonex immediately at 602-437-0250 (MACTEC), or Scott Thompson if Anne is not available.

2. Each lab shall complete three replicates of the mix design, with one set of Rices per replicate. Please present the results for each replicate (3 plugs each at 3 AR binder contents and 1 set of Rices) separately for inclusion in the statistical analysis. A blank Mix Design Data Report Form is attached and an electronic copy will be provided.

3. Check aggregate gradations with washed sieve analysis. Batch aggregates in oven dry condition to meet mix design gradation targets for the respective sieve sizes.

4. Determine specific gravities (bulk oven dry, SSD, and apparent) and absorption of the composited coarse and fine aggregate fractions.

5. Use "Wet Prep" method of admixture addition – mix the designated proportion of lime with the dry aggregate, then add 3% water by aggregate weight and mix thoroughly

6. Include admixture (added by wet prep) in the Rice specimens, and 6% AR binder by total mix weight.

7. Cure Rice specimens at the same temperature (330 ± 5ºF) for the same amount of time (2 hours) as the loose GG AR AC mixture.

8. Batch Marshall specimens at 6.5%, 7.5%, and 8.5% AR binder content by total mix weight.

9. Mixing temperature for Marshall and Rice specimens is: AR binder @ 350ºF, aggregate @ 325ºF

10. Compaction temperature for Marshall specimens is 330 ± 5ºF

11. DO NOT place any weights on the compacted Marshall specimens.

12. Cool the compacted specimens in the molds to ≤ 90ºF before extruding them. Specimens shall be cooled, extruded, and bulk specific gravity determined within 8 hours from the time of compaction.

13. Measure and report Marshall stability and flow.

14. For each replicate of the mix design, and for each binder content, use Asphalt Institute formulas in the User's Guide to calculate mixture volumetrics including: effective binder volume, VMA, VFA, effective air voids, effective specific gravity of aggregate–admixture blend, binder absorption and effective binder content.

15. Report results to MACTEC by no later than Monday, November 15, 2004 on the provided Mix Design Data Report Form (e-mail transmittal to astonex@mactec.com is preferred).

Figure 2 Instructions For Round Robin Mix Design Testing

The commonly used term coefficient of variation (COV) refers to the one-sigma limit in percent (1s%) and is sometimes used as the basis of precision statements for physical tests. The COV is calculated by dividing the standard deviation (1s) by the average of the test results and multiplying by 100%.

The acceptable difference between two test results for construction materials has been standardized as the difference two sigma limit (d2s), which is calculated by multiplying 1s by $2\sqrt{2}$ rounded to 2.83. The acceptable difference expressed in percent (d2s%) is simply 1s% multiplied by 2.83. The level of confidence for d2s is 95%, which means that this difference would be exceeded on average no more than once in 20 correctly performed tests.

ASTM C 670[23] includes a table of multiplier factors to use for numbers of test results ranging from 2 through 10; the multiplier increases as the number of test results increase. Therefore, this ASTM procedure cautions that an index of precision (d2s) based on the difference of two results should not be applied to cases where more than two results are compared. However if differences among more than two results fall within the narrower acceptable range for two results, the resulting testing precision is well within the acceptable range.

ADOT supplied multilaboratory statistics (1s, d2s, 1s%, d2s%) from the last 10 years of their asphaltic concrete proficiency sample program for information. MACTEC also reviewed multilaboratory and single operator Marshall Proficiency Sample Program (PSP) statistics presented on the AASHTO Materials Reference Laboratory (AMRL) website and in the study "Effects of Test Variability on Mixture Volumetrics and Mix Design Verification" by Hand and Epps[24] to evaluate the quality of the testing performed. Analyses of precision of test results obtained for this study are primarily concerned with acceptable differences between two or more laboratories, rather than for a single operator. However to evaluate possible problems with test performance, replicate results from the respective participating laboratories for bulk and maximum theoretical specific gravities were reviewed with respect to single operator precision information. The ranges of results were within acceptable limits compared to precision statements and ranges of available Marshall proficiency sample program results, and no problems were identified.

3.5.1 Considerations Regarding Volumetric Calculations and Analysis

The ultimate products of the mix design procedure are loose mix specimens for Rice determination and a series of compacted Marshall specimens at designated binder contents, for which bulk density, stability and flow are measured. Each activity involved in making and testing these mix specimens is a possible source of variation or error which may be reflected in the final test results. These activities include materials sampling, sieve analysis and batching, mixing aggregates with admixture and AR binder,

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[23] Ibid

[24] Hand, Adam J. and Amy Epps. "Effects of Test Variability on Mixture Volumetrics and Mix Design Verification." *Journal of the Association of Asphalt Paving Technologists,* Vol. 69, pages 635-674, 2000.

and conditioning, compacting, and testing the resulting mix specimens. The AR binder may introduce additional variability.

Volumetric properties including effective binder volume, air voids content, VMA, and VFA, are calculated rather than measured. Marshall stability and flow are not volumetric properties and are of limited interest for AR-AC materials. AR binder content is controlled in the laboratory along with aggregate gradation. As pointed out by Hand and Epps,[25] direct property measurements are limited to the following tests, of which each has its own range of variability:

- Asphalt cement specific gravity (Gb).
- Combined aggregate specific gravity (Gsb).
- Bulk specific gravity of compacted Marshall specimens (Gmb).
- Maximum theoretical specific gravity of the mix (Gmm).

Because of these considerations, two approaches were used to evaluate the round robin data. For preliminary evaluation, AR-AC mixture volumetric properties were calculated for each laboratory's replicates based on the corresponding aggregate specific gravities and absorption, and respective Rice and Gmb results supplied. The compiled results are listed and plotted in Appendix F, which also includes the statistical analysis using ANOVA, and groups and ranks mean results for the volumetric properties, Marshall stability and flow.

The second approach was to normalize the data for analysis by using single values for Gsb, absorption, and Gmm for volumetric calculations for each laboratory's data**.** It was decided that the most representative values would be the overall averages of the values for Gsb, absorption, and Gmm measured by the laboratories.

3.6 ROUND ROBIN TEST RESULTS

The results of round robin testing and analyses are presented in Appendices F (preliminary) and G (normalized). As customary for round robin exercises, the names of the laboratories have been coded as A, B, C, and D. Each laboratory determined specific gravities (bulk oven dry, SSD, and apparent) and absorption of the composited coarse and fine aggregate fractions. These results are compiled and presented in Table 10. Labs A and C submitted the aggregate and Rice results, along with Marshall specimen results for bulk specific gravity, stability and flow, but did not perform the requested volumetric calculations.

The non-normalized volumetric results for each laboratory were calculated based on the individual laboratory's aggregate results, Rice results, and the calculations in the User's Guide. These are compiled and plotted in Appendix F. The overall values in the

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[25] Ibid

rightmost column of Table 10 were used to normalize the aggregate results, except that the numerical overall average for water absorption (2.08%) was slightly lower than, and thus replaced with, the corresponding calculated value of 2.14%.

Table 10 Compiled Round Robin Results for Aggregate Specific Gravity

Laboratory	MACTEC	D	B	A	C	Overall Round Robin "Average"
Source of Data	Original Mix Design	Round Robin	Round Robin	Round Robin	Round Robin	
Coarse Aggregate						
Bulk OD Specific Gravity	2.744	2.731	2.750	2.765	2.743	2.747
SSD Sp. Gravity	2.786	2.783	2.798	2.811	2.794	2.797
Apparent Specific Gravity	2.886	2.879	2.888	2.897	2.89	2.889
Water Absorption	1.55%	1.88%	1.74%	1.66%	1.85%	1.78%
Fine Aggregate						
Bulk OD Specific Gravity	2.719	2.682	2.722	2.695	2.708	2.702
SSD Specific Gravity	2.778	2.761	2.782	2.765	2.79	2.775
Apparent Specific Gravity	2.889	2.912	2.896	2.900	2.951	2.915
Water Absorption	2.17%	2.94%	2.21%	2.63%	3.05%	2.71%
Combined Coarse & Fine without Mineral Admixture						
Bulk OD Specific Gravity	2.735	2.713	2.739	2.740	2.731	2.731
SSD Specific Gravity	2.783	2.775	2.792	2.794	2.793	2.789
Apparent Specific Gravity	2.874	2.891	2.891	2.898	2.911	2.898
Water Absorption	1.77%	2.29%	1.89%	2.00%	2.14%	2.08%

Compiled Rice results are presented in Table 11, along with related precision calculations for the round robin testing. The precision statement for ASTM D 2041 for single operator, dry back procedure cites a “1s” value of 0.0064 for the bowl method. Although the ADOT method uses flasks, this is the only available comparison for a single operator. Based on this value, the allowable difference among three results would be 3.3(0.0064) = 0.0211, and the allowable difference among six results (Lab A) would be 4.0(0.0064) = 0.0256. The results in Table 11 are within these ranges. The overall average Rice value of 2.512 was used to normalize volumetric calculations.

Table 11 Compiled Round Robin Results for Rice at 6.0% AR Binder Content

Laboratory	MACTEC	D	B	A	C	
Rice Results	Original Mix Design*	Round Robin	Round Robin	Round Robin	Round Robin	
Rice 1	2.516	2.507	2.505	2.522	2.533	
Rice 2	2.519	2.499	2.509	2.517	2.520	
Rice 3	2.523	2.497	2.499	2.497	2.525	
Rice 4				2.515		
Rice 5				2.507		
Rice 6				2.509		
Rice Precision Calculations						Overall
Average	2.519	2.501	2.504	2.511	2.526	2.512
Standard Deviation (1s)	0.0035	0.0053	0.0050	0.0088	0.0066	0.0106
d2s	0.0099	0.0150	0.0142	0.0250	0.0186	0.0299
COV (1s%)	0.139	0.212	0.201	0.351	0.260	0.421
d2s%	0.394	0.599	0.569	0.994	0.735	1.190
* Original mix design used different AR binder than Round Robin						

Table 12 presents additional comparisons for Rice testing, including ranges of average Rice results gleaned from AMRL and ADOT Proficiency Sample Program (PSP) multilaboratory statistics, along with the corresponding precision statistics from ASTM D 2041-03a, with and without dry back. The multilaboratory ASTM statistics may include results from bowls and flasks, which may account for some of the differences from ADOT PSP data.

Table 12 Multilaboratory Proficiency Sample Program Ranges for Rice Results

Range of Results	AMRL Gmm Results	ADOT Gmm Results	ADOT MAX Density	ASTM D 2041-03a Precision for 2 results	
Average	2.417-2.591	2.420-2.460		Dryback (Bowl only)	No Dryback
1 Standard Deviation	0.011-0.020	0.012-0.0243		0.0193	0.016
2 Standard Deviations	0.031-0.057	0.033-0.069		0.055	0.044
Coefficient Of Variation (1s%)	0.43-0.84	0.477-0.988	0.38-0.99		
Coefficient Of Variation (2s%)	1.27-2.37	1.349-2.795	1.08-2.80		

Laboratory A experienced problems with their Marshall hammer during round robin testing. It is not clear if these problems were resolved before round robin testing was completed, but their Marshall compaction equipment was subsequently replaced. Lab A asked for additional samples of materials to make and test additional replicates, and submitted data for eight sets of replicates. These results were checked for outliers according to ADOT methods. No outliers were identified, although one data point was right at the upper outlier limit. Thus results for each of the 8 replicates were included in the statistical analysis. This unbalanced the experimental design, but it does not appear to have interfered with the One-Way ANOVA analysis.

For each laboratory, results of aggregate bulk specific gravity (Gsb) testing were also reviewed. Standard deviations were calculated for combined sets of replicate plugs at each of the three AR binder contents, and are shown on the compiled data sheets in Appendix F for each participating laboratory. Gsb is directly measured, so these values were not affected by normalizing the data for volumetric calculations. Because these specimens were to be tested for stability and flow, no paraffin or parafilm could be used. This factor would be expected to increase variability of Gsb measurement, particularly for specimens with relatively high air voids contents. The ranges of standard deviations within each laboratory are compiled in Table 13. The within laboratory results are considered equivalent to single operator precision for this comparison, although in some cases more than one person performed the testing. Comparisons of within laboratory standard deviations with AASHTO Materials Reference Library (AMRL) statistics for ASTM D 2726-00 do not indicate any serious or systematic problems with the precision of the round robin Gsb testing.

Table 13 Within Laboratory Standard Deviation (1s) Ranges of Gsb Results

Lab ID	Number of Replicates	Round Robin Range of 1s values	ASTM D 2726-00
A	9 6	0.007-0.015 0.025	Single Operator 1s limit=0.0124 2 sample d2s limit = 0.035
B	9	0.007-0.011	
C	9	0.006-0.008	
D	9	0.009-0.020	

ASTM D 2726-04 provides precision data only for mixes made with aggregates with water absorption less than 1.5%, which does not apply to the highly absorptive Dugas aggregate used in the round robin. Although the single operator precision limits for nominal ¾-inch mixes are very similar to those listed in Table 13, the multilaboratory limits are much tighter for low absorption aggregates. A multilaboratory comparison of precision of test results is included in Appendix F which supports that Gsb testing among the respective laboratories was generally performed within acceptable limits.

Preliminary analysis of this round robin experiment indicated that at least two of the means differed for each property of interest at each AR binder content, except for Marshall stability at 6.5 and 7.5% AR content. When at least two means were found to differ, Duncan’s Multiple Range Test was used to compare and rank the respective means, to identify which means were statistically similar and which differed. The Duncan test can be applied to unequal sample sizes.[26] The Summary of Duncan's Multiple Range Comparisons is presented graphically in Appendix F. Lines are used to group like means and distinguish among groups. Results for Labs A and C were often similar to each other, while Labs B and D often grouped with each other.

To evaluate the practical differences among the results, design AR contents were determined for the respective AR-AC mix design replicates and are presented in Table 14. Labs C and D would have selected AR contents of 8.5% to meet mix design air voids criteria of 5.5% ± 1%, while Lab B's data would allow slightly lower AR contents of 8.0% to 8.3%. Lab A did not achieve the design air voids requirements within the given range of AR contents, which may be related to the previously noted equipment problems.

Table 14 Preliminary AR Content Selection

Lab Set No.	B	C	D	A
	% AR, % Air voids	% AR, % Air voids	% AR, % Air voids	% AR, % Air voids
1	8.2% AR, 5.5% AV	8.5% AR, 6.5% AV	8.5% AR, 5.6% AV	8.5% AR, 7.1% AV
2	8.3% AR, 5.6% AV	8.5% AR, 6.2% AV	8.5% AR, 5.6% AV	At 7.5 and 8.5% AR, 6.8% AV
3	8.0% AR, 5.4% AV	8.5% AR, 6.2% AV	8.5% AR, 5.7% AV	8.5% AR, 6.8% AV
1R				8.5% AR, 9.1% AV
2R				8.5% AR, 8.6% AV
3R				8.5% AR, 9.0% AV
4				At 7.5 and 8.5% AR, 8.6% AV
5				8.5% AR, 9.0% AV

Normalizing the results removed some of the noise from the data, and results converged so that statistical differences were eliminated from VMA at 6.5 and 7.5% AR content, from VFA at 6.5% AR, and effective air voids at 6.5% AR. The normalized results are compiled and plotted in Appendix G, along with ANOVA and the Summary of Duncan's Multiple Range Comparison tests. When there was a difference in means, results from Labs A and C still tended to group together and results from Labs D and B generally continued to form a second group. However normalizing had no effect on the measured values for Marshall Gsb, stability, or flow.

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[26] Montgomery, Douglas C. *Design and Analysis of Experiments* Second Edition. John Wiley & Sons, 1984. pp 66-68

To evaluate the practical effects of normalizing the data, AR contents were selected based on the normalized results and determinations are presented in Table 15.

Table 15 Normalized AR Content Selection

Lab Set No.	B	C	D	A
	% AR, % Air voids	% AR, % Air voids	% AR, % Air voids	% AR, % Air voids
1	8.4% AR, 5.4% AV	8.5% AR, 5.8 % AV	8.5% AR, 5.8 % AV	8.5%AR, 6.8% AV
2	8.5% AR, 5.4% AV	8.5% AR, 5.9 % AV	8.5% AR, 6.1 % AV	At 7.5 and 8.5% AR, 6.6% AV
3	8.3% AR, 5.5% AV	8.5% AR, 6.0 % AV	8.5% AR, 6.2 % AV	8.5% AR, 7.4 % AV
1R				8.5% AR, 9.1% AV
2R				8.5% AR, 8.7 % AV
3R				8.5% AR, 9.3 % AV
4				At 7.5 and 8.5% AR, 8.6% AV
5				8.5% AR, 9.1% AV

For Labs C and D, the range of voids at 8.5% AR converged; the voids for Lab C dropped and those for Lab D increased. For Lab B, the selected AR content shifted from 8.0-8.3% to 8.3-8.5% to correspond more closely with results from Labs C and D. Lab A results were based on values that were close to the overall averages selected for normalizing the data so little change was achieved. Lab A results did not meet the ADOT design criterion for effective air voids, which may be related to the compactor problems encountered. However results of the other 3 participating labs are in close agreement.

3.7 ADDITIONAL CONSIDERATIONS

3.7.1 Laboratory Technicians and Equipment

Although the round robin results reported herein have been coded as customary to protect the participants, there is some additional information that should not be omitted from the analysis. Technician experience with the highly modified AR-AC materials appears to be a factor in repeatability (within lab) and reproducibility (between laboratories) in the design procedure.

During the round robin phase of this study, Lab A not only had major problems with Marshall hammer calibration, but also lost the technicians who had the most experience with working with AR-AC mixtures. Lab C, whose results often grouped closely with those of Lab A, routinely performed conventional mix design testing but had relatively limited experience in designing AR-AC mixes. Labs B and D, whose results also tended to group closely together and often differed from the other two labs, had fairly extensive experience in designing AR binders and AR-AC mixes.

3.7.2 Field Performance

Although ADOT AR-AC mixes have historically performed well, sections of the subject AR-AC mixture and several others constructed in 2004 experienced significant failures. AMEC Earth & Environmental, Inc. evaluated three of these AR-AC projects including Big Bug for ADOT and determined that the primary cause was moisture susceptibility due to high in-place air voids.[27]

The subject AR-AC mixture for the Big Bug project was placed on the north and south bound lanes of I-17 between mileposts 263 and 256 at night from September 1 to October 4, 2004. The AR-AC was placed at a nominal compacted thickness of two inches on a new replacement layer in accordance with ADOT 417. Results of acceptance tests indicated that AR binder content and aggregate gradation were generally within limits.[28] In-place compaction was not an acceptance requirement for AR-AC mixes at that time. The AR-AC was surfaced with a nominal 2/3-inch thick layer in accordance with ADOT 414 Asphaltic Concrete Friction Course (Asphalt-Rubber), which failed rapidly by raveling during the winter and was replaced in spring 2005. Additional distress, including rutting and potholes, developed during summer 2005 that was related to the AR-AC rather than the friction course. Areas of the AR-AC mix stripped severely, particularly in the southbound lanes. Although it is clear that water entered the AR-AC layer, questions remain as to why the water did not drain out.

Forensic data from the failure investigation by AMEC included air voids contents of 31 cores obtained from this project that ranged from 4.9 to 10.8%, with an average of 8.1%. Four cores had 6.0% air voids or less; three had 10.0% air voids or more.

At this time, ADOT agrees with AMEC that the observed moisture damage in the projects reviewed is most likely due to inadequate compaction. Marginally low ambient temperatures during and immediately after construction are considered to be a primary reason that compaction was not achieved. Night paving at higher elevations conflicts with the need for relatively high placement and compaction temperatures.

In an effort to avoid such failures in the future, ADOT has implemented a new specification for AR-AC: in ADOT 415[29] Asphaltic Concrete (Asphalt-Rubber)-End Product. ADOT 415 adds compaction requirements, including a target of 7.0% in-place air voids, with Upper Limit of 9.0% and Lower Limit of 4.0% in-place air voids. AMEC applied these requirements in its forensic analysis and found that the failing materials were not in compliance, which supports the value of the density requirements.

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[27] Hanson, Douglas I. and Joseph Phillips. “Forensic Analysis Asphalt Rubber Asphalt Concrete (ARAC)” Report No. 1, AMEC Earth & Environmental, Inc., Phoenix, AZ, May 18, 2006.

[28] Ibid

[29] ADOT. *Standard Specifications for Road and Bridge Construction 2000*. Section 415

3.7.3 Resistance to Moisture Damage

Neither the ADOT 415 AR-AC End Product specification nor the proposed laboratory mix design procedure addresses testing to evaluate resistance to moisture damage. There are some issues to be addressed in determining what method and limits to use for such testing. The standard immersion-compression test is not appropriate for AR-AC materials, as the unconfined AR-AC specimens slump and deform during conditioning. AMEC and others have suggested consideration of tensile strength ratio as a criterion for evaluating resistance to moisture damage. However, further research is needed to assess whether this approach will do a better job of predicting AR-AC resistance to moisture damage than it did when ADOT evaluated use of such tests for predicting susceptibility of conventional asphaltic concrete mixes to moisture damage.

3.7.4 Draft ARIZ 832 (October 17, 2006) Marshall Method for AR-AC

The proposed mix design method is currently designated as Draft ARIZ 832 (October 17, 2006) Marshall Mix Design Method for Asphaltic Concrete (Asphalt-Rubber) [AR-AC]. It is presented in Appendix H. Technical changes from Version 2 used in the round robin primarily consist of reducing temperatures for mixing (aggregate at 325 ± 3°F instead of 330 ± 5°F), and for curing and compaction (300 ± 5°F instead of 330 ± 5°F). Other changes were made to improve clarity and presentation of the text and calculations. The October 17 draft is currently under review by ADOT and industry and may be revised during the approval process. Further refinements may be suggested as the AR-AC mix design procedure is implemented and used, and may include addition of some method of evaluating resistance to moisture damage.

Decreasing the mixing and compaction temperatures from that used in the Big Bug round robin may have some related effects on mixture volumetrics. The increased AR binder stiffness at lower temperatures is likely to increase the air voids contents measured in the mix design, which would increase design AR binder content. High AR binder contents are intrinsic to the performance properties of the desired product, as long as they are not excessively high.

What is most important is that future AR-AC mixes designed according to this procedure are able to provide the same enhanced performance properties that ADOT has grown to expect from the pre-2004 mixes.

4. CONCLUSIONS

Based on the results of testing performed in Rounds 1 and 2, and results of the Round Robin, Draft ARIZ 832 (October 17, 2006) appears to be an acceptable and appropriate procedure for the intended purpose. Although mix design results are somewhat variable, evaluation of the statistics for the same tests applied to conventional asphaltic concrete materials indicates the measured variability is very similar.

It does not appear that using asphalt-rubber binder makes the testing of the AR-AC mixtures significantly more variable than the testing of conventional or polymer modified asphaltic concrete materials. This was a major concern during this study. No extra laboratory equipment will be required to perform ARIZ 832. However, as for any bituminous material, experience, properly operating equipment, and good practices are required to achieve representative results. Additional training may be appropriate for technicians who are not experienced in working with AR-AC materials.

The most substantial changes from the previous modified ADOT 815c[30] AR-AC mix design procedure are in the preparation and treatment of the Rice specimens. AR-AC Rice specimens will include mineral admixture and no liquid antistrip will be added. Rice specimens will be prepared at 6.0% AR binder content and cured at the same time and temperature as the loose Marshall specimens. Temperatures for mixing, and for curing and compacting AR-AC specimens have been modified and the allowable ranges are now tighter to reduce variability. Volumetric calculations are performed according to national standards. Rebound is now addressed: no confining weights will be used to prevent specimen rebound, and if rebound is observed after compaction, the specimens will be discarded and the target aggregate gradation will be adjusted to better accommodate the AR binder.

Implementation of ARIZ 832 and ADOT 415 began on a limited basis during the 2006 construction season. It appears that there is a “learning curve” involved in meeting AR-AC compaction requirements. A combination of favorable ambient temperatures, proper equipment, and good practices for materials handling and equipment operation are needed to meet the requirements.

This study has documented that the asphalt-rubber binder is a major factor in AR-AC volumetrics. This supports experience and practical observations by ADOT personnel and others who have been involved in AR-AC mix design. Finer rubber gradations in the AR binder are likely to facilitate AR-AC mix design. Coarse rubber gradations in the AR binder may interfere with establishing an appropriate aggregate matrix (target gradation) and may not permit development of a suitable AR-AC mix design. If this occurs, the first alternate should be to try using a binder made with a finer rubber gradation. However in cases where suitably fine crumb rubber is not available, adjustment of the aggregate gradation may be necessary.

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[30] Ibid. Section 815c

APPENDIX A
EXISTING MODIFICATIONS TO ARIZ 815C[31] USED FOR AR-AC MIX DESIGNS UNTIL 2006
(VERSION 5-28-03)

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[31] Ibid

Note: This document describes the existing modifications to the ARIZ 815 mix design procedure that ADOT currently uses in design of Section 413 Asphaltic Concrete (Asphalt-Rubber) mixes. No changes were made to Figures 1 through 11 that remain in current use but are not attached to this version for ease of transmittal. MACTEC's recommended revisions to ARIZ 815c for use in the proposed mix design procedure being developed for GAP-Graded Asphalt Rubber Concrete will be presented in a separate document.

ARIZ 815c
Modified for Asphaltic Concrete (Asphalt-Rubber)
May 2003
(23 Pages including Figures 1 through 11)

MARSHALL MIX DESIGN METHOD FOR ASPHALTIC CONCRETE (ASPHALT-RUBBER)

(A Modification of AASHTO T 245)

Scope

1. This method is used to design Section 413 Asphaltic Concrete (Asphalt-Rubber) mixes using four-inch Marshall apparatus.

Apparatus

2. The apparatus necessary includes all items required to perform the individual test methods referred to in this procedure as follows:

ARIZ 201c	Sieving of Coarse and Fine Graded Soils and Aggregates
ARIZ 210b	Specific Gravity and Absorption of Coarse Aggregate
ARIZ 211c	Specific Gravity and Absorption of Fine Aggregate
ARIZ 410c	Compaction and Testing of Bituminous Mixtures Utilizing Four-Inch Marshall Apparatus (see AASHTO T 245 for required equipment)
ARIZ 415b	Bulk Specific Gravity of Compacted Bituminous Mixes
ARIZ 806e	Maximum Theoretical Specific Gravity of Laboratory Prepared Bituminous Mixtures (Rice Test).

Materials

3. (a) Mineral Aggregate - The mineral aggregate for the asphaltic concrete shall be produced material from the source(s) for the project. Use of natural sand is not permitted in asphalt-rubber mixtures.

   1) Mineral aggregate from each source shall be tested for compliance to the project requirements for Abrasion (AASHTO T 96).

2) The mineral aggregate shall be combined using the desired percentages of the different produced materials.
3) The composite blend of mineral aggregate shall be tested for compliance to the grading limits in Table 413-2 of the specifications according to (ARIZ 201) Gradation, modified so that the No. 8 sieve is the smallest coarse sieve.
4) The composite blend of mineral aggregate shall conform to the requirements of Table 413-3 of the specifications for Sand Equivalent (AASHTO T 176) and for Crushed Faces (ARIZ 212)

(b) Bituminous Material - The bituminous material used in the design shall be the asphalt-rubber conforming to the requirements of Section 1009 of the specifications, which is to be used in the production of the asphaltic concrete. No dilution with extender oil, kerosene, or other solvents is allowed. The specific gravity of the bituminous material shall be determined in accordance with AASHTO T 228.

(c) Mineral Admixtures - Mineral admixture is required in the amount of 1.0 percent by weight of the mineral aggregate and shall be the same type of material to be used on the project. Mineral admixture shall be either portland cement, blended hydraulic cement, or hydrated lime conforming to the requirements of Table 413-4 of the specifications.

Determination of Composite Gradation

4. The composite gradation of the mineral aggregate is determined using desired percentages. When mineral admixture is used, the composite of mineral aggregate and mineral admixture is also determined. When mix designs are performed using bin material a composite of the bin material is performed using the desired percentages, along with a composite of the stockpile material which feeds the bins at the desired percentages. For designs developed using both bin material and stockpile material the composite gradation of the bin material is used for the design aggregate gradation.

NOTE: The sieve analysis for the aggregate from each individual stockpile or bin shall be determined in accordance with ARIZ 201. The Pass No. 4 fraction of each aggregate shall then be screened into No. 8 and Pass No. 8 sizes, and the weights for each recorded. The proportion of the Pass No. 4 fraction which passes the No. 8 sieve is determined by dividing the weight of Pass No. 8 material by the total weight of the No. 8 and Pass No. 8 material. This value is multiplied by the Pass No. 4 from the sieve analysis to determine the actual Pass No. 8, which is recorded to the nearest whole percent. This value is compared to the Pass No. 8 value from sieve analysis to provide a check on the representativeness of the fine sieve analysis. If the difference between the two Pass No. 8 values is greater than 4 the fine sieve analysis shall be adjusted by multiplying the percent pass for each sieve smaller than No. 8 by a factor obtained by dividing the actual Pass No.8 by the Pass No. 8 from sieve analysis.

(a) The compositing of aggregate materials is performed as described in ARIZ 205, "Composite Grading", with the following exceptions: (An example of a composite done for mix design is given in Figure 1, which shows the procedure outlined below.)

1) The Pass No 8 fraction is calculated for each type of aggregate by multiplying the % Pass No. 8 from the sieve analysis for the material by the "% of composite" that the type of aggregate represents and the total of each of the Pass No. 8 fractions is recorded as the "Composite of Pass No. 8 from Gradation of Each Stockpile or Bin".

2) The "Composite of Pass No. 8 from Gradation of Each Stockpile or Bin" is rounded to the whole % and recorded as the composite % Pass No. 8 sieve.

3) Adjust fractions of material passing the No. 8 sieve for each type of aggregate as necessary to correspond to the value for each calculated % Pass No. 8.

4) After summing the % retained for each size fraction and rounding to the whole percent, any adjustments are made to the composite so that the calculated value for Pass No. 8 is not changed.

NOTE: If desired, the composite of aggregate materials may be adjusted using the method of "artificially grading" as shown in ARIZ 244.

(b) When mineral admixture is included in the mix the aggregate composite and gradation is adjusted to indicate the composite using the desired % mineral admixture "by weight of the aggregate". An example of the calculations is given in the equation below:

The aggregate "% of composite" for each aggregate stockpile or bin is adjusted by the following:

$$\begin{array}{c}\text{Adjusted}\\ \text{Aggregate}\\ \text{"\% of Composite"}\end{array} = \frac{\text{Aggregate "\% of Composite"}}{100 + (\text{\% mineral admixture})} \text{ X } 100$$

Example (for coarse aggregate and 2% mineral admixture):

$$\begin{array}{c}\text{Adjusted}\\ \text{Aggregate \% of}\\ \text{Composite}\end{array} = \frac{26}{100 + 2} \text{ X } 100 = 25.49\% = 25\%$$

2) The percentage of mineral admixture in the adjusted composite is determined:

$$\text{Adjusted \% Mineral Admixture} = \frac{\text{\% mineral admixture}}{100 + (\text{\% of mineral admixture})} \times 100$$

Example (For 2% mineral admixture):

$$\text{Adjusted \% mineral admixture} = \frac{2}{100 + 2} \times 100 = 1.96\% = 2\%$$

3) The aggregate gradation (for % passing) is adjusted for mineral admixture by performing the following calculation for each sieve:

$$\text{Adjusted \% Pass Each Sieve} = \frac{\text{\% Pass From Aggregate Composite} + \text{\% Mineral Admixture}}{100 + (\text{\% of mineral admixture})} \text{ X } 100$$

Example (For No. 16 sieve):

$$\text{Adjusted \% Pass} = \frac{36 + 2}{100 + 2} \times 100 = 37.25\% = 37\%$$

4) The % retained on each sieve is determined:

$$\text{\% Retained on Each Sieve} = \text{\% passing next larger sieve size} - \text{\% passing desired sieve size}$$

Example (For 1/4" sieve):

% retained = 78% - 67% = 11%

(c) The composited gradation of the aggregate (and composite of aggregate and mineral admixture when used) is shown on the design card, along with the percentage of each material.

Preparing Samples for Mix Designs Using Stockpile Material

5. The samples necessary in the design are prepared and weighed up for testing utilizing the stockpile composite information.

(a) Representative samples, for each size fraction in the composite, are obtained for the tests necessary in the design. The size fractions which shall be utilized are individual sizes from each stockpile for material of No. 8 sieve size and larger, and minus No. 8 material from each stockpile. A weigh up sheet is shown in Figure 2, which gives an example illustrating the use of the composite information and the material sizes required.

NOTE: If the composite was accomplished using the "artificial grading" method, the preparation of samples will be as directed in ARIZ 244.

(b) The aggregate sample sizes, number of samples required for design tests, and other pertinent information in preparing the samples are given in Section 7.

Preparing Samples for Mix Designs Using Bin Material

6. When bin material is used for the mix design the samples are prepared and weighed up for testing as outlined below.

(a) The stockpile composite gradation shall be adjusted to the desired gradation of the bin composite. This is accomplished as outlined in ARIZ 244.

(b) Representative samples of bin material, for each size fraction in the bin composite, are obtained for performing the Marshall Stability/Flow and Density tests. Size fractions to be used are individual sizes from each bin for material of No. 8 sieve size and larger, and Pass No. 8 material from each bin.

(c) Representative samples of stockpile material, using the adjusted composite information obtained from "artificially grading" in ARIZ 244, are obtained for performing all other required tests (Sand Equivalent, Crushed Faces, Abrasion, Fine and Coarse Aggregate Specific Gravity/Absorption, Rice Test, and Immersion Compression Test). The size fractions to be used are individual sizes from each stockpile for material of No. 8 sieve size and larger; and for the Pass No. 8 material, the amount of each size fraction for Pass No. 8 to Retained No. 40, Pass No. 40 to Retained No. 200, and Pass No. 200. An illustration of the use of the above size fractions is shown in Figure 4 of ARIZ 244.

(d) The aggregate sample sizes, number of samples required for design tests, and other pertinent information in preparing the samples are given in Section 7.

Aggregate Sample Sizes

7. (a) The following table gives the aggregate samples sizes and the number of samples required for each test. The aggregate weight shown below for Maximum Theoretical Specific Gravity will provide 3 test samples and the amount shown for Density-Stability/Flow will produce 3 Marshall specimens.

Test	Aggregate Sample Size	Number Samples
Fine Aggregate Specific Gravity/ Absorption	1200 grams	1
Coarse Aggregate Specific Gravity/Absorption	*	1
Maximum Theoretical Specific Gravity (Rice Test)	3000 grams	1
Density-Stability/Flow	**3000 grams	***

* Minimum weight of the test sample is determined by nominal maximum size of the aggregate, in accordance with AASHTO T 85.

** Generally the weight shown will provide specimens of acceptable heights, but adjustments may be necessary in some cases. If the combined specific gravity of the coarse and fine mineral aggregate is known, the following equation will normally provide specimens within the specified criteria:

$$\text{Adjusted Weight of Aggregate} = \frac{\text{Combined Bulk O.D. Agg. Specific Gravity}}{2.650} \times \text{Approx. Sample Size Shown(3000 grams for Density-Stability/Flow)}$$

*** 1 Sample for each asphalt content desired to be tested.

NOTE: The proper amount of mineral admixture is added dry to the composited aggregate samples for Density-Stability/Flow specimens only. The mineral admixture and aggregate shall be thoroughly mixed together.

Aggregate Specific Gravities and Absorption

8. (a) The Bulk Oven Dry, S.S.D., Apparent specific gravities and absorption of the fine and coarse mineral aggregate shall be determined in accordance with ARIZ 211 and 210 respectively.

NOTE: When different sources of fine mineral aggregate are to be used in the production of asphaltic concrete the specific gravity and absorption of each individual fine material shall be determined and recorded and the combined specific gravity and absorption calculated as specified in ARIZ 211. This allows for the combining of fine aggregates in varying amounts without having to composite a sample of the different sources and testing the combined materials. If "artificial grading" has been performed, the fine aggregate specific gravity and absorption shall be determined on a sample of the combined material from the different sources.

(b) The combined Bulk Oven Dry, S.S.D., Apparent specific gravities and combined absorption for the coarse and fine mineral aggregate are calculated by the following:

$$\text{Combined Specific Gravity} = \frac{100}{\dfrac{Pc}{Gc} + \dfrac{Pf}{Gf}}$$

Where: Pc = weight percent of coarse aggregate (Plus No. 4)
Pf = weight percent of fine aggregate (Minus No. 4)
Gc= specific gravity of coarse aggregate
Gf = specific gravity of fine aggregate

(Note the Pc and Pf are for aggregate material only. If mineral admixture is being used in the design, Pc and Pf shall be determined for composite of mineral aggregate only, not for the aggregate and mineral admixture composite.)

Example (For combined S.S.D. specific gravity):

$$\text{Combined S.S.D. Specific Gravity} = \frac{100}{\dfrac{41}{2.597} + \dfrac{59}{2.626}} = 2.614$$

$$\text{Combined Absorption} = \frac{\text{Combined S.S.D. Specific Gravity} - \text{Combined Bulk O.D. Specific Gravity}}{(\text{Combined Bulk O.D. Specific Gravity})} \times 100$$

Example: Combined S.S.D. Sp. Gr. = 2.614
Combined Bulk O.D. Sp. Gr. = 2.576

$$\text{Combined Absorption} = \frac{2.614 - 2.576}{2.576} \times 100 = 1.48\%$$

Preparation of Specimens for Density and Stability/Flow Determination

9. Marshall specimens shall be prepared as follows, using apparatus shown in AASHTO T 245 and the procedures in ARIZ 410c with the modifications presented herein.

(a) The temperature of the asphalt and aggregate at the time mixing begins shall be 325 ± 10ºF.

(b) The aggregate and mineral admixture shall be dried to constant weight at the temperature required as shown in paragraph 6 (a). Bring samples to desired weight of approximately 3000 grams to make a batch of three Marshall specimens by adding a small amount of proportioned Pass No. 8 make up material.

NOTE: Normally a range of 3 different asphalt-rubber binder contents at 1.0 % increments will provide sufficient information, although in some cases it may be necessary to prepare additional sets of samples at other asphalt-rubber contents. Two series of binder contents are typically used: either 6.0, 7.0, and 8.0% asphalt-rubber by total mix weight; or 6.5, 7.5, and 8.5% asphalt-rubber by total mix weight.

(c) Before each batch is mixed, the asphalt-rubber binder shall be heated in a forced draft oven for approximately 2 hours or as necessary to reach a temperature of 325 to 350F. Upon removal from the oven, the asphalt-rubber shall be thoroughly stirred to uniformly distribute rubber particles throughout the binder before adding the designated proportion to the aggregate-admixture blend. If there is any delay before beginning of mixing the binder with the composite aggregate blend, thoroughly stir the asphalt-rubber again immediately before pouring.

CAUTION: Do not use a hot plate or open flame to heat the asphalt-rubber, to avoid damaging it. Once the asphalt-rubber temperature has reached 325F or the desired temperature, the container may briefly be moved to a hot plate for 3 to 5 minutes, if the asphalt-rubber is constantly stirred to avoid sticking or scorching, to maintain temperature and facilitate batching and mixing with aggregates and admixture. Do not heat the binder longer than necessary to complete batching and mixing operations, or damage by overheating. Properties of asphalt-rubber vary with time and temperature, and changes to the binder are likely to affect mixture volumetric properties.

NOTE: Before each batch is mixed, the mixing bowl and whip shall be heated to 325±10F.

(d) The aggregate, mineral admixture, and asphalt-rubber binder shall be mechanically mixed for 90 to 120 seconds in a commercial dough mixer with a minimum 10 quart capacity and equipped with a wire whip and then hand mixed as necessary to ensure thorough coating.

(e) After mixing, each batch shall be placed on a tarp or sheet of heavy paper and in a rolling motion thoroughly mixed and spread according to the procedures described in ARIZ 416c, 3 (d) and (e). The material shall be spread into a circular mass 1 1/2 to 2 inches thick. The circular mass shall be cut into 6 equal segments, taking opposite segments for each individual sample and using up the batch.

(f) Each sample shall be placed in a pan and allowed to cure for 2 hours ± 10 minutes at approximately 325 ± 10F. A mold assembly (base plate, mold and collar) shall be heated to approximately 325± 10 F. The face of the compaction hammer shall be thoroughly cleaned and heated on hot plate set at approximately 325± 10 F.

(g) Lightly spray one side of a 4" paper disc with PAM (vegetable cooking spray used as release agent), and place the disc PAM-side up in the bottom of the mold before the mixture is introduced. Place the entire batch in the mold with a heated spoon. Spade the mixture vigorously with a heated flat metal spatula, with a blade approximately 1" wide and 6" long and stiff enough to penetrate the entire layer of material, 15 times around the perimeter and 10 times at random into the mixture, penetrating the mixture to the bottom of the mold. Smooth the surface of mix to a slightly rounded shape.

(h) Before compaction, put the mold containing the mix sample back in the 325F oven for 45 to 60 minutes to assure that the mixture shall be at the proper compaction temperature of 325± 10F.

(i) Lightly spray one side of a 4" paper disc with PAM, and immediately upon removing the mold assembly and mix from the oven, place the paper disc with PAM side down on top of mixture, place the mold assembly on the compaction pedestal in the mold holder, and apply 75 blows with the compaction hammer. Remove the base plate and collar, and reverse and reassemble the mold. Apply 75 compaction blows to the face of the reversed specimen.

NOTE: The compaction hammer shall apply only one blow after each fall, that is, there shall not be a rebound impact.

(j) Remove the collar and top paper disc and allow the compacted specimen to cool in a vertical position in the mold with base plate to approximately 77 to 90F. Rotate the base plate occasionally to prevent sticking.

NOTE: Cooling may be accomplished at room temperature, in a 77 F. air bath, or if more rapid cooling is desired the mold and specimen may be placed in front of a fan until cool, *but do not turn the mold on its side*.

(k) Extrude the specimen from the mold on the same day that it is compacted, but not until it is time to test it.

NOTE: Care shall be taken in extruding the specimen from the mold, so as not to deform or damage the specimen. If any specimen is deformed or damaged during extrusion, the entire set of specimens at that asphalt-rubber content shall be discarded and a new set prepared.

(l) Immediately upon extrusion, measure the height of the specimen to the nearest 0.001 inch and its weight in air to the nearest 0.1 gram.

NOTE: Compacted specimens shall be 2.50 ± 0.20 inches in height. If this criteria is not met for the specimens at each asphalt content the entire set of specimens at that asphalt content shall be discarded and a new set prepared after necessary adjustments in the aggregate weight have been made.

(m) Follow the procedure in paragraphs (f) through (l) for all specimens required.

Specific Gravity/Bulk Density of Specimens

10. (a) Determine the specific gravity of the three specimens at each asphalt-rubber content in accordance with ARIZ 415, Method A, except that paraffin coating cannot be applied to specimens that are to be tested for Marshall stability and the paraffin method shall not be used in the mix design. The determination of the "Weight in Water" and "S.S.D. Weight" of each specimen will be completed before the next specimen is submerged for its "Weight in Water" determination.

NOTE: Specimens fabricated in the laboratory that have not been exposed to moisture do not require drying after extrusion from the molds. The specimen weight obtained in 9(l) is its dry weight.

(b) Determine the density in lbs./cu. ft., by multiplying the specific gravity of each specimen by 62.3 lbs./cu. ft.

NOTE: For each asphalt-rubber content, the densities shall not differ by more than 2.0 lbs/cu. ft. If this density requirement is not met the entire set of specimens at that asphalt-rubber content shall be discarded and a new set of specimens prepared.

(c) Determine the average specific gravity and bulk density values for each asphalt-rubber content and plot each on a separate graph versus asphalt-rubber content. Connect the plotted points with a smooth curve that provides the “best fit” for all values.

Stability and Flow Determination

11. The stability (including height corrections) and flow of each specimen shall be determined according to ARIZ 410c, Sections 4.(f) through 4(k) except that flow is recorded in units of 0.01 inch.

(a) Determine and record the average values for stability and flow for each asphalt content, and plot each on a separate graph using the same scale for asphalt-rubber content as used in 10. (c). Connect the plotted points with a smooth curve that provides the “best fit” for all values.

Maximum Theoretical Specific Gravity (Rice Test)

12. The maximum specific gravity of the mixture shall be determined in accordance with ARIZ 806 at 6.0% asphalt-rubber content and calculated for the other contents tested in the mix design.

Determination of Design Asphalt-Rubber Content

13. The design asphalt-rubber content is determined as follows in paragraphs (a) through (e).

(a) For each asphalt-rubber content used, calculate effective (air) voids (EV) according to ARIZ 424, and percent absorbed asphalt-rubber, voids in mineral aggregate (VMA), and voids filled with asphalt (VF) in accordance with the example given in Figures 8 and 9 for mixes including mineral admixture.

(b) Using a separate graph for each of the volumetric properties calculated in 13(a), plot the average value for each set of three specimens versus asphalt-rubber content. Connect the plotted points with a smooth curve that provides the “best fit” for all values.

NOTE: The percentage of absorbed asphalt-rubber (Pba) and the effective specific gravity of the aggregate (Gse) do not vary with asphalt-rubber binder content.

(c) The design asphalt-rubber content shall be the asphalt-rubber content which meets the Mix Design Criteria requirements in Table 413-1 of the specifications, and provides air voids as close as possible to the middle of the specified range.

(d) Use the effective (air) voids plot to select the asphalt-rubber content that yields the target air voids content in Table 413-1. Use the other plots to pick off the values of bulk density, VMA, VF, stability and flow that correspond to the selected asphalt-rubber content, and compare these with the limits in Table 413-1. Properties for which limits are not specified are evaluated by the Engineer for information only.

(e) If it is not possible to obtain specification compliance within the range of asphalt-rubber contents used, a determination must be made to either redesign the mix (different aggregate gradation) or prepare additional specimens at other asphalt-rubber contents for density, stability/flow testing, and voids relationships analysis.

(f) Calculate the maximum theoretical density for the design asphalt content by the equation below. This value is recorded on the design card as shown in the equation below.

$$\text{Maximum Density} = \frac{\text{Bulk Density}}{100 - \%\ \text{Air Voids}} \times 100$$

Mix Design Gradation Target Values

14. The desired target values for the aggregate and mineral admixture in the asphalt-rubber mixture shall be from the composited gradation and shall be expressed as percent passing particular sieve sizes as required by the specifications for the project.

NOTE: The target values for aggregate with mineral admixture are shown on the design card. The gradation of samples taken for specification compliance are compared to the applicable target values, (e.g., a mix design requires mineral admixture and the mineral admixture is blended with the asphalt. The sample for specification compliance will be aggregate only and therefore is compared to the target values given without cement).

Report and Example

15. Report the test results and data obtained on the appropriate form. Liberal use of the remarks area to clarify and/or emphasize any element of the design is recommended.

APPENDIX B
INITIAL CONTROL MIX DESIGN DATA

ARAC Trial Summary

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	CKC B1Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	CKC Plant
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Type II Cement

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Washed MA	31674	15.84
3/8" Chips	31673	44.55
3/4" Aggregate	31672	38.61
Type II Cement (Wet Prep)	Cement	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	84	(80-100)	84
3/8" / 9.5	68	(65-80)	69
1/4" / 6.3	51		52
#4 / 4.75	41	(28-42)	41
#8 / 2.36	19	(14-22)	20
#10 / 2.00	17		17
#16 / 1.18	12		13
#30 / .600	8		9
#40 / .425	6		7
#50 / .300	5		6
#100 / .150	3		4
#200 / .075	1.9	(0-2.5)	2.9

Recommended % Asphalt: ***

ARAC Supplier:	
ADOT Lab No.:	
Asphalt Source:	Paramount / CRM
Asphalt Grade:	PG 58-22 / Type II
Admix Source:	
Mixing Temperature:	325 F
Compaction Temperature:	325 F

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.520	2.545	2.530	2.35-2.85
"SSD" Sp. Gravity:	2.574	2.596	2.583	
Apparent Sp. Gravity:	2.663	2.683	2.671	
Water Absorption(%):	2.13	2.02	2.09	0-2.5
Admixture Sp. Gravity:	3.150		Asphalt Sp. Gravity:	1.050
Sand Equivalent value:			81	Min 55
Fractured Face 2 Face (%):			92	Min 85
Fractured Face 1 Face (%):			96.0	
Asphalt Absorbed into Dry Aggregate (%):			0.55	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			5	Max 9
L.A. Abrasion @ 500 Rev.(%):			20	Max 40

Remarks:

High air voids and VMA with Paramount binder. Trying Ergon binder.

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

CKC B1 Control Trial A
Figure 3

MACTEC

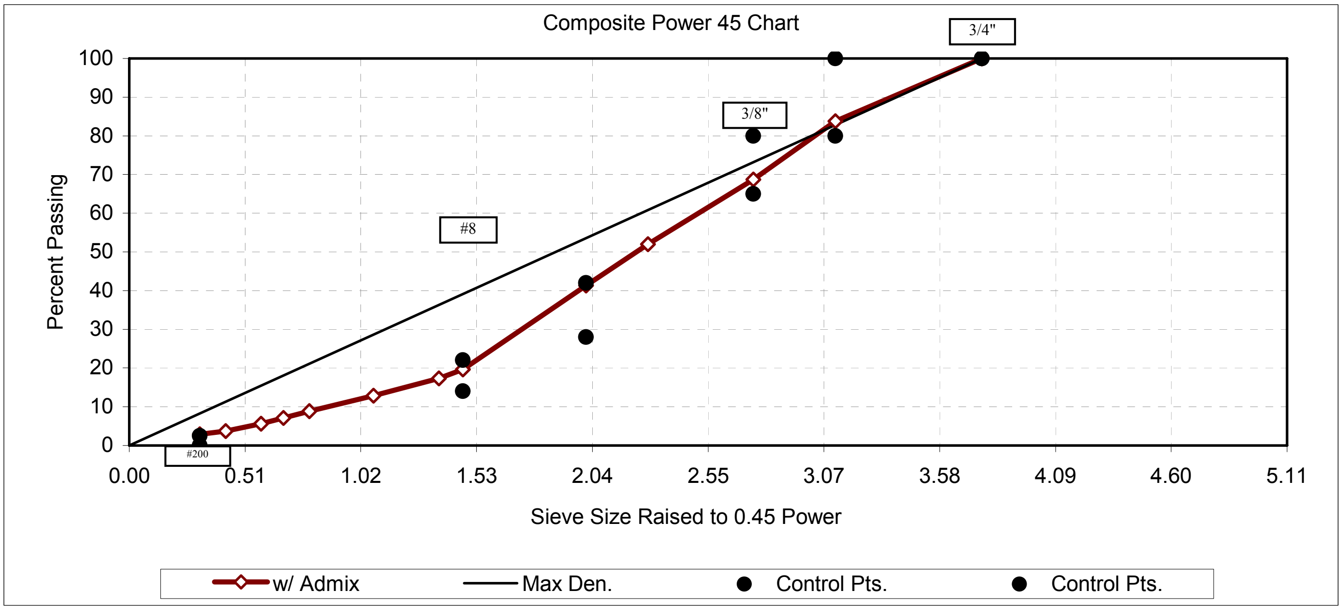
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: CKC B1Control Trial A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: CKC Plant
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Type II Cement

Lab No.		Aggregate Name	Percentage	Adjusted %
31674	Aggregate #1:	Washed MA	16.0	15.84
31673	Aggregate #2:	3/8" Chips	45.0	44.55
31672	Aggregate #3:	3/4" Aggregate	39.0	38.61
				0.00
Cement	Admixture:	Type II Cement (Wet Prep)	1.0	0.99
		Total:	101.0	100.0
Test Method:	ADOT 201 & 815	Difference:	1.0	0.0

31674	31673	31672				Cement	Lab No.	ADOT	ADOT	ADOT	ADOT
16.0	45.0	39.0				1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3				Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100				100	1.5" / 37.5	100		100	
100	100	100				100	1.25 / 31.5	100		100	
100	100	100				100	1" / 25	100		100	
100	100	100				100	3/4" / 19	100	(100)	100	
100	100	58				100	1/2" / 12.5	84	(80-100)	84	
100	100	19				100	3/8" / 9.5	68	(65-80)	69	
100	78	1				100	1/4" / 6.3	51		52	
100	54	1				100	#4 / 4.75	41	(28-42)	41	
84	12	0				100	#8 / 2.36	19	(14-22)	20	
75	10	0				100	#10 / 2.00	17		17	
52	8	0				100	#16 / 1.18	12		13	
30	7	0				100	#30 / .600	8		9	
22	6	0				100	#40 / .425	6		7	
15	5	0				100	#50 / .300	5		6	
6	4	0				100	#100 / .150	3		4	
3.2	3.0	0.1				100.0	#200 / .075	1.9	(0-2.5)	2.9	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	CKC B1Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	CKC Plant
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Type II Cement

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1063.2
	Flask 2	1063.1
	Flask 3	1063.9
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3882.9
	Flask 2	3862.0
	Flask 3	3807.5
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1063.2
	Flask 2	1063.1
	Flask 3	1063.9
Loss of binder from mixing:		1.3
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3882.9
	Flask 2	3862.0
	Flask 3	3807.5
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1065.3
	Flask 2	1065.0
	Flask 3	1065.8
Volume of Voidless Mix ("Vvm"):	Flask 1	450.4
	Flask 2	450.0
	Flask 3	451.3
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.361
	Flask 2	2.362
	Flask 3	2.357
Average Maximum Sp. Gravity ("Gmm"):		**2.360**
Average Maximum Density (PCF):		147.0
"Gmm" Range:		0.005

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.564
Asphalt Absorbed (%):	0.55

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2979.2
"SSD" Weight(g):	3042.6
Weight in Water(g):	1860.5
Bulk (Dry) Sp. Gravity:	2.520
"SSD" Sp. Gravity:	2.574
Apparent Sp. Gravity:	2.663
Water Absorption(%):	2.13

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	490.1
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	673.5
Weight of Flask, Water & Sample(g):	980.9
Bulk (Dry) Sp. Gravity:	2.545
"SSD" Sp. Gravity:	2.596
Apparent Sp. Gravity:	2.683
Water Absorption(%):	2.02

Combined Specific Gravity

Admixture Sp. Gravity:	3.150
Comp. Bulk(Dry)(W/O Admix):	2.530
Comp. "SSD"(W/O Admix):	2.583
Comp. Apparent(W/O Admix):	2.671
Comp Water Absorb. (%)	2.09
Comp. Bulk(Dry)(with Admix):	2.535
Comp. "SSD"(with Admix):	2.588
Comp. Apparent(with Admix):	2.675

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	81	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	92	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	96	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	5	Max 9
L.A. Abrasion @ 500 Rev.(%):	20	Max 40

MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	CKC B1Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	CKC Plant
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Type II Cement

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1074.3
	Flask 2	1076.8
	Flask 3	1074.2
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3883.3
	Flask 2	3864.3
	Flask 3	3808.4
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1074.3
	Flask 2	1076.8
	Flask 3	1074.2
Loss of binder from mixing:		0.5
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3883.3
	Flask 2	3864.3
	Flask 3	3808.4
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1076.0
	Flask 2	1077.9
	Flask 3	1076.3
Volume of Voidless Mix ("Vvm"):	Flask 1	460.7
	Flask 2	460.6
	Flask 3	460.9
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.332
	Flask 2	2.338
	Flask 3	2.331
Average Maximum Sp. Gravity ("Gmm"):		**2.334**
Average Maximum Density (PCF):		145.4
"Gmm" Range:		0.007

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.570
Asphalt Absorbed (%):	0.64

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2979.2
"SSD" Weight(g):	3042.6
Weight in Water(g):	1860.5
Bulk (Dry) Sp. Gravity:	2.520
"SSD" Sp. Gravity:	2.574
Apparent Sp. Gravity:	2.663
Water Absorption(%):	2.13

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	490.1
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	673.5
Weight of Flask, Water & Sample(g):	980.9
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"SSD" Sp. Gravity:	2.596
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Combined Specific Gravity

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Comp. "SSD"(with Admix):	2.588
Comp. Apparent(with Admix):	2.675

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	81	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	92	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	96	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	5	Max 9
L.A. Abrasion @ 500 Rev.(%):	20	Max 40

MACTEC

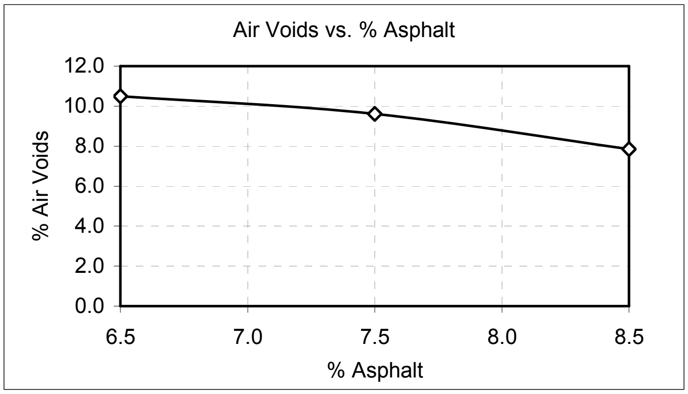
Volumetric Calculations

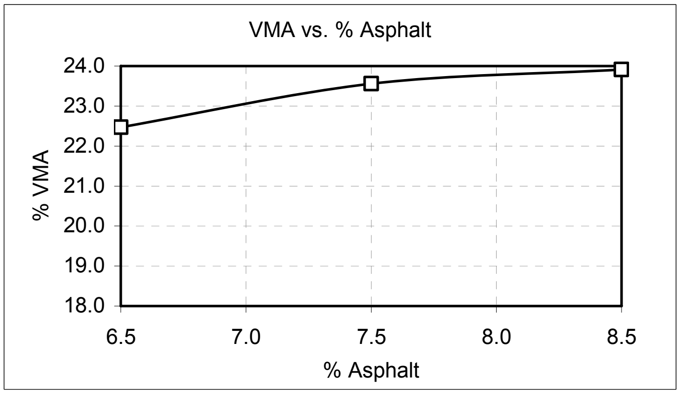
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: CKC B1Control Trial A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

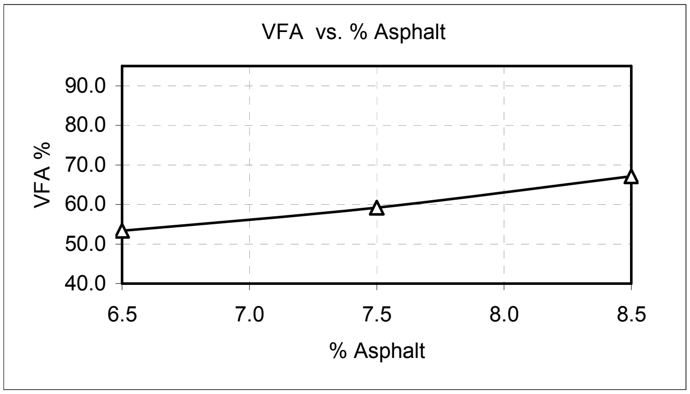
Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: CKC Plant
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Type II Cement

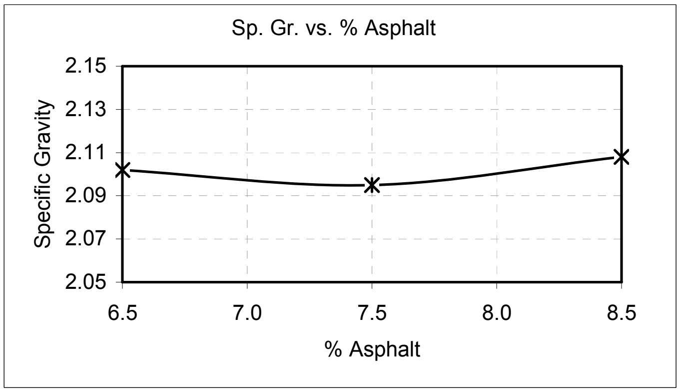
Volumetric Calculations Compaction Method: Marshall Calculation Method: ARIZ 815

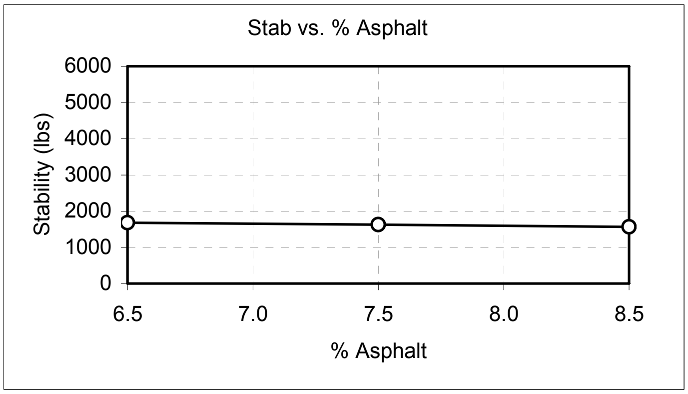
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.102	92.574	1.0	0.926	76.910	0.618	5.987	0.48	11.985	1680	20	22.47	53.33	10.5	2.348
7.5	2.095	91.584	1.0	0.916	75.834	0.609	6.992	0.41	13.951	1628	18	23.56	59.22	9.6	2.318
8.5	2.108	90.594	1.0	0.906	75.480	0.606	7.998	0.36	16.056	1567	20	23.91	67.14	7.9	2.288
												Min 19		(4.5-6.5)	

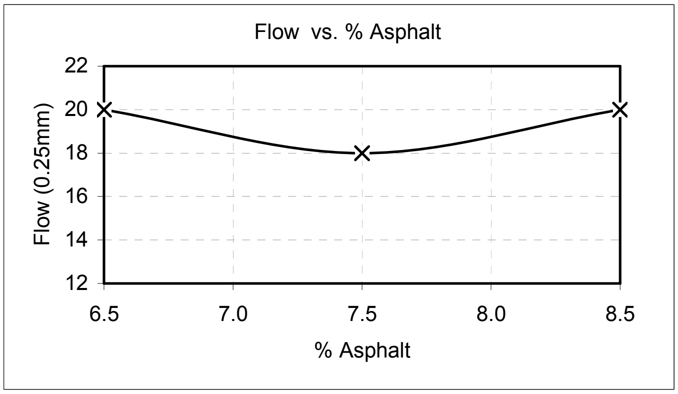












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: CKC B1Control Trial A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: CKC Plant
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Type II Cement

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1082.3	575.0	1060.4	2.090	130.2	2.611	1700	0.94	1598	7.1	20
	2	1081.5	575.6	1060.6	2.096	130.6	2.614	1650	0.94	1551	6.9	20
	3	1076.8	577.4	1058.8	2.120	132.1	2.544	1950	0.97	1892	8.4	21
				Average:	2.102	131.0			Average:	1680	7.5	20
				Range:	0.030	1.9						
7.5	4	1089.5	579.0	1073.2	2.102	131.0	2.617	1750	0.93	1628	7.2	18
	5	1085.1	573.2	1069.8	2.090	130.2	2.626	1800	0.93	1674	7.4	19
	6	1087.1	574.2	1073.5	2.093	130.4	2.620	1700	0.93	1581	7.0	18
				Average:	2.095	130.5			Average:	1628	7.2	18
				Range:	0.012	0.8						
8.5	7	1087.6	575.1	1081.2	2.110	131.5	2.606	1500	0.94	1410	6.3	18
	8	1088.6	575.3	1081.5	2.107	131.3	2.608	1800	0.94	1692	7.5	21
	9	1089.7	576.1	1081.6	2.106	131.2	2.608	1700	0.94	1598	7.1	21
				Average:	2.108	131.3			Average:	1567	7.0	20
				Range:	0.004	0.3						

CKC B2 Trial A Mod
Figure 3

MACTEC

ARAC Design Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: CKC B2 Trial A Mod
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: July, 2003
Mix Type: ADOT 413
Source of Aggregate: CKC Plant
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Type II Cement

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Washed MA	31674	20.79
3/8" Chips	31673	38.61
3/4" Aggregate	31672	39.60
Type II Cement (Wet Prep)	Cement	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	83	(80-100)	83
3/8" / 9.5	68	(65-80)	68
1/4" / 6.3	52		52
#4 / 4.75	42	(28-42)	43
#8 / 2.36	22	(14-22)	23
#10 / 2.00	20		20
#16 / 1.18	14		15
#30 / .600	9		10
#40 / .425	7		8
#50 / .300	5		6
#100 / .150	3		4
#200 / .075	1.9	(0-2.5)	2.9

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Recommended % Asphalt: 8.5 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Admix Source: Phoenix Cement
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	8.5		
Bulk Specific Gravity :	2.165		
Bulk Specific Density (kg/m3):	2161		
Bulk Specific Density (PCF):	134.9		
Theor. Max. Sp. Gr. (Gmm):	2.288		
Stability (lbs):	2281		
Flow (0.25 mm):	18		
Percent Air Voids:	5.4	(4.5-6.5)	
Percent VMA:	21.87	Min 19	
Percent Voids Filled:	75.5		
Percent Effective Asphalt:	8.004		
Dust to Eff. Asphalt Ratio:	0.36		
Effective Sp. Gr.(w/ Admix):	2.569		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.520	2.545	2.531	2.35-2.85
"SSD" Sp. Gravity:	2.574	2.596	2.583	
Apparent Sp. Gravity:	2.663	2.683	2.671	
Water Absorption(%):	2.13	2.02	2.08	0-2.5
Admixture Sp. Gravity:	3.150	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			81	Min 55
Fractured Face 2 Face (%):			92	Min 85
Fractured Face 1 Face (%):			96	
Asphalt Absorbed into Dry Aggregate (%):			0.55	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			5	Max 9
L.A. Abrasion @ 500 Rev.(%):			20	Max 40

Remarks:

CKC B2 Trial A Mod
Figure 4

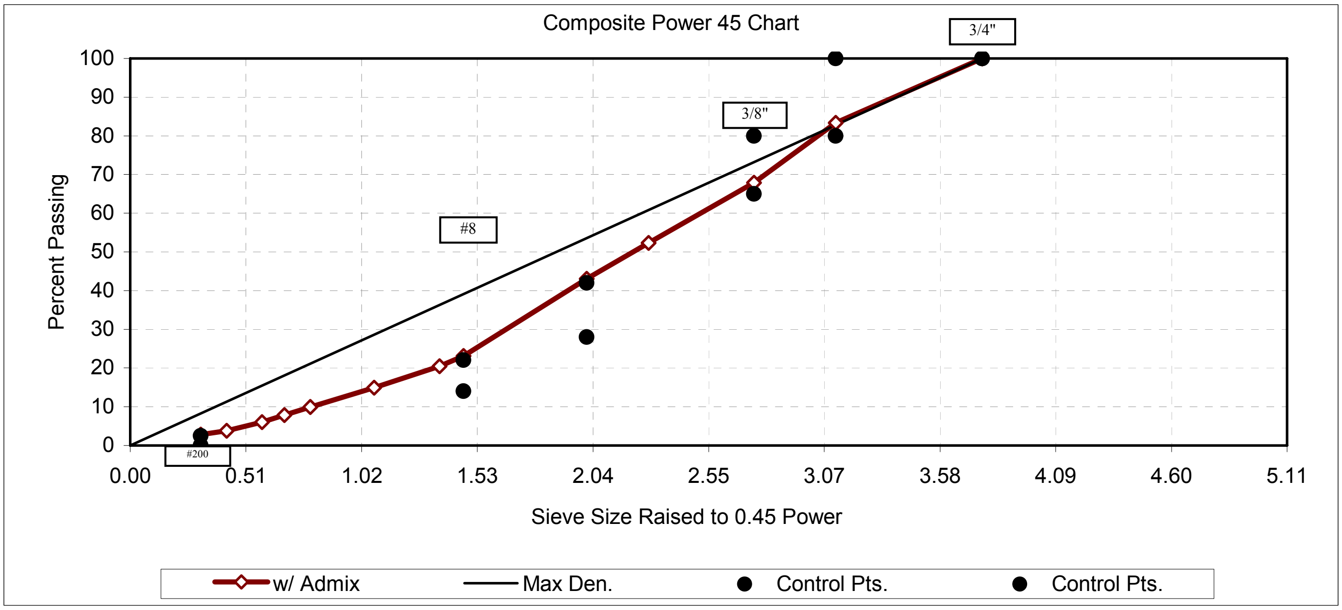
MACTEC

Aggregate Composite

MACTEC Job No.:	4975-03-3008	Date:	July, 2003
MACTEC Lab No.:	CKC B2 Trial A Mod	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	CKC Plant
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Type II Cement

Lab No.		Aggregate Name	Percentage	Adjusted %
31674	Aggregate #1:	Washed MA	21.0	20.79
31673	Aggregate #2:	3/8" Chips	39.0	38.61
31672	Aggregate #3:	3/4" Aggregate	40.0	39.60
Cement	Admixture:	Type II Cement (Wet Prep)	1.0	0.99
		Total:	101.0	100.0
Test Method:	ADOT 201 & 815	Difference:	1.0	0.0

31674	31673	31672				Cement	Lab No.	ADOT	ADOT	ADOT	ADOT
21.0	39.0	40.0				1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3				Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100				100	1.5" / 37.5	100		100	
100	100	100				100	1.25 / 31.5	100		100	
100	100	100				100	1" / 25	100		100	
100	100	100				100	3/4" / 19	100	(100)	100	
100	100	58				100	1/2" / 12.5	83	(80-100)	83	
100	100	19				100	3/8" / 9.5	68	(65-80)	68	
100	78	1				100	1/4" / 6.3	52		52	
100	54	1				100	#4 / 4.75	42	(28-42)	43	
84	12	0				100	#8 / 2.36	22	(14-22)	23	
75	10	0				100	#10 / 2.00	20		20	
52	8	0				100	#16 / 1.18	14		15	
30	7	0				100	#30 / .600	9		10	
22	6	0				100	#40 / .425	7		8	
15	5	0				100	#50 / .300	5		6	
6	4	0				100	#100 / .150	3		4	
3.2	3.0	0.1				100.0	#200 / .075	1.9	(0-2.5)	2.9	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	July, 2003
MACTEC Lab No.:	CKC B2 Trial A Mod	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	CKC Plant
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Type II Cement

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1063.2
	Flask 2	1063.1
	Flask 3	1063.9
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3882.9
	Flask 2	3862.0
	Flask 3	3807.5
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1063.2
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	Flask 2	1065.0
	Flask 3	1065.8
Volume of Voidless Mix ("Vvm"):	Flask 1	450.4
	Flask 2	450.0
	Flask 3	451.3
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.361
	Flask 2	2.362
	Flask 3	2.357
Average Maximum Sp. Gravity ("Gmm"):		**2.360**
Average Maximum Density (PCF):		147.0
"Gmm" Range:		0.005

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
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Coarse Specific Gravity

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Water Absorption(%):	2.13

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	490.1
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	673.5
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Water Absorption(%):	2.02

Combined Specific Gravity

Admixture Sp. Gravity:	3.150
Comp. Bulk(Dry)(W/O Admix):	2.531
Comp. "SSD"(W/O Admix):	2.583
Comp. Apparent(W/O Admix):	2.671
Comp Water Absorb. (%)	2.08
Comp. Bulk(Dry)(with Admix):	2.535
Comp. "SSD"(with Admix):	2.588
Comp. Apparent(with Admix):	2.675

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	81	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	92	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	96	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	5	Max 9
L.A. Abrasion @ 500 Rev.(%):	20	Max 40

Volumetric Calculations

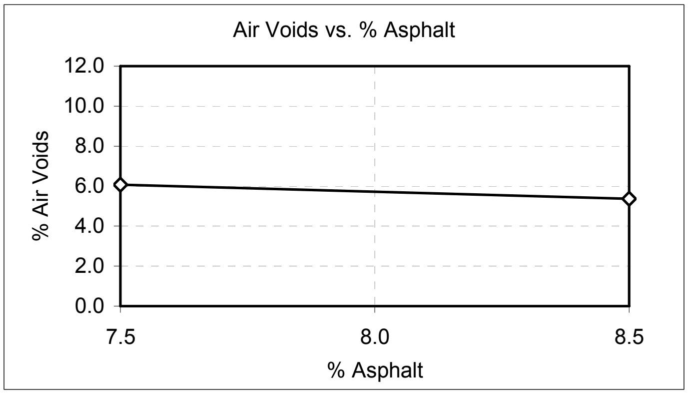
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: CKC B2 Trial A Mod
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

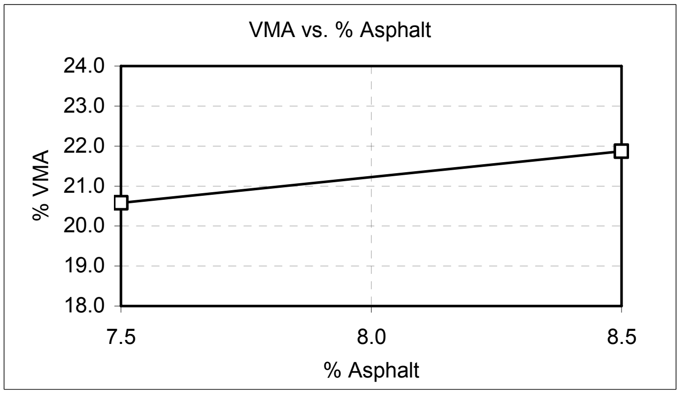
Date: July, 2003
Mix Type: ADOT 413
Source of Aggregate: CKC Plant
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Type II Cement

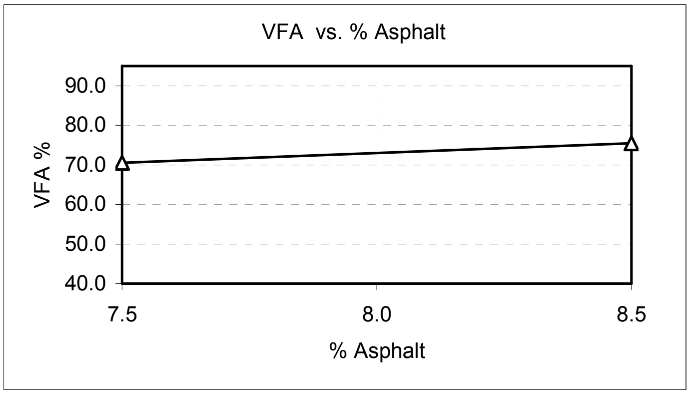
Volumetric Calculations

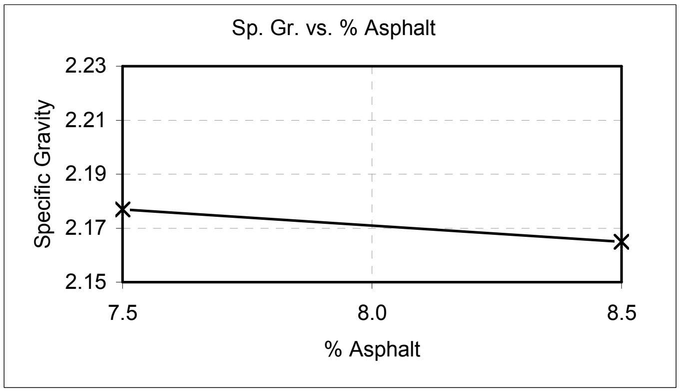
Compaction Method: Marshall
Calculation Method: ARIZ 815

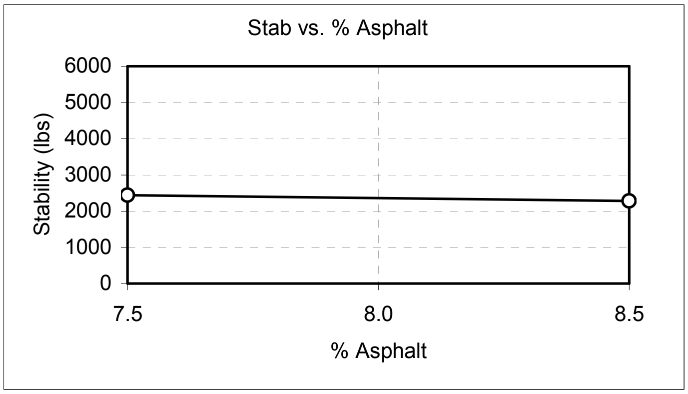
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
7.5	2.177	91.584	1.0	0.916	78.789	0.633	6.999	0.41	14.511	2441	17	20.58	70.51	6.1	2.318
8.5	2.165	90.594	1.0	0.906	77.507	0.623	8.004	0.36	16.504	2281	18	21.87	75.46	5.4	2.288
8.5	**2.165**	**90.594**	**1.0**	**0.906**	**77.507**	**0.623**	**8.004**	**0.36**	**16.504**	**2281**	**18**	**21.87**	**75.46**	**5.4**	**2.288**
												Min 19		(4.5-6.5)	

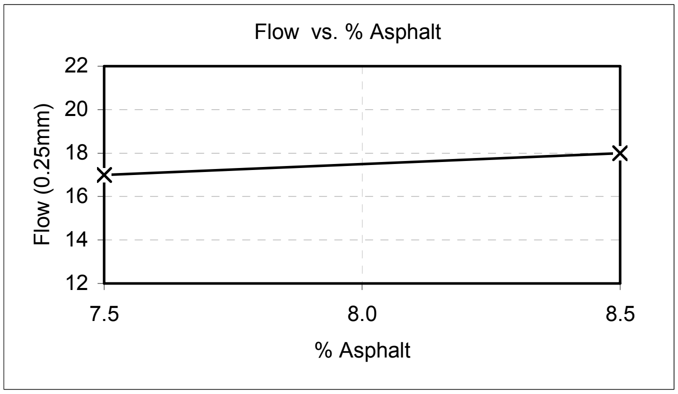












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: CKC B2 Trial A Mod
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:
Date: July, 2003
Mix Type: ADOT 413
Source of Aggregate: CKC Plant
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Type II Cement

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
	1				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
	2				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
	3				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
				Average:	#DIV/0!	#DIV/0!			Average:	#N/A	#N/A	#DIV/0!
				Range:	#DIV/0!	#DIV/0!						
7.5	4	1055.0	572.8	1050.0	2.178	135.7	2.412	2450	1.06	2597	11.6	16
	5	1052.6	571.1	1048.5	2.178	135.7	2.419	2250	1.05	2363	10.5	17
	6	1052.0	569.9	1048.0	2.174	135.4	2.425	2250	1.05	2363	10.5	17
				Average:	2.177	135.6			Average:	2441	10.9	17
				Range:	0.004	0.3						
8.5	7	1062.0	573.9	1058.1	2.168	135.1	2.460	2075	1.03	2137	9.5	17
	8	1059.3	571.3	1056.0	2.164	134.8	2.429	2250	1.05	2363	10.5	18
	9	1059.7	571.3	1056.4	2.163	134.8	2.446	2275	1.03	2343	10.4	20
				Average:	2.165	134.9			Average:	2281	10.1	18
				Range:	0.005	0.3						

CKC B2 Trial A Mod
Figure 4

Compiled GAP Graded AR AC Control Mix Design Data
CKC Aggregate
Table 16

CKC Mixes	ARB	Effective Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Control Designs													
Gradation A	6.5	11.985		22.47		53.33		10.5		1680		20	
	7.5	13.951		23.56		59.22		9.6		1628		18	
	8.5	16.056		23.91		67.14		7.9		1567		20	
Gradation A Mod													
	7.5		14.511		20.58		70.51		6.1		2441		17
	8.5		16.504		21.87		75.46		5.4		2281		18
NOTES													
Binder 1: Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC													
Binder 2: Ergon 58-28 with 22.7% fine CRM rubber by weight of AC													

Compiled GAP-Graded AR AC Control Mix Design Data
Grey Mountain Aggregate
Table 17

Grey Mtn. Mixes	ARB	Effective Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Control Designs													
Gradation A	6.5	13.334		22.02		60.54		8.7		2122		18	
	7.5	15.507	15.413	22.96	23.43	67.54	65.78	7.5	8.0	1915	1909	21	18
	8.5	17.729	17.753	23.66	23.56	74.94	75.35	*5.9	5.8	1784	1930	24	20
Gradation B	7.5	16.288	16.382	20.31	18.66	80.21	87.78	4.0	2.3	2433	2488	17	19
w/ Cr.Fines	8.5	18.525	18.510	21.33	20.34	86.83	91.00	2.8	1.8	2149	2159	18	18

NOTES

Binder 1: Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC

Binder 2: Ergon 58-28 with 22.7% fine CRM rubber by weight of AC

* Results meet design criteria but this design is not recommended due to increasing VMA, falling stability and rising flow that indicate possible problems.

Compiled MACEC GAP-Graded AR AC Control Mix Design Data
Round 1 Rinker Aggregate with Binders 1 and 2
Table 18

Salt River Mix	ARB	Effect. Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Control	6.5	13.297	13.328	20.28	19.78	65.56	67.38	7.0	6.5	2268	2312	17	15
Designs	7.5	15.436	15.494	21.06	20.50	73.28	75.59	5.6	5.0	2010	2174	18	17
C1	8.5	17.674	17.629	21.43	21.39	82.49	82.41	3.8	3.8	1751	1835	20	20
	7.0		14.468		20.14		71.84		5.7		1998		16
	8.0		16.786		20.15		83.30		3.4		2155		18
Repeat 1	6.5	13.345	13.355	20.32	19.78	65.68	67.52	7.0	6.4	1477	2475	17	15
C2	7.5	15.559	15.536	20.71	20.43	75.13	76.06	5.2	4.9	1304	2326	20	16
	8.5	17.623	17.688	21.88	21.25	80.54	83.23	4.3	3.6	1484	2402	17	18
Repeat 2	6.5	13.220	13.397	20.03	19.31	66.00	69.36	6.8	5.9	2204	2605	17	16
C3	7.5	15.429	15.646	20.50	19.68	75.28	79.49	5.1	4.0	1979	2379	17	16
	8.5	17.495	17.881	21.71	20.23	80.60	88.37	4.2	2.4	1734	2226	19	17

NOTES

Binder 1 (**B1**): Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC

Binder 2 (**B2**): Ergon 58-28 with 22.7% fine CRM rubber by weight of AC

C1, C2, C3: Control Mix designations used in graph legends

PC1, PC2, PC3: Proposed Changes mix designations used in graph legends

MACTEC

ARAC Design Summary

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	GM B1 Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31680	26.73
3/8" Aggregate	31678	22.77
1/2" Aggregate	31677	49.50
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	96	(80-100)	96
3/8" / 9.5	78	(65-80)	78
1/4" / 6.3	42		42
#4 / 4.75	33	(28-42)	34
#8 / 2.36	20	(14-22)	20
#10 / 2.00	17		18
#16 / 1.18	11		12
#30 / .600	6		7
#40 / .425	5		6
#50 / .300	4		5
#100 / .150	2		3
#200 / .075	1.9	(0-2.5)	2.9

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Recommended % Asphalt: 8.5 ***

ARAC Supplier: **FNF Construction, Inc.**
ADOT Lab No.:
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	8.5		
Bulk Specific Gravity :	2.295		
Bulk Specific Density (kg/m3):	2290		
Bulk Specific Density (PCF):	143.0		
Theor. Max. Sp. Gr. (Gmm):	2.440		
Stability (lbs):	1784		
Flow (0.25 mm):	24		
Percent Air Voids:	5.9	(4.5-6.5)	
Percent VMA:	23.66	Min 19	
Percent Voids Filled:	74.9		
Percent Effective Asphalt:	8.112		
Dust to Eff. Asphalt Ratio:	0.35		
Effective Sp. Gr.(w/ Admix):	2.782		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.748	2.777	2.758	2.35-2.85
"SSD" Sp. Gravity:	2.796	2.823	2.805	
Apparent Sp. Gravity:	2.885	2.912	2.894	
Water Absorption(%):	1.72	1.67	1.72	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			77	Min 55
Fractured Face 2 Face (%):			97	Min 85
Fractured Face 1 Face (%):			99	
Asphalt Absorbed into Dry Aggregate (%):			0.43	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			6	Max 9
L.A. Abrasion @ 500 Rev.(%):			23	Max 40

Remarks:

The CRA blend material was submitted to MACTEC by ADOT.

GM B1 Control Trial A
Figure 5

MACTEC

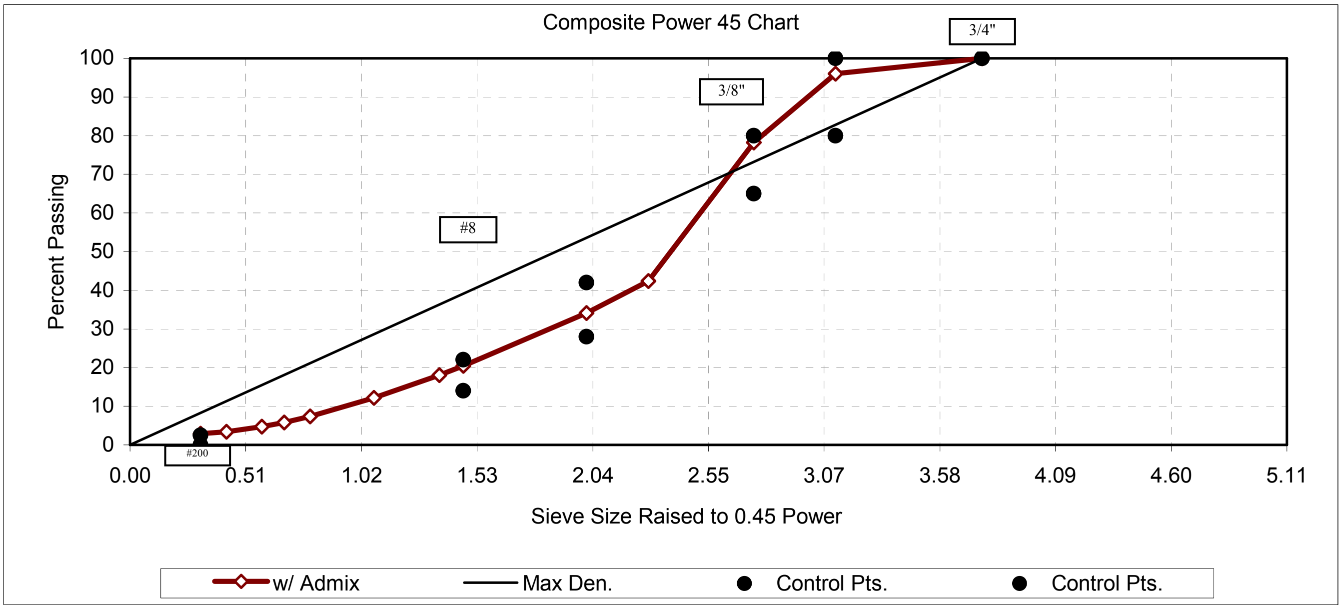
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B1 Control Trial A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31680	Aggregate #1:	Clean Crusher Fines	27.0	26.73
31678	Aggregate #2:	3/8" Aggregate	23.0	22.77
31677	Aggregate #3:	1/2" Aggregate	50.0	49.50
				0.00
				0.00
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method:	ADOT 201 & 815	Difference:	1.0	0.0

31680	31678	31677				Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
27.0	23.0	50.0				1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3				Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100				100	1.5" / 37.5	100		100	
100	100	100				100	1.25 / 31.5	100		100	
100	100	100				100	1" / 25	100		100	
100	100	100				100	3/4" / 19	100	(100)	100	
100	100	92				100	1/2" / 12.5	96	(80-100)	96	
100	100	56				100	3/8" / 9.5	78	(65-80)	78	
100	60	2				100	1/4" / 6.3	42		42	
100	26	1				100	#4 / 4.75	33	(28-42)	34	
70	1	1				100	#8 / 2.36	20	(14-22)	20	
61	1	1				100	#10 / 2.00	17		18	
39	1	1				100	#16 / 1.18	11		12	
23	1	0				100	#30 / .600	6		7	
18	0	0				100	#40 / .425	5		6	
14	0	0				100	#50 / .300	4		5	
9	0	0				100	#100 / .150	2		3	
6.2	0.5	0.2				100.0	#200 / .075	1.9	(0-2.5)	2.9	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	GM B1 Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1062.5
	Flask 2	1063.7
	Flask 3	1063.5
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3914.4
	Flask 2	3895.5
	Flask 3	3841.6
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1062.5
	Flask 2	1063.7
	Flask 3	1063.5
Loss of binder from mixing:		1.8
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3914.4
	Flask 2	3895.5
	Flask 3	3841.6
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1066.0
	Flask 2	1067.0
	Flask 3	1067.8
Volume of Voidless Mix ("Vvm"):	Flask 1	419.6
	Flask 2	418.5
	Flask 3	419.2
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.532
	Flask 2	2.542
	Flask 3	2.537
Average Maximum Sp. Gravity ("Gmm"):		**2.537**
Average Maximum Density (PCF):		158.1
"Gmm" Range:		0.010

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.789
Asphalt Absorbed (%):	0.43

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2964.1
"SSD" Weight(g):	3015.2
Weight in Water(g):	1936.7
Bulk (Dry) Sp. Gravity:	2.748
"SSD" Sp. Gravity:	2.796
Apparent Sp. Gravity:	2.885
Water Absorption(%):	1.72

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	491.8
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.4
Weight of Flask, Water & Sample(g):	986.3
Bulk (Dry) Sp. Gravity:	2.777
"SSD" Sp. Gravity:	2.823
Apparent Sp. Gravity:	2.912
Water Absorption(%):	1.67

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.758
Comp. "SSD"(W/O Admix):	2.805
Comp. Apparent(W/O Admix):	2.894
Comp Water Absorb. (%)	1.72
Comp. Bulk(Dry)(with Admix):	2.751
Comp. "SSD"(with Admix):	2.797
Comp. Apparent(with Admix):	2.885

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	77	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	97	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	99	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	GM B1 Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1069.3
	Flask 2	1075.6
	Flask 3	1079.9
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3915.2
	Flask 2	3897.0
	Flask 3	3844.4
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1069.3
	Flask 2	1075.6
	Flask 3	1079.9
Loss of binder from mixing:		1.0
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3915.2
	Flask 2	3897.0
	Flask 3	3844.4
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1072.3
	Flask 2	1078.1
	Flask 3	1082.5
Volume of Voidless Mix ("Vvm"):	Flask 1	425.1
	Flask 2	428.1
	Flask 3	431.1
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.515
	Flask 2	2.512
	Flask 3	2.505
Average Maximum Sp. Gravity ("Gmm"):		**2.511**
Average Maximum Density (PCF):		156.4
"Gmm" Range:		0.010

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.805
Asphalt Absorbed (%):	0.64

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2964.1
"SSD" Weight(g):	3015.2
Weight in Water(g):	1936.7
Bulk (Dry) Sp. Gravity:	2.748
"SSD" Sp. Gravity:	2.796
Apparent Sp. Gravity:	2.885
Water Absorption(%):	1.72

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	491.8
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.4
Weight of Flask, Water & Sample(g):	986.3
Bulk (Dry) Sp. Gravity:	2.777
"SSD" Sp. Gravity:	2.823
Apparent Sp. Gravity:	2.912
Water Absorption(%):	1.67

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.758
Comp. "SSD"(W/O Admix):	2.805
Comp. Apparent(W/O Admix):	2.894
Comp Water Absorb. (%)	1.72
Comp. Bulk(Dry)(with Admix):	2.751
Comp. "SSD"(with Admix):	2.797
Comp. Apparent(with Admix):	2.885

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	77	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	97	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	99	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

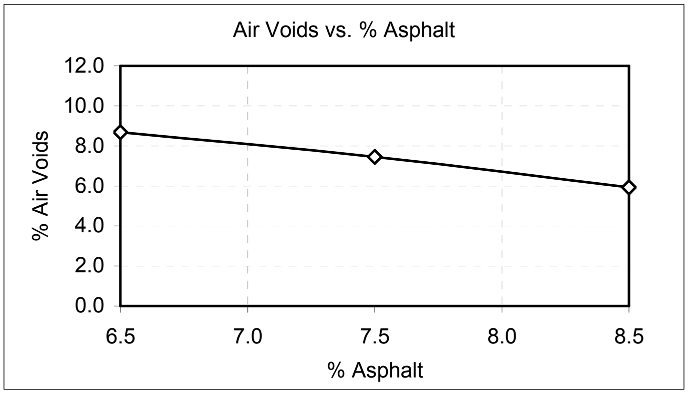
MACTEC

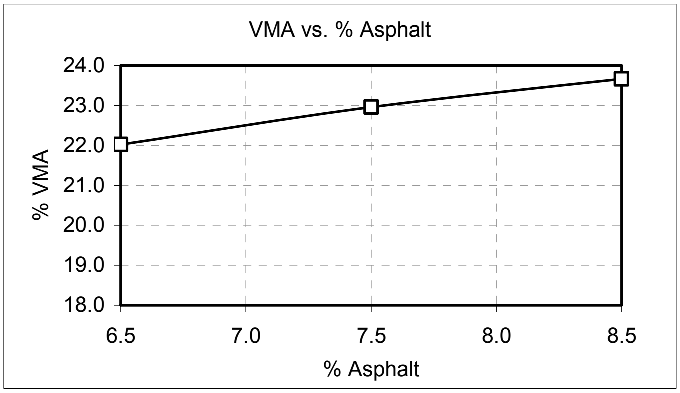
Volumetric Calculations

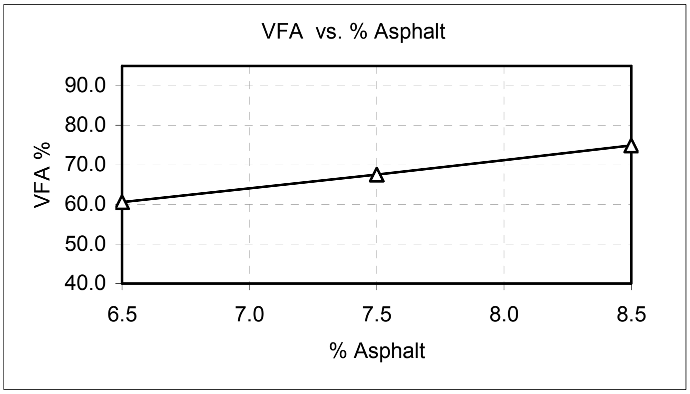
MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	GM B1 Control Trial A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

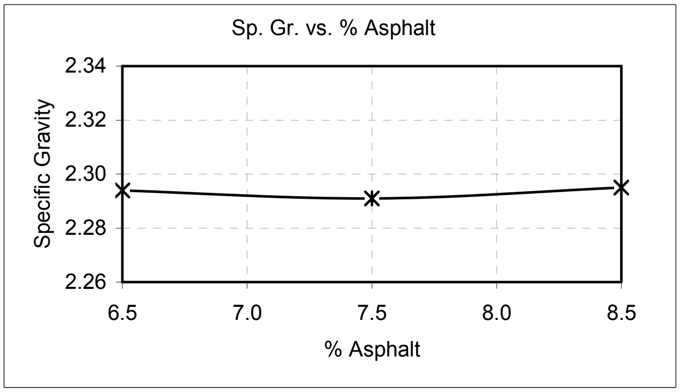
Volumetric Calculations Compaction Method: Marshall Calculation Method: ARIZ 815

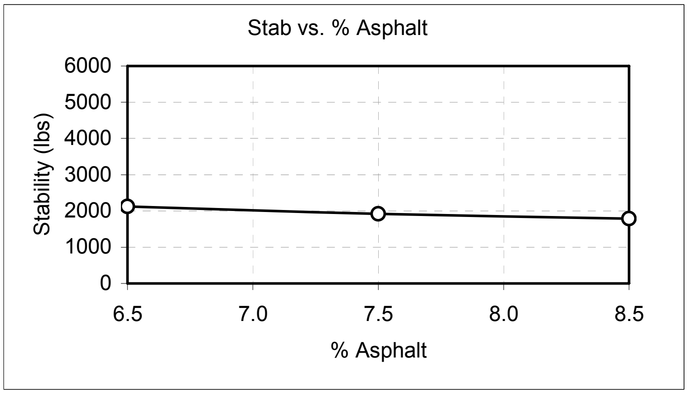
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.294	92.574	1.0	0.926	77.010	0.965	6.103	0.47	13.334	2122	18	22.02	60.54	8.7	2.512
7.5	2.291	91.584	1.0	0.916	76.087	0.954	7.107	0.40	15.507	1915	21	22.96	67.54	7.5	2.475
8.5	2.295	90.594	1.0	0.906	75.395	0.945	8.112	0.35	17.729	1784	24	23.66	74.94	5.9	2.440
8.5	**2.295**	**90.594**	**1.0**	**0.906**	**75.395**	**0.945**	**8.112**	**0.35**	**17.729**	**1784**	**24**	**23.66**	**74.94**	**5.9**	**2.440**
													Min 19		(4.5-6.5)	

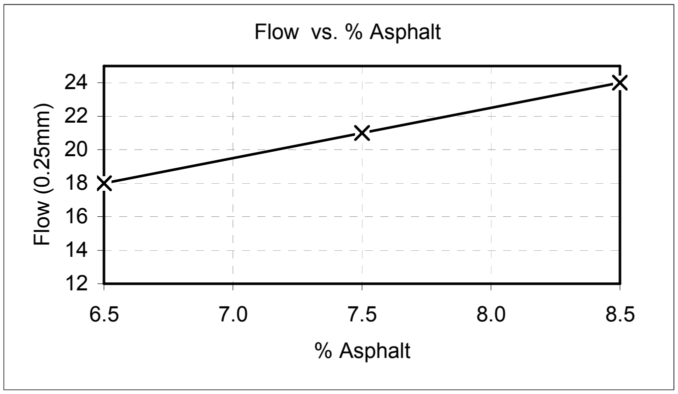












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B1 Control Trial A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1082.7	613.8	1072.7	2.288	142.5	2.401	1850	1.07	1980	8.8	16
	2	1084.3	615.1	1075.2	2.292	142.8	2.406	2050	1.06	2173	9.7	20
	3	1082.6	617.3	1071.0	2.302	143.4	2.388	2050	1.08	2214	9.8	18
				Average:	2.294	142.9			Average:	2122	9.4	18
				Range:	0.014	0.9						
7.5	4	1089.4	620.7	1083.9	2.313	144.1	2.415	2100	1.06	2226	9.9	22
	5	1089.1	615.0	1081.4	2.281	142.1	2.424	1550	1.05	1628	7.2	20
	6	1086.2	612.7	1079.2	2.279	142.0	2.424	1800	1.05	1890	8.4	20
				Average:	2.291	142.7			Average:	1915	8.5	21
				Range:	0.034	2.1						
8.5	7	1091.8	616.0	1088.3	2.287	142.5	2.416	1650	1.06	1749	7.8	26
	8	1092.7	618.8	1089.1	2.298	143.2	2.410	1700	1.06	1802	8.0	23
	9	1092.3	618.7	1089.4	2.300	143.3	2.410	1700	1.06	1802	8.0	24
				Average:	2.295	143.0			Average:	1784	7.9	24
				Range:	0.013	0.8						

GM B1 Control Trial A
Figure 5

ARAC Trial Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: 31675 Trial B Crusher Fines Paramount
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31680	0.00
3/8" Aggregate	31678	26.73
1/2" Aggregate	31677	45.54
Crusher Fines	31679	26.73
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	96	(80-100)	96
3/8" / 9.5	80	(65-80)	80
1/4" / 6.3	44		45
#4 / 4.75	34	(28-42)	35
#8 / 2.36	22	(14-22)	22
#10 / 2.00	19		20
#16 / 1.18	14		15
#30 / .600	10		11
#40 / .425	8		9
#50 / .300	7		8
#100 / .150	5		6
#200 / .075	4.3	(0-2.5)	5.3

Recommended % Asphalt: ***

ARAC Supplier:
ADOT Lab No.:
Asphalt Source: Paramount / CRM
Asphalt Grade: PG 58-22 / Type II
Admix Source: Chemical Lime
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.748	2.815	2.771	2.35-2.85
"SSD" Sp. Gravity:	2.796	2.844	2.812	
Apparent Sp. Gravity:	2.885	2.900	2.890	
Water Absorption(%):	1.72	1.05	1.50	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:	1.050	
Sand Equivalent value:			67	Min 55
Fractured Face 2 Face (%):				Min 85
Fractured Face 1 Face (%):			99.0	
Asphalt Absorbed into Dry Aggregate (%):			0.35	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			6	Max 9
L.A. Abrasion @ 500 Rev.(%):			23	Max 40

Remarks:

Substituting Crusher Fines dropped voids below minimum 4.5%

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

31675 Trial B Crusher Fines Paramount
Figure 6

MACTEC

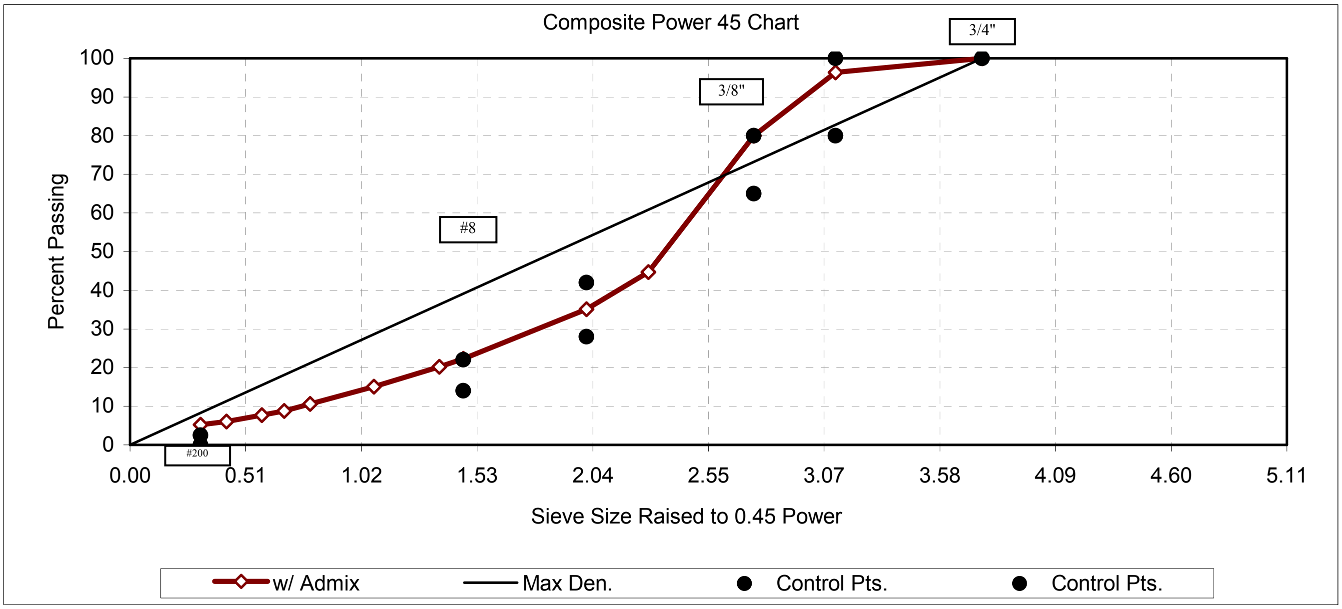
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: 31675 Trial B Crusher Fines Paramount
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31680	Aggregate #1:	Clean Crusher Fines	0.0	0.00
31678	Aggregate #2:	3/8" Aggregate	27.0	26.73
31677	Aggregate #3:	1/2" Aggregate	46.0	45.54
31679	Aggregate #4:	Crusher Fines	27.0	26.73
				0.00
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31680	31678	31677	31679			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
0.0	27.0	46.0	27.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	92	100			100	1/2" / 12.5	96	(80-100)	96	
100	100	56	100			100	3/8" / 9.5	80	(65-80)	80	
100	60	2	100			100	1/4" / 6.3	44		45	
100	26	1	100			100	#4 / 4.75	34	(28-42)	35	
70	1	1	77			100	#8 / 2.36	22	(14-22)	22	
61	1	1	69			100	#10 / 2.00	19		20	
39	1	1	50			100	#16 / 1.18	14		15	
23	1	0	35			100	#30 / .600	10		11	
18	0	0	29			100	#40 / .425	8		9	
14	0	0	25			100	#50 / .300	7		8	
9	0	0	19			100	#100 / .150	5		6	
6.2	0.5	0.2	15.1			100.0	#200 / .075	4.3	(0-2.5)	5.3	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	31675 Trial B Crusher Fines Paramount	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1063.3
	Flask 2	1063.6
	Flask 3	1063.0
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3879.4
	Flask 2	3895.7
	Flask 3	3842.1
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1063.3
	Flask 2	1063.6
	Flask 3	1063.0
Loss of binder from mixing:		1.6
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3879.4
	Flask 2	3895.7
	Flask 3	3842.1
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1066.9
	Flask 2	1067.2
	Flask 3	1066.3
Volume of Voidless Mix ("Vvm"):	Flask 1	418.9
	Flask 2	418.5
	Flask 3	417.2
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.538
	Flask 2	2.541
	Flask 3	2.548
Average Maximum Sp. Gravity ("Gmm"):		**2.542**
Average Maximum Density (PCF):		158.4
"Gmm" Range:		0.010

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.796
Asphalt Absorbed (%):	0.35

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2964.1
"SSD" Weight(g):	3015.2
Weight in Water(g):	1936.7
Bulk (Dry) Sp. Gravity:	2.748
"SSD" Sp. Gravity:	2.796
Apparent Sp. Gravity:	2.885
Water Absorption(%):	1.72

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	494.8
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	988.1
Bulk (Dry) Sp. Gravity:	2.815
"SSD" Sp. Gravity:	2.844
Apparent Sp. Gravity:	2.900
Water Absorption(%):	1.05

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.771
Comp. "SSD"(W/O Admix):	2.812
Comp. Apparent(W/O Admix):	2.890
Comp Water Absorb. (%)	1.50
Comp. Bulk(Dry)(with Admix):	2.764
Comp. "SSD"(with Admix):	2.805
Comp. Apparent(with Admix):	2.881

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	67	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):		Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	99	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

Volumetric Calculations

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: 31675 Trial B Crusher Fines Paramount
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

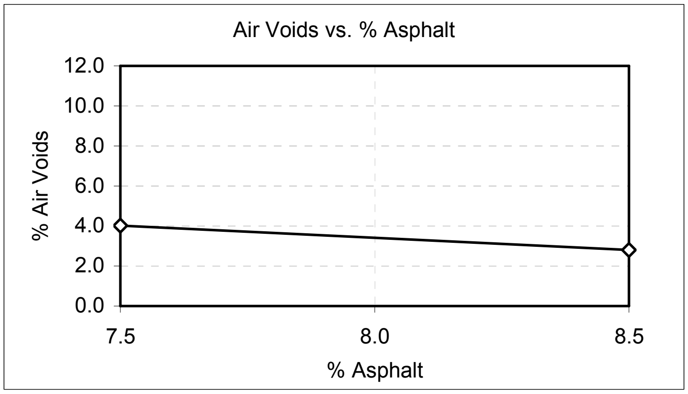
Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

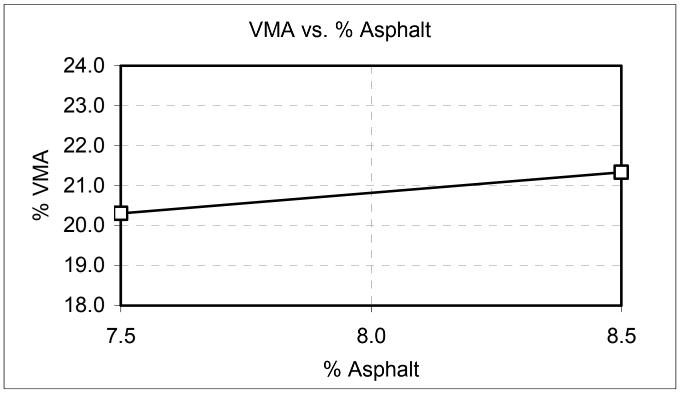
Volumetric Calculations

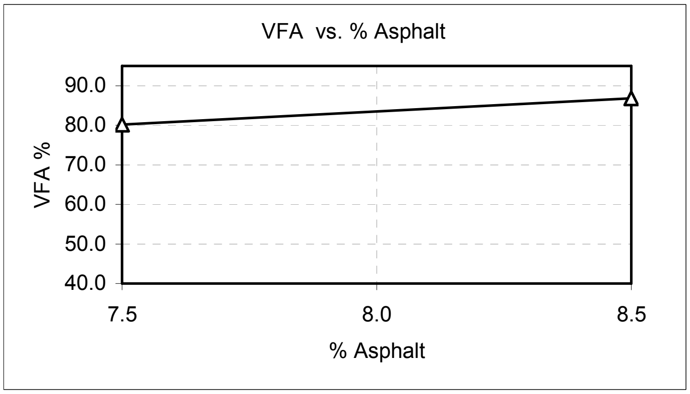
Compaction Method: Marshall

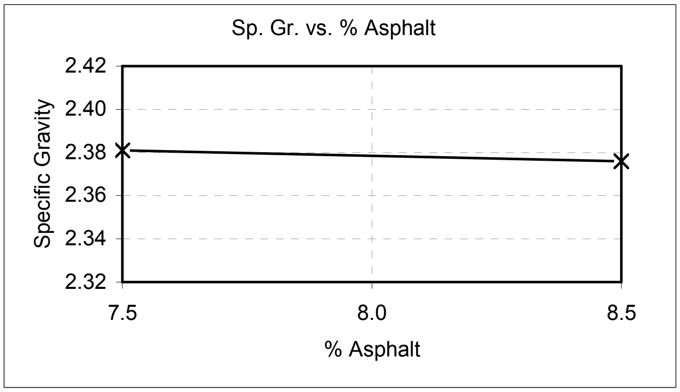
Calculation Method: ARIZ 815

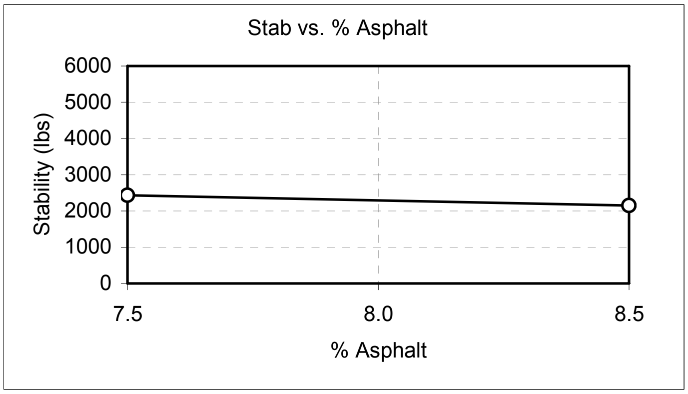
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
7.5	2.381	91.584	1.0	0.916	78.702	0.991	7.183	0.73	16.288	2433	17	20.31	80.21	4.0	2.481
8.5	2.376	90.594	1.0	0.906	77.687	0.978	8.186	0.64	18.525	2149	18	21.33	86.83	2.8	2.445
												Min 19		(4.5-6.5)	

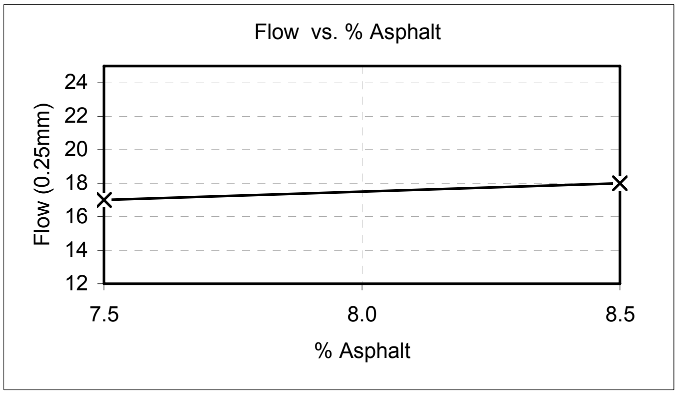

Air Voids vs. % Asphalt


VMA vs. % Asphalt


VFA vs. % Asphalt


Sp. Gr. vs. % Asphalt


Stab vs. % Asphalt


Flow vs. % Asphalt

MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: 31675 Trial B Crusher Fines Paramount
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
	1				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
	2				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
	3				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
				Average:	#DIV/0!	#DIV/0!			Average:	#N/A	#N/A	#DIV/0!
				Range:	#DIV/0!	#DIV/0!						
	4	1127.9	652.4	1125.1	2.366	147.4	2.399	2350	1.07	2515	11.2	17
7.5	5	1124.0	653.1	1122.1	2.383	148.5	2.362	2250	1.10	2475	11.0	16
	6	1123.4	655.0	1121.0	2.393	149.1	2.362	2100	1.10	2310	10.3	18
				Average:	2.381	148.3			Average:	2433	10.8	17
				Range:	0.027	1.7						
	7	1126.4	651.6	1125.4	2.370	147.7	2.390	1850	1.08	1998	8.9	19
8.5	8	1123.7	651.9	1122.5	2.379	148.2	2.387	2050	1.08	2214	9.8	18
	9	1131.6	656.3	1130.1	2.378	148.1	2.374	2050	1.09	2235	9.9	18
				Average:	2.376	148.0			Average:	2149	9.6	18
				Range:	0.009	0.5						

31675 Trial B Crusher Fines Paramount
Figure 6

MACTEC

ARAC Design Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: July, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31680	26.73
3/8" Aggregate	31678	22.77
1/2" Aggregate	31677	49.50
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	96	(80-100)	96
3/8" / 9.5	78	(65-80)	78
1/4" / 6.3	42		42
#4 / 4.75	33	(28-42)	34
#8 / 2.36	20	(14-22)	20
#10 / 2.00	17		18
#16 / 1.18	11		12
#30 / .600	6		7
#40 / .425	5		6
#50 / .300	4		5
#100 / .150	2		3
#200 / .075	1.9	(0-2.5)	2.9

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Recommended % Asphalt: 8.5 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	8.5		
Bulk Specific Gravity :	2.298		
Bulk Specific Density (kg/m3):	2293		
Bulk Specific Density (PCF):	143.2		
Theor. Max. Sp. Gr. (Gmm):	2.440		
Stability (lbs):	1930		
Flow (0.25 mm):	20		
Percent Air Voids:	5.8	(4.5-6.5)	
Percent VMA:	23.56	Min 19	
Percent Voids Filled:	75.4		
Percent Effective Asphalt:	8.112		
Dust to Eff. Asphalt Ratio:	0.35		
Effective Sp. Gr.(w/ Admix):	2.782		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.748	2.777	2.758	2.35-2.85
"SSD" Sp. Gravity:	2.796	2.823	2.805	
Apparent Sp. Gravity:	2.885	2.912	2.894	
Water Absorption(%):	1.72	1.67	1.72	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			77	Min 55
Fractured Face 2 Face (%):			97	Min 85
Fractured Face 1 Face (%):			99	
Asphalt Absorbed into Dry Aggregate (%):			0.43	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			6	Max 9
L.A. Abrasion @ 500 Rev.(%):			23	Max 40

Remarks:

GM B2 Control A
Figure 7

MACTEC

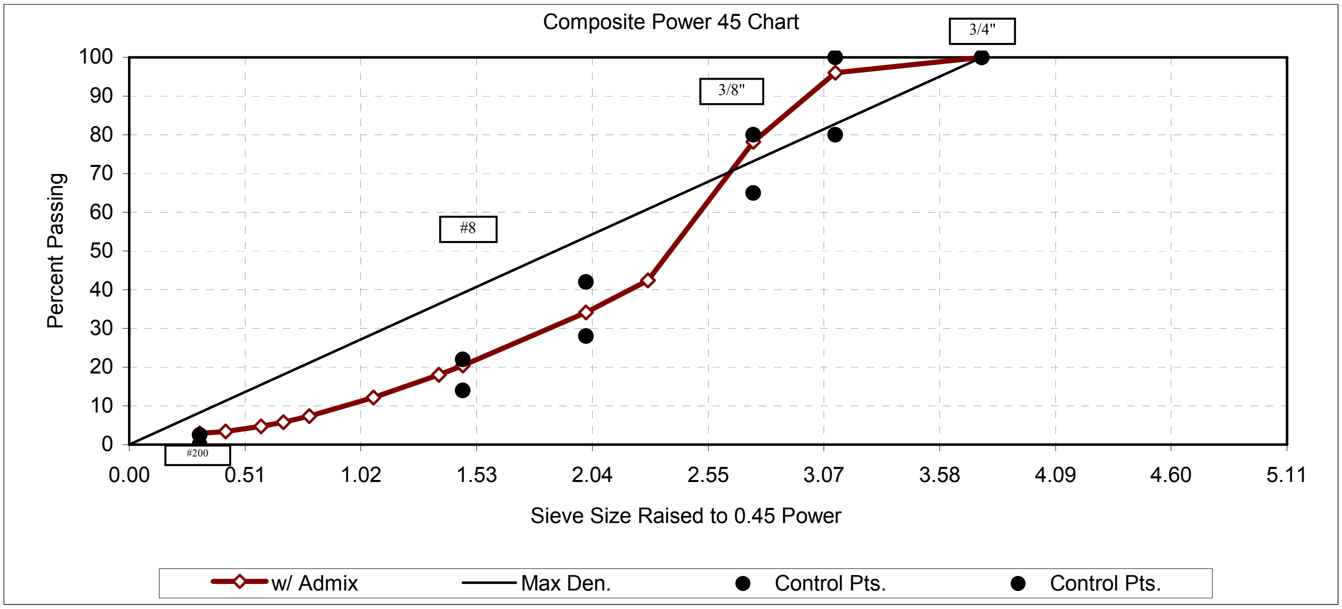
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: July, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31680	Aggregate #1:	Clean Crusher Fines	27.0	26.73
31678	Aggregate #2:	3/8" Aggregate	23.0	22.77
31677	Aggregate #3:	1/2" Aggregate	50.0	49.50
				0.00
				0.00
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31680	31678	31677				Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
27.0	23.0	50.0				1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3				Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100				100	1.5" / 37.5	100		100	
100	100	100				100	1.25 / 31.5	100		100	
100	100	100				100	1" / 25	100		100	
100	100	100				100	3/4" / 19	100	(100)	100	
100	100	92				100	1/2" / 12.5	96	(80-100)	96	
100	100	56				100	3/8" / 9.5	78	(65-80)	78	
100	60	2				100	1/4" / 6.3	42		42	
100	26	1				100	#4 / 4.75	33	(28-42)	34	
70	1	1				100	#8 / 2.36	20	(14-22)	20	
61	1	1				100	#10 / 2.00	17		18	
39	1	1				100	#16 / 1.18	11		12	
23	1	0				100	#30 / .600	6		7	
18	0	0				100	#40 / .425	5		6	
14	0	0				100	#50 / .300	4		5	
9	0	0				100	#100 / .150	2		3	
6.2	0.5	0.2				100.0	#200 / .075	1.9	(0-2.5)	2.9	



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Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	July, 2003
MACTEC Lab No.:	GM B2 Control A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1062.5
	Flask 2	1063.7
	Flask 3	1063.5
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3914.4
	Flask 2	3895.5
	Flask 3	3841.6
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1062.5
	Flask 2	1063.7
	Flask 3	1063.5
Loss of binder from mixing:		1.8
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3914.4
	Flask 2	3895.5
	Flask 3	3841.6
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1066.0
	Flask 2	1067.0
	Flask 3	1067.8
Volume of Voidless Mix ("Vvm"):	Flask 1	419.6
	Flask 2	418.5
	Flask 3	419.2
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.532
	Flask 2	2.542
	Flask 3	2.537
Average Maximum Sp. Gravity ("Gmm"):		**2.537**
Average Maximum Density (PCF):		158.1
"Gmm" Range:		0.010

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.789
Asphalt Absorbed (%):	0.43

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2964.1
"SSD" Weight(g):	3015.2
Weight in Water(g):	1936.7
Bulk (Dry) Sp. Gravity:	2.748
"SSD" Sp. Gravity:	2.796
Apparent Sp. Gravity:	2.885
Water Absorption(%):	1.72

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	491.8
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.4
Weight of Flask, Water & Sample(g):	986.3
Bulk (Dry) Sp. Gravity:	2.777
"SSD" Sp. Gravity:	2.823
Apparent Sp. Gravity:	2.912
Water Absorption(%):	1.67

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.758
Comp. "SSD"(W/O Admix):	2.805
Comp. Apparent(W/O Admix):	2.894
Comp Water Absorb. (%)	1.72
Comp. Bulk(Dry)(with Admix):	2.751
Comp. "SSD"(with Admix):	2.797
Comp. Apparent(with Admix):	2.885

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	77	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	97	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	99	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

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Volumetric Calculations

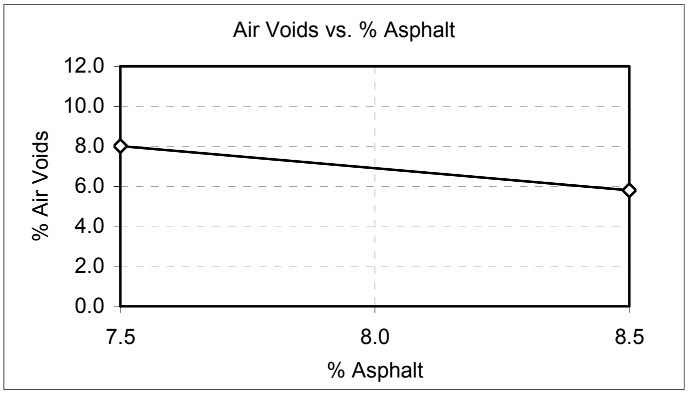
MACTEC Job No.:	4975-03-3008	Date:	July, 2003
MACTEC Lab No.:	GM B2 Control A	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

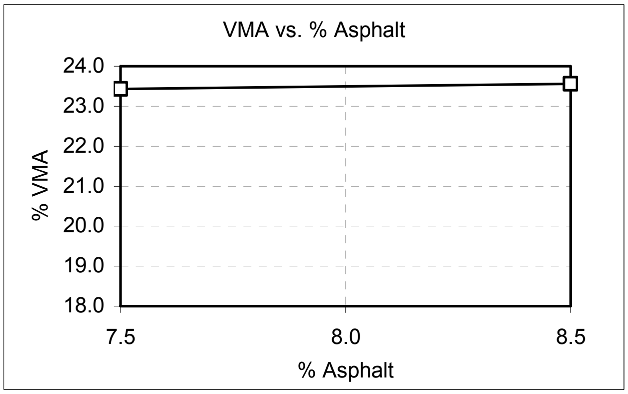
Volumetric Calculations

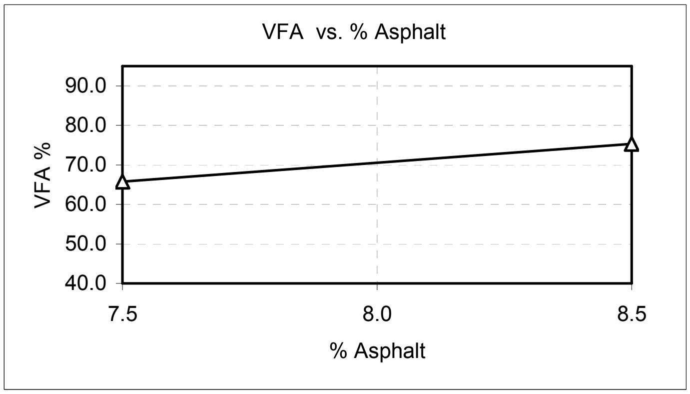
Compaction Method: Marshall

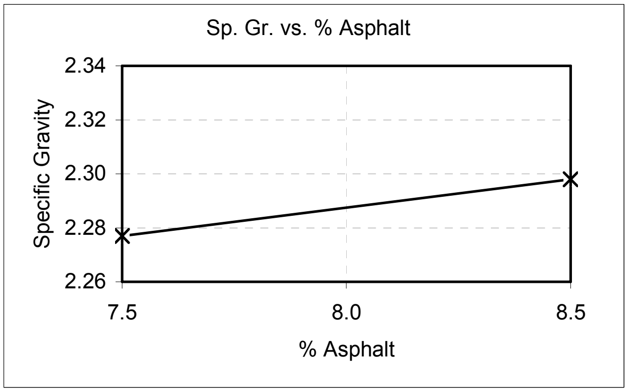
Calculation Method: ARIZ 815

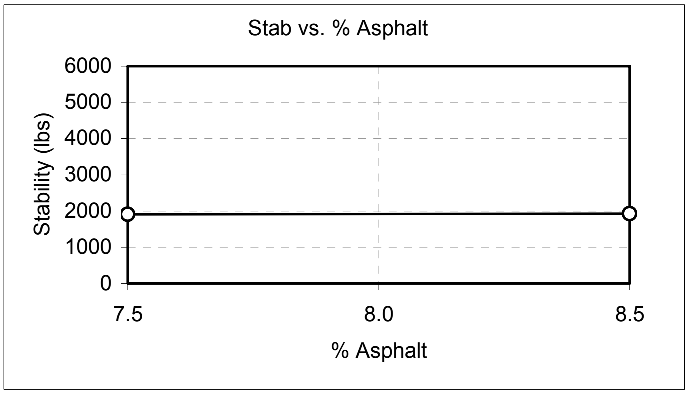
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow .25m	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
7.5	2.277	91.584	1.0	0.916	75.622	0.948	7.107	0.40	15.413	1909	18	23.43	65.78	8.0	2.475
8.5	2.298	90.594	1.0	0.906	75.494	0.946	8.112	0.35	17.753	1930	20	23.56	75.35	5.8	2.440
8.5	**2.298**	**90.594**	**1.0**	**0.906**	**75.494**	**0.946**	**8.112**	**0.35**	**17.753**	**1930**	**20**	**23.56**	**75.35**	**5.8**	**2.440**
												Min 19		(4.5-6.5)	

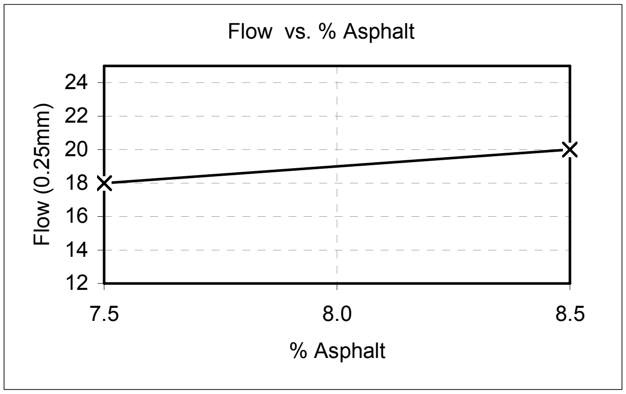












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Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control A
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: July, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75 | Compaction / Mixing Temp: 325/325 F | Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	orrect ab (k	Flow (0.25 mm)
6.5	1				#DIV/0!	#DIV/0!			#N/A	#N/A	##	
	2				#DIV/0!	#DIV/0!			#N/A	#N/A	##	
	3				#DIV/0!	#DIV/0!			#N/A	#N/A	##	
				Average:	#DIV/0!	#DIV/0!			Average:	#N/A	##	#DIV/0!
				Range:	#DIV/0!	#DIV/0!						
7.5	4	1128.2	633.2	1120.2	2.263	141.0	2.525	1750	0.98	1715	7.6	19
	5	1128.6	638.7	1122.3	2.291	142.7	2.470	2125	1.02	2168	9.6	18
	6	1126.3	635.3	1118.3	2.278	141.9	2.490	1825	1.01	1843	8.2	18
				Average:	2.277	141.9			Average:	1909	8.5	18
				Range:	0.028	1.7						
8.5	7	1132.4	640.9	1127.3	2.294	142.9	2.496	1700	1.00	1700	7.6	17
	8	1131.3	642.2	1127.0	2.304	143.5	2.470	2000	1.02	2040	9.1	21
	9	1130.7	640.4	1126.2	2.297	143.1	2.499	2050	1.00	2050	9.1	21
				Average:	2.298	143.2			Average:	1930	8.6	20
				Range:	0.010	0.6						

GM B2 Control A
Figure 7

ARAC Trial Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control Trial B Crshr Fines
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31680	0.00
3/8" Aggregate	31678	26.73
1/2" Aggregate	31677	45.54
Crusher Fines	31679	26.73
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	96	(80-100)	96
3/8" / 9.5	80	(65-80)	80
1/4" / 6.3	44		45
#4 / 4.75	34	(28-42)	35
#8 / 2.36	22	(14-22)	22
#10 / 2.00	19		20
#16 / 1.18	14		15
#30 / .600	10		11
#40 / .425	8		9
#50 / .300	7		8
#100 / .150	5		6
#200 / .075	4.3	(0-2.5)	5.3

Recommended % Asphalt: ***

ARAC Supplier:
ADOT Lab No.:
Asphalt Source: Ergon / CRM
Asphalt Grade: PG 58-22 / Type II
Admix Source: Chemical Lime
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.748	2.777	2.758	2.35-2.85
"SSD" Sp. Gravity:	2.796	2.823	2.805	
Apparent Sp. Gravity:	2.885	2.912	2.894	
Water Absorption(%):	1.72	1.67	1.72	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:	1.050	

Sand Equivalent value:	77	Min 55
Fractured Face 2 Face (%):	97	Min 85
Fractured Face 1 Face (%):	99.0	
Asphalt Absorbed into Dry Aggregate (%):	0.42	Max 1.0
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

Remarks:

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

GM B2 Control Trial B Crusher Control
Figure 8

MACTEC

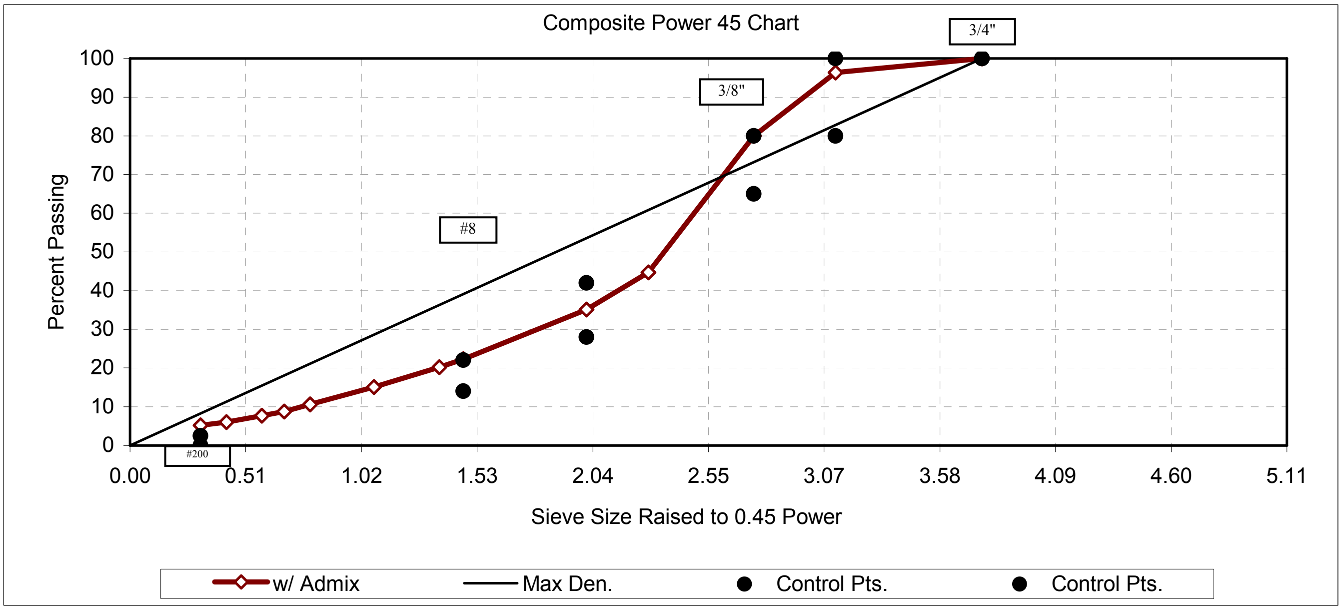
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control Trial B Crshr Fines
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31680	Aggregate #1:	Clean Crusher Fines	0.0	0.00
31678	Aggregate #2:	3/8" Aggregate	27.0	26.73
31677	Aggregate #3:	1/2" Aggregate	46.0	45.54
31679	Aggregate #4:	Crusher Fines	27.0	26.73
				0.00
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31680	31678	31677	31679			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
0.0	27.0	46.0	27.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	92	100			100	1/2" / 12.5	96	(80-100)	96	
100	100	56	100			100	3/8" / 9.5	80	(65-80)	80	
100	60	2	100			100	1/4" / 6.3	44		45	
100	26	1	100			100	#4 / 4.75	34	(28-42)	35	
70	1	1	77			100	#8 / 2.36	22	(14-22)	22	
61	1	1	69			100	#10 / 2.00	19		20	
39	1	1	50			100	#16 / 1.18	14		15	
23	1	0	35			100	#30 / .600	10		11	
18	0	0	29			100	#40 / .425	8		9	
14	0	0	25			100	#50 / .300	7		8	
9	0	0	19			100	#100 / .150	5		6	
6.2	0.5	0.2	15.1			100.0	#200 / .075	4.3	(0-2.5)	5.3	



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Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	GM B2 Control Trial B Crshr Fines	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Grey Mountain
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1062.5
	Flask 2	1063.7
	Flask 3	1063.5
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3914.4
	Flask 2	3895.5
	Flask 3	3841.6
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1062.5
	Flask 2	1063.7
	Flask 3	1063.5
Loss of binder from mixing:		1.8
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3914.4
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Surface Dry Wt. SSD ("Wsd"):	Flask 1	1066.0
	Flask 2	1067.0
	Flask 3	1067.8
Volume of Voidless Mix ("Vvm"):	Flask 1	419.6
	Flask 2	418.5
	Flask 3	419.2
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.532
	Flask 2	2.542
	Flask 3	2.537
Average Maximum Sp. Gravity ("Gmm"):		**2.537**
Average Maximum Density (PCF):		158.1
"Gmm" Range:		0.010

Weights in grams. 0.0 = item was tared

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2964.1
"SSD" Weight(g):	3015.2
Weight in Water(g):	1936.7
Bulk (Dry) Sp. Gravity:	2.748
"SSD" Sp. Gravity:	2.796
Apparent Sp. Gravity:	2.885
Water Absorption(%):	1.72

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	491.8
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.4
Weight of Flask, Water & Sample(g):	986.3
Bulk (Dry) Sp. Gravity:	2.777
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Apparent Sp. Gravity:	2.912
Water Absorption(%):	1.67

Combined Specific Gravity

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Comp. "SSD"(W/O Admix):	2.805
Comp. Apparent(W/O Admix):	2.894
Comp Water Absorb. (%)	1.72
Comp. Bulk(Dry)(with Admix):	2.751
Comp. "SSD"(with Admix):	2.798
Comp. Apparent(with Admix):	2.885

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	77	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	97	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	99	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.789
Asphalt Absorbed (%):	0.42

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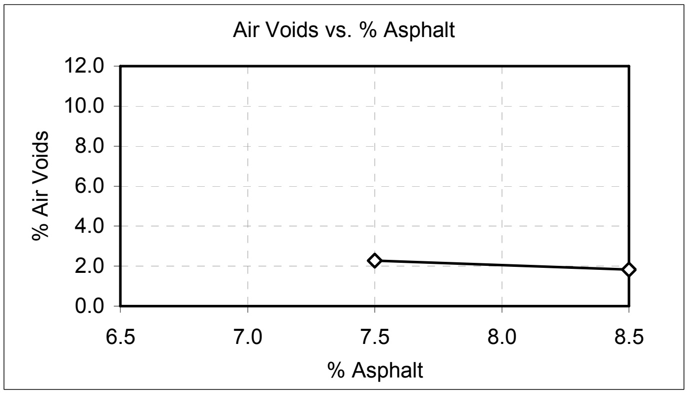
Volumetric Calculations

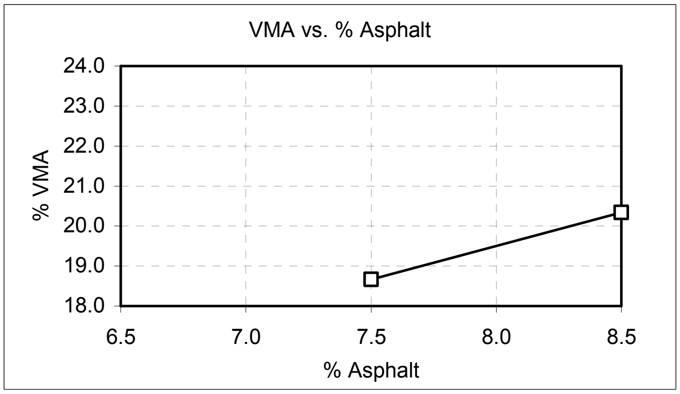
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control Trial B Crshr Fines
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

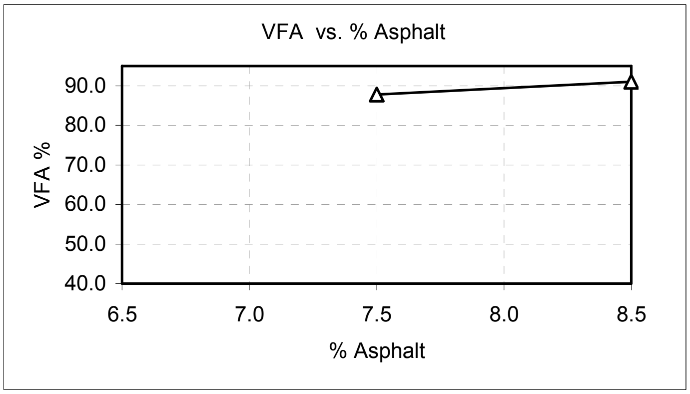
Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

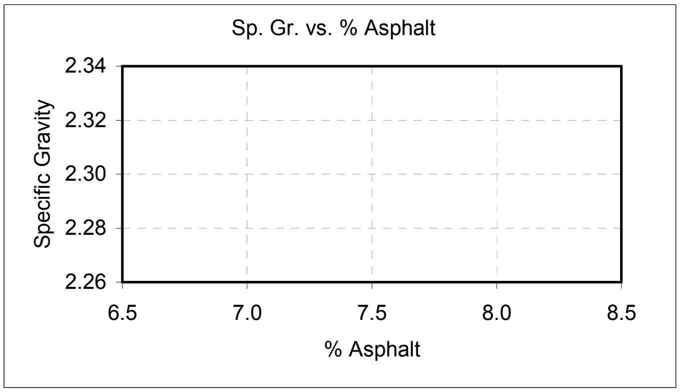
Volumetric Calculations Compaction Method: Marshall Calculation Method: ARIZ 815

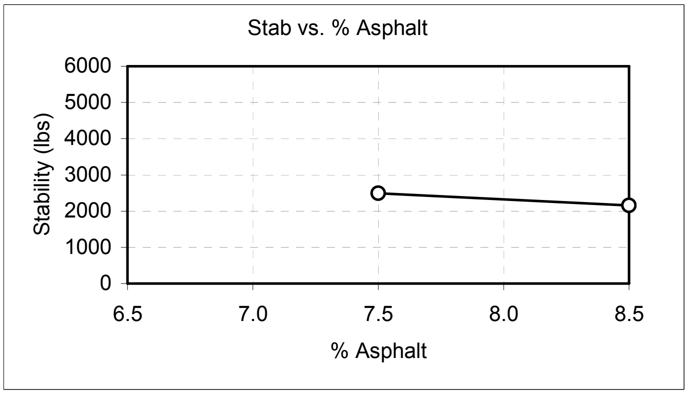
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
7.5	2.419	91.584	1.0	0.916	80.329	1.007	7.111	0.74	16.382	2488	19	18.66	87.78	2.3	2.475
8.5	2.395	90.594	1.0	0.906	78.672	0.986	8.115	0.65	18.510	2159	18	20.34	91.00	1.8	2.440
												Min 19		(4.5-6.5)	

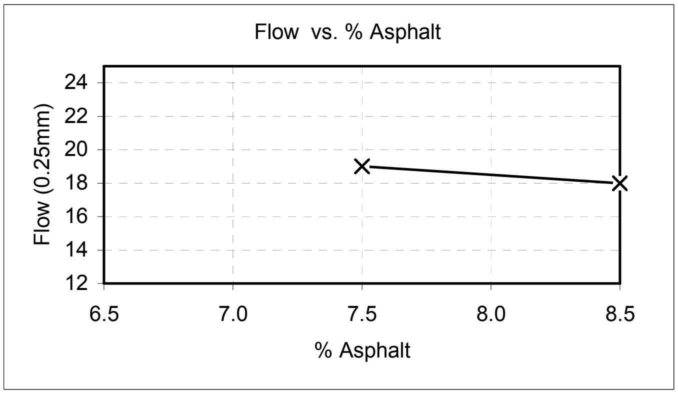












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: GM B2 Control Trial B Crshr Fines
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Grey Mountain
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
	1				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
	2				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
	3				#DIV/0!	#DIV/0!			#N/A	#N/A	#N/A	
				Average:	#DIV/0!	#DIV/0!			Average:	#N/A	#N/A	#DIV/0!
				Range:	#DIV/0!	#DIV/0!						
7.5	4	1081.4	633.3	1079.2	2.408	150.0	2.345	2425	1.11	2692	12.0	16
	5	1077.7	632.4	1076.0	2.416	150.5	2.337	2175	1.12	2436	10.8	20
	6	1073.2	630.4	1076.9	2.432	151.5	2.311	2050	1.14	2337	10.4	20
				Average:	2.419	150.7			Average:	2488	11.1	19
				Range:	0.024	1.5						
8.5	7	1083.2	630.8	1081.9	2.391	149.0	2.354	2025	1.11	2248	10.0	17
	8	1082.4	630.5	1081.2	2.393	149.1	2.341	1850	1.12	2072	9.2	18
	9	1081.3	631.6	1080.2	2.402	149.6	2.336	1925	1.12	2156	9.6	19
				Average:	2.395	149.2			Average:	2159	9.6	18
				Range:	0.011	0.6						

GM B2 Control Trial B Crusher Control
Figure 8

MACTEC

ARAC Design Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31721	19.80
Crusher Fines	31720	10.89
3/8" Aggregate	31719	20.79
1/2" Aggregate	31718	47.52
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	98	(80-100)	98
3/8" / 9.5	74	(65-80)	74
1/4" / 6.3	41		41
#4 / 4.75	32	(28-42)	33
#8 / 2.36	21	(14-22)	22
#10 / 2.00	18		19
#16 / 1.18	13		14
#30 / .600	9		10
#40 / .425	8		9
#50 / .300	6		7
#100 / .150	4		5
#200 / .075	2.0	(0-2.5)	3.0

Recommended % Asphalt: 7.5 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	7.5		
Bulk Specific Gravity :	2.228		
Bulk Specific Density (kg/m3):	2223		
Bulk Specific Density (PCF):	138.8		
Theor. Max. Sp. Gr. (Gmm):	2.361		
Stability (lbs):	2010		
Flow (0.25 mm):	18		
Percent Air Voids:	5.6	(4.5-6.5)	
Percent VMA:	21.06	Min 19	
Percent Voids Filled:	73.3		
Percent Effective Asphalt:	7.275		
Dust to Eff. Asphalt Ratio:	0.41		
Effective Sp. Gr.(w/ Admix):	2.627		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.610	2.628	2.616	2.35-2.85
"SSD" Sp. Gravity:	2.637	2.648	2.640	
Apparent Sp. Gravity:	2.682	2.682	2.682	
Water Absorption(%):	1.02	0.77	0.95	0-2.5
Admixture Sp. Gravity:	2.200		Asphalt Sp. Gravity:	1.050
Sand Equivalent value:			68	Min 55
Fractured Face 2 Face (%):			88	Min 85
Fractured Face 1 Face (%):			94	
Asphalt Absorbed into Dry Aggregate (%):			0.25	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			4	Max 9
L.A. Abrasion @ 500 Rev.(%):			19	Max 40

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Remarks:

Salt River B1C1
Figure 9

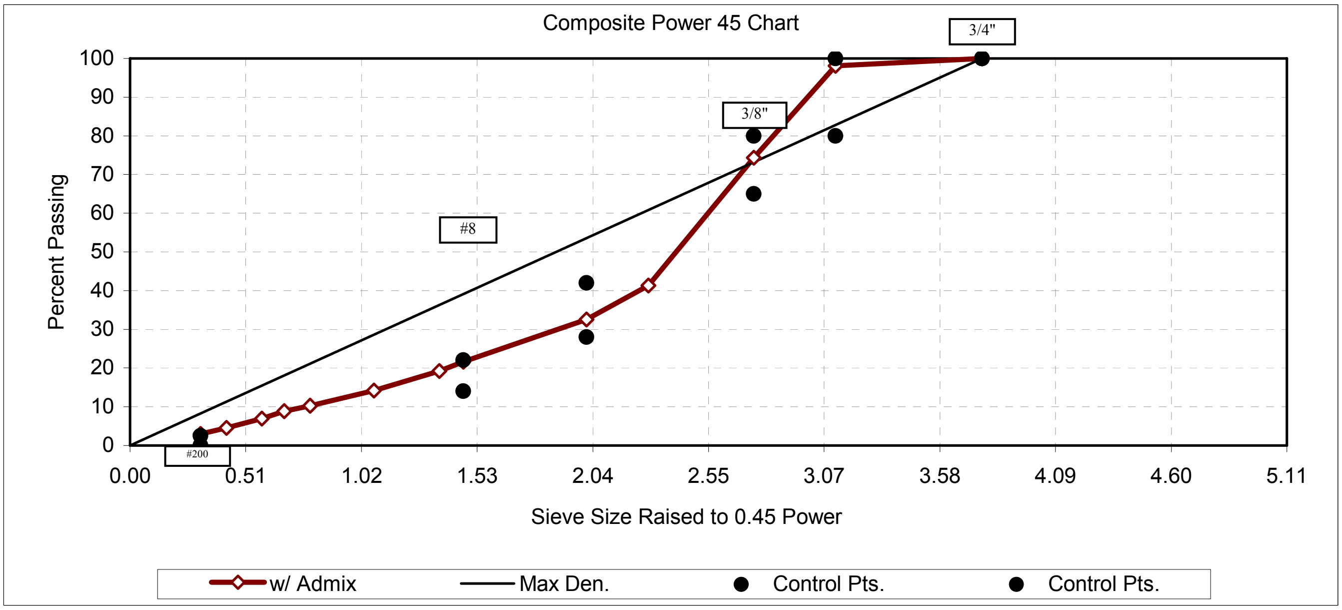
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31721	Aggregate #1:	Clean Crusher Fines	20.0	19.80
31720	Aggregate #2:	Crusher Fines	11.0	10.89
31719	Aggregate #3:	3/8" Aggregate	21.0	20.79
31718	Aggregate #4:	1/2" Aggregate	48.0	47.52
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31721	31720	31719	31718			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
20.0	11.0	21.0	48.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	100	96			100	1/2" / 12.5	98	(80-100)	98	
100	100	91	50			100	3/8" / 9.5	74	(65-80)	74	
100	100	35	5			100	1/4" / 6.3	41		41	
95	95	7	2			100	#4 / 4.75	32	(28-42)	33	
63	62	2	2			100	#8 / 2.36	21	(14-22)	22	
55	55	2	2			100	#10 / 2.00	18		19	
39	42	2	1			100	#16 / 1.18	13		14	
26	30	2	1			100	#30 / .600	9		10	
21	26	2	1			100	#40 / .425	8		9	
15	21	1	1			100	#50 / .300	6		7	
7	14	1	1			100	#100 / .150	4		5	
3.5	9.2	0.7	0.3			100.0	#200 / .075	2.0	(0-2.5)	3.0	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	Salt River B1C1	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1065.8
	Flask 2	1061.4
	Flask 3	1061.5
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3892.6
	Flask 2	3870.2
	Flask 3	3815.1
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1065.8
	Flask 2	1061.4
	Flask 3	1061.5
Loss of binder from mixing:		2.8
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3892.6
	Flask 2	3870.2
	Flask 3	3815.1
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1066.6
	Flask 2	1062.0
	Flask 3	1062.4
Volume of Voidless Mix ("Vvm"):	Flask 1	442.0
	Flask 2	438.8
	Flask 3	440.3
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.411
	Flask 2	2.419
	Flask 3	2.411
Average Maximum Sp. Gravity ("Gmm"):		**2.414**
Average Maximum Density (PCF):		150.4
"Gmm" Range:		0.008

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.632
Asphalt Absorbed (%):	0.25

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	Salt River B1C1	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1077.2
	Flask 2	1072.8
	Flask 3	1074.0
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3892.6
	Flask 2	3870.0
	Flask 3	3817.2
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1077.2
	Flask 2	1072.8
	Flask 3	1074.0
Loss of binder from mixing:		1.8
Wt. of Flask ,and Water,(B):	Flask 1	3268.0
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3892.6
	Flask 2	3870.0
	Flask 3	3817.2
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1077.9
	Flask 2	1073.5
	Flask 3	1075.1
Volume of Voidless Mix ("Vvm"):	Flask 1	453.3
	Flask 2	450.5
	Flask 3	450.9
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.376
	Flask 2	2.381
	Flask 3	2.382
Average Maximum Sp. Gravity ("Gmm"):		**2.380**
Average Maximum Density (PCF):		148.3
"Gmm" Range:		0.006

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.631
Asphalt Absorbed (%):	0.23

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

MACTEC

Volumetric Calculations

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

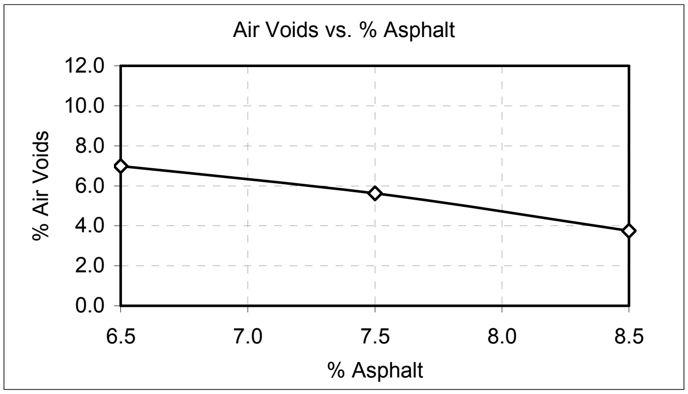
Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

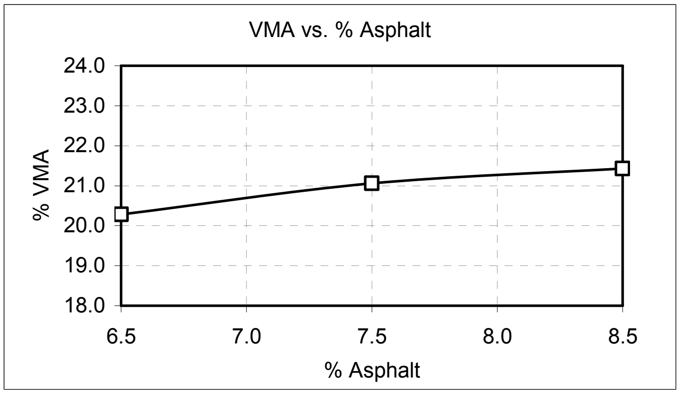
Volumetric Calculations

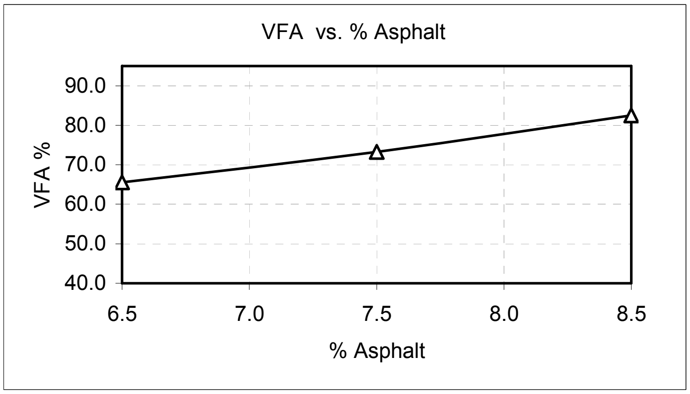
Compaction Method: Marshall

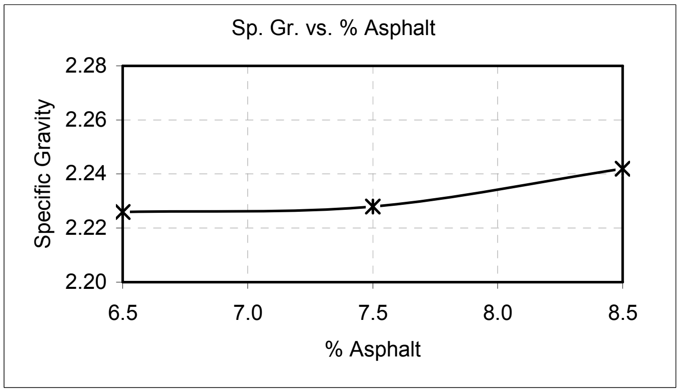
Calculation Method: ARIZ 815

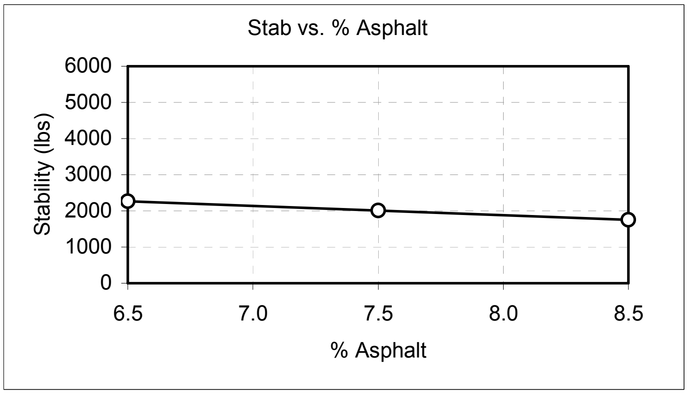
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.226	92.574	1.0	0.926	78.782	0.937	6.272	0.47	13.297	2268	17	20.28	65.56	7.0	2.393
7.5	2.228	91.584	1.0	0.916	78.009	0.927	7.275	0.41	15.436	2010	18	21.06	73.28	5.6	2.361
8.5	2.242	90.594	1.0	0.906	77.651	0.923	8.277	0.36	17.674	1751	20	21.43	82.49	3.8	2.329
7.5	**2.228**	**91.584**	**1.0**	**0.916**	**78.009**	**0.927**	**7.275**	**0.41**	**15.436**	**2010**	**18**	**21.06**	**73.28**	**5.6**	**2.361**
												Min 19		(4.5-6.5)	

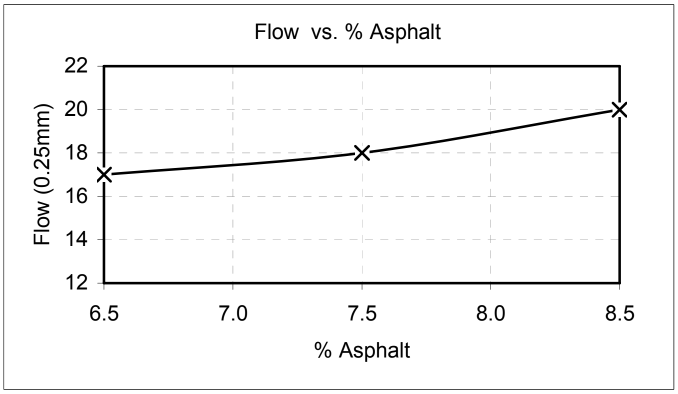












Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1092.3	603.1	1086.3	2.221	138.4	2.473	2150	1.02	2193	9.8	17
	2	1086.7	601.4	1080.9	2.227	138.7	2.460	2200	1.03	2266	10.1	17
	3	1089.7	605.2	1080.5	2.230	138.9	2.475	2300	1.02	2346	10.4	17
				Average:	2.226	138.7			Average:	2268	10.1	17
				Range:	0.009	0.5						
7.5	4	1095.7	604.8	1092.3	2.225	138.6	2.480	2000	1.01	2020	9.0	17
	5	1090.8	603.4	1087.3	2.231	139.0	2.475	2000	1.02	2040	9.1	17
	6	1096.8	606.4	1092.7	2.228	138.8	2.478	1950	1.01	1970	8.8	19
				Average:	2.228	138.8			Average:	2010	8.9	18
				Range:	0.006	0.4						
8.5	7	1099.6	611.5	1098.2	2.250	140.2	2.462	1700	1.02	1734	7.7	19
	8	1099.3	611.2	1097.7	2.249	140.1	2.470	1750	1.02	1785	7.9	21
	9	1100.0	606.7	1098.8	2.227	138.7	2.473	1700	1.02	1734	7.7	20
				Average:	2.242	139.7			Average:	1751	7.8	20
				Range:	0.023	1.5						

Rinker B1C1
Figure 9

MACTEC

ARAC Design Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31721	19.80
Crusher Fines	31720	10.89
3/8" Aggregate	31719	20.79
1/2" Aggregate	31718	47.52
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	98	(80-100)	98
3/8" / 9.5	74	(65-80)	74
1/4" / 6.3	41		41
#4 / 4.75	32	(28-42)	33
#8 / 2.36	21	(14-22)	22
#10 / 2.00	18		19
#16 / 1.18	13		14
#30 / .600	9		10
#40 / .425	8		9
#50 / .300	6		7
#100 / .150	4		5
#200 / .075	2.0	(0-2.5)	3.0

Recommended % Asphalt: 7.3 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	7.3		
Bulk Specific Gravity :	2.235		
Bulk Specific Density (kg/m3):	2230		
Bulk Specific Density (PCF):	139.2		
Theor. Max. Sp. Gr. (Gmm):	2.366		
Stability (lbs):	1339		
Flow (0.25 mm):	19		
Percent Air Voids:	5.5	(4.5-6.5)	
Percent VMA:	20.64	Min 19	
Percent Voids Filled:	73.2		
Percent Effective Asphalt:	7.099		
Dust to Eff. Asphalt Ratio:	0.42		
Effective Sp. Gr.(w/ Admix):	2.625		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.610	2.628	2.616	2.35-2.85
"SSD" Sp. Gravity:	2.637	2.648	2.640	
Apparent Sp. Gravity:	2.682	2.682	2.682	
Water Absorption(%):	1.02	0.77	0.95	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			68	Min 55
Fractured Face 2 Face (%):			88	Min 85
Fractured Face 1 Face (%):			94	
Asphalt Absorbed into Dry Aggregate (%):			0.22	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			4	Max 9
L.A. Abrasion @ 500 Rev.(%):			19	Max 40

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James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Remarks:

Salt River B1C2
Figure 10

MACTEC

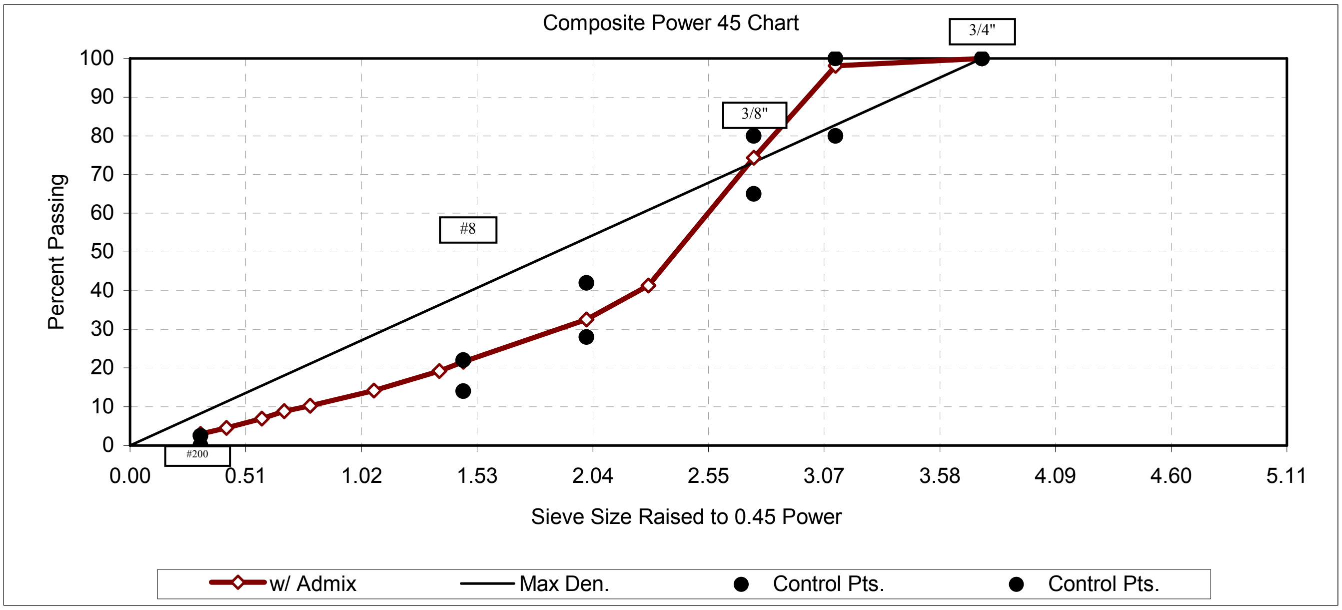
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31721	Aggregate #1:	Clean Crusher Fines	20.0	19.80
31720	Aggregate #2:	Crusher Fines	11.0	10.89
31719	Aggregate #3:	3/8" Aggregate	21.0	20.79
31718	Aggregate #4:	1/2" Aggregate	48.0	47.52
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31721	31720	31719	31718			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
20.0	11.0	21.0	48.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	100	96			100	1/2" / 12.5	98	(80-100)	98	
100	100	91	50			100	3/8" / 9.5	74	(65-80)	74	
100	100	35	5			100	1/4" / 6.3	41		41	
95	95	7	2			100	#4 / 4.75	32	(28-42)	33	
63	62	2	2			100	#8 / 2.36	21	(14-22)	22	
55	55	2	2			100	#10 / 2.00	18		19	
39	42	2	1			100	#16 / 1.18	13		14	
26	30	2	1			100	#30 / .600	9		10	
21	26	2	1			100	#40 / .425	8		9	
15	21	1	1			100	#50 / .300	6		7	
7	14	1	1			100	#100 / .150	4		5	
3.5	9.2	0.7	0.3			100.0	#200 / .075	2.0	(0-2.5)	3.0	



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Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	Salt River B1C2	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1062.9
	Flask 2	1063.5
	Flask 3	1063.8
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3855.2
	Flask 2	3868.7
	Flask 3	3815.6
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1062.9
	Flask 2	1063.5
	Flask 3	1063.8
Loss of binder from mixing:		1.3
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3855.2
	Flask 2	3868.7
	Flask 3	3815.6
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1063.5
	Flask 2	1063.9
	Flask 3	1064.4
Volume of Voidless Mix ("Vvm"):	Flask 1	439.7
	Flask 2	442.2
	Flask 3	440.6
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.417
	Flask 2	2.405
	Flask 3	2.414
Average Maximum Sp. Gravity ("Gmm"):		**2.412**
Average Maximum Density (PCF):		150.3
"Gmm" Range:		0.012

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.630
Asphalt Absorbed (%):	0.22

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

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Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	June, 2003
MACTEC Lab No.:	Salt River B1C2	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1075.9
	Flask 2	1072.1
	Flask 3	1075.4
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3856.0
	Flask 2	3870.6
	Flask 3	3816.2
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1075.9
	Flask 2	1072.1
	Flask 3	1075.4
Loss of binder from mixing:		2.4
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3856.0
	Flask 2	3870.6
	Flask 3	3816.2
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1076.6
	Flask 2	1072.9
	Flask 3	1076.1
Volume of Voidless Mix ("Vvm"):	Flask 1	452.0
	Flask 2	449.3
	Flask 3	451.7
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.380
	Flask 2	2.386
	Flask 3	2.381
Average Maximum Sp. Gravity ("Gmm"):		**2.382**
Average Maximum Density (PCF):		148.4
"Gmm" Range:		0.006

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.634
Asphalt Absorbed (%):	0.28

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

MACTEC

Volumetric Calculations

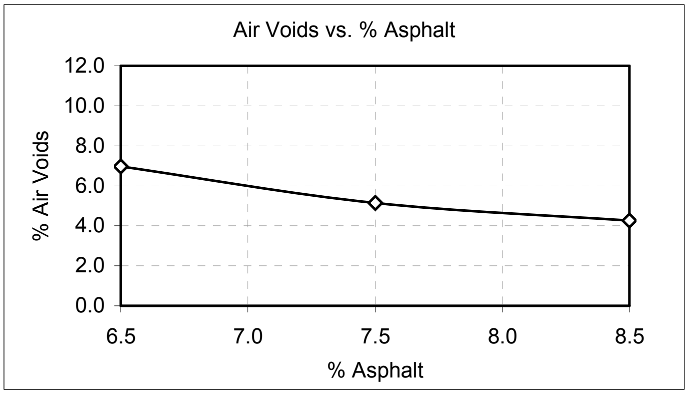
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

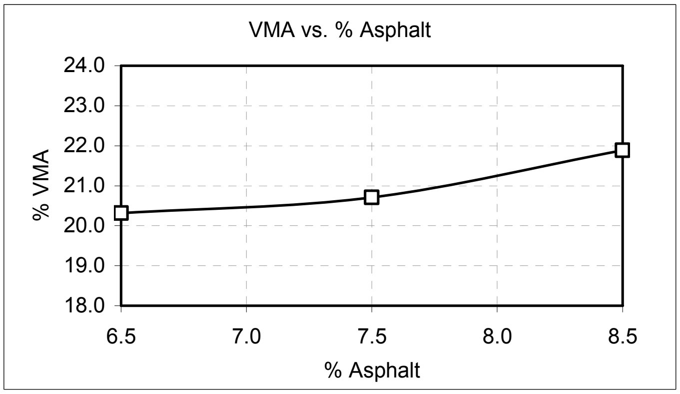
Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

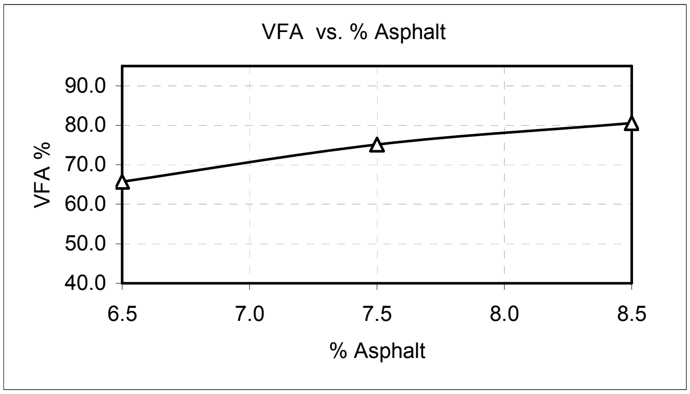
Volumetric Calculations

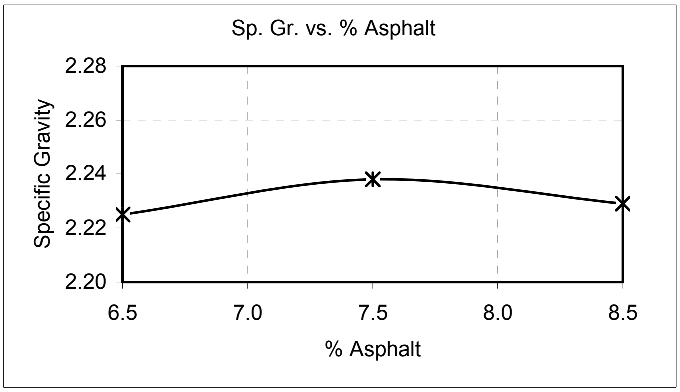
Compaction Method: Marshall
Calculation Method: ARIZ 815

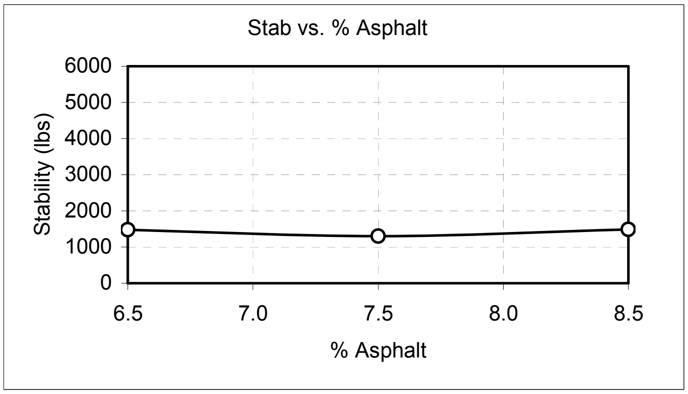
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.225	92.574	1.0	0.926	78.746	0.936	6.297	0.47	13.345	1477	17	20.32	65.68	7.0	2.392
7.5	2.238	91.584	1.0	0.916	78.359	0.932	7.300	0.41	15.559	1304	20	20.71	75.13	5.2	2.360
8.5	2.229	90.594	1.0	0.906	77.200	0.918	8.302	0.36	17.623	1484	17	21.88	80.54	4.3	2.328
7.3	**2.235**	**91.782**	**1.0**	**0.918**	**78.423**	**0.932**	**7.099**	**0.42**	**15.111**	**1339**	**19**	**20.64**	**73.20**	**5.5**	**2.366**
												Min 19		(4.5-6.5)	

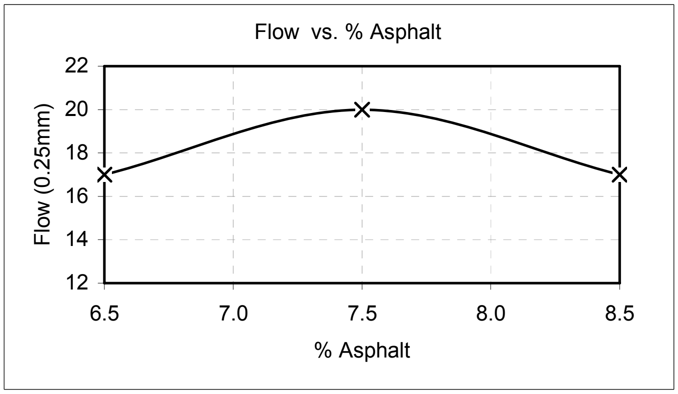












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: June, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1089.2	602.5	1081.8	2.223	138.5	2.490	1425	1.01	1439	6.4	16
	2	1060.2	587.8	1052.6	2.228	138.8	2.482	1550	1.01	1566	7.0	18
	3	1095.4	606.8	1086.3	2.223	138.5	2.500	1425	1.00	1425	6.3	17
				Average:	2.225	138.6			Average:	1477	6.6	17
				Range:	0.005	0.3						
7.5	4	1097.1	608.6	1093.5	2.238	139.4	2.474	1300	1.02	1326	5.9	20
	5	1096.0	606.8	1092.3	2.233	139.1	2.489	1425	1.01	1439	6.4	21
	6	1094.3	607.4	1091.8	2.242	139.7	2.473	1125	1.02	1148	5.1	19
				Average:	2.238	139.4			Average:	1304	5.8	20
				Range:	0.009	0.6						
8.5	7	1100.5	606.7	1097.8	2.223	138.5	2.499	1450	1.00	1450	6.5	18
	8	1099.0	604.8	1096.7	2.219	138.2	2.508	1525	0.99	1510	6.7	17
	9	1098.2	609.8	1096.3	2.245	139.9	2.457	1450	1.03	1494	6.6	17
				Average:	2.229	138.9			Average:	1484	6.6	17
				Range:	0.026	1.7						

Salt River B1C2
Figure 10

MACTEC

ARAC Design Summary

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B1C3	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31721	19.80
Crusher Fines	31720	10.89
3/8" Aggregate	31719	20.79
1/2" Aggregate	31718	47.52
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	98	(80-100)	98
3/8" / 9.5	74	(65-80)	74
1/4" / 6.3	41		41
#4 / 4.75	32	(28-42)	33
#8 / 2.36	21	(14-22)	22
#10 / 2.00	18		19
#16 / 1.18	13		14
#30 / .600	9		10
#40 / .425	8		9
#50 / .300	6		7
#100 / .150	4		5
#200 / .075	2.0	(0-2.5)	3.0

Recommended % Asphalt: 7.3 ***

ARAC Supplier:	
ADOT Lab No.:	
Asphalt / Rubber Source:	Paramount / CRM
Asphalt Grade / Blend Type:	PG 58-22 / Type II
Admix Source:	Chemical Lime Co.
Mixing Temperature:	325 F
Compaction Temperature:	325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	7.3		
Bulk Specific Gravity :	2.242		
Bulk Specific Density (kg/m3):	2237		
Bulk Specific Density (PCF):	139.7		
Theor. Max. Sp. Gr. (Gmm):	2.370		
Stability (lbs):	2024		
Flow (0.25 mm):	17		
Percent Air Voids:	5.4	(4.5-6.5)	
Percent VMA:	20.40	Min 19	
Percent Voids Filled:	73.5		
Percent Effective Asphalt:	7.019		
Dust to Eff. Asphalt Ratio:	0.42		
Effective Sp. Gr.(w/ Admix):	2.631		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.610	2.628	2.616	2.35-2.85
"SSD" Sp. Gravity:	2.637	2.648	2.640	
Apparent Sp. Gravity:	2.682	2.682	2.682	
Water Absorption(%):	1.02	0.77	0.95	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			68	Min 55
Fractured Face 2 Face (%):			88	Min 85
Fractured Face 1 Face (%):			94	
Asphalt Absorbed into Dry Aggregate (%):			0.31	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			4	Max 9
L.A. Abrasion @ 500 Rev.(%):			19	Max 40

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Remarks:

Salt River B1C3
Figure 11

MACTEC

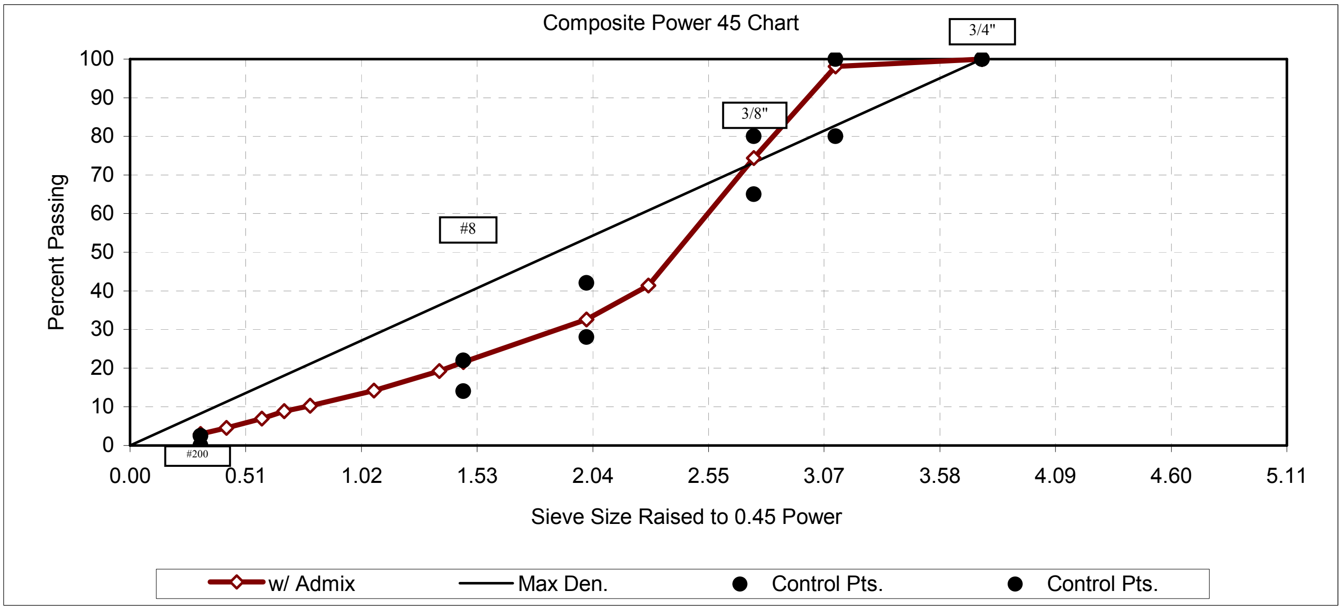
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31721	Aggregate #1:	Clean Crusher Fines	20.0	19.80
31720	Aggregate #2:	Crusher Fines	11.0	10.89
31719	Aggregate #3:	3/8" Aggregate	21.0	20.79
31718	Aggregate #4:	1/2" Aggregate	48.0	47.52
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31721	31720	31719	31718			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
20.0	11.0	21.0	48.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	100	96			100	1/2" / 12.5	98	(80-100)	98	
100	100	91	50			100	3/8" / 9.5	74	(65-80)	74	
100	100	35	5			100	1/4" / 6.3	41		41	
95	95	7	2			100	#4 / 4.75	32	(28-42)	33	
63	62	2	2			100	#8 / 2.36	21	(14-22)	22	
55	55	2	2			100	#10 / 2.00	18		19	
39	42	2	1			100	#16 / 1.18	13		14	
26	30	2	1			100	#30 / .600	9		10	
21	26	2	1			100	#40 / .425	8		9	
15	21	1	1			100	#50 / .300	6		7	
7	14	1	1			100	#100 / .150	4		5	
3.5	9.2	0.7	0.3			100.0	#200 / .075	2.0	(0-2.5)	3.0	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1062.0
	Flask 2	1061.2
	Flask 3	1062.4
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3853.4
	Flask 2	3869.2
	Flask 3	3818.3
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1062.0
	Flask 2	1061.2
	Flask 3	1062.4
Loss of binder from mixing:		5.9
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3853.4
	Flask 2	3869.2
	Flask 3	3818.3
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1063.2
	Flask 2	1062.1
	Flask 3	1063.5
Volume of Voidless Mix ("Vvm"):	Flask 1	441.2
	Flask 2	439.9
	Flask 3	437.0
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.407
	Flask 2	2.412
	Flask 3	2.431
Average Maximum Sp. Gravity ("Gmm"):		**2.417**
Average Maximum Density (PCF):		150.6
"Gmm" Range:		0.024

Weights in grams. 0.0 = item was tared

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.636
Asphalt Absorbed (%):	0.31

MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B1C3	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Paramount / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1074.5
	Flask 2	1074.1
	Flask 3	1073.0
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3855.2
	Flask 2	3871.3
	Flask 3	3815.1
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1074.5
	Flask 2	1074.1
	Flask 3	1073.0
Loss of binder from mixing:		4.2
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3855.2
	Flask 2	3871.3
	Flask 3	3815.1
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1075.7
	Flask 2	1075.0
	Flask 3	1074.1
Volume of Voidless Mix ("Vvm"):	Flask 1	451.9
	Flask 2	450.7
	Flask 3	450.8
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.378
	Flask 2	2.383
	Flask 3	2.380
Average Maximum Sp. Gravity ("Gmm"):		**2.380**
Average Maximum Density (PCF):		148.3
"Gmm" Range:		0.005

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.631
Asphalt Absorbed (%):	0.24

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

MACTEC

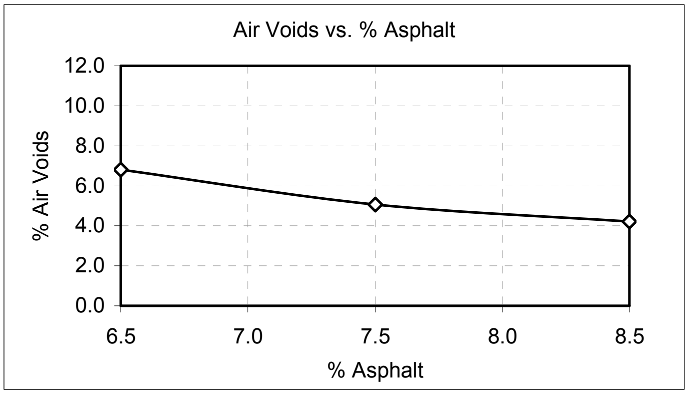
Volumetric Calculations

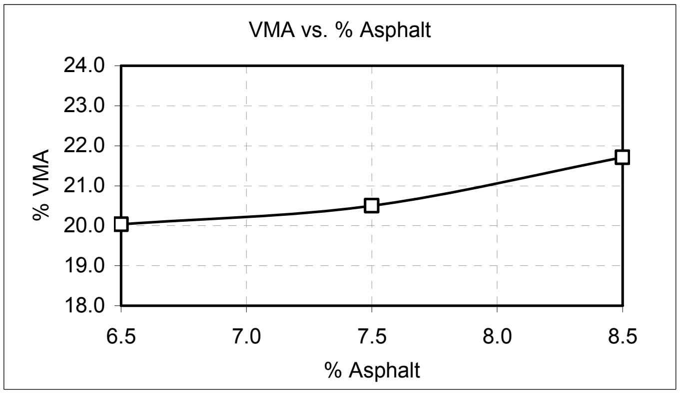
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

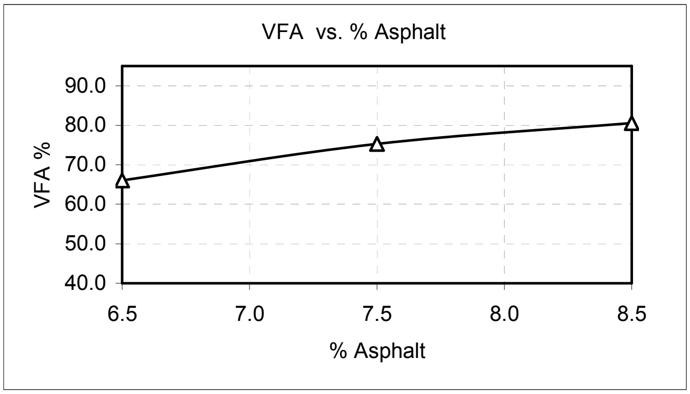
Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

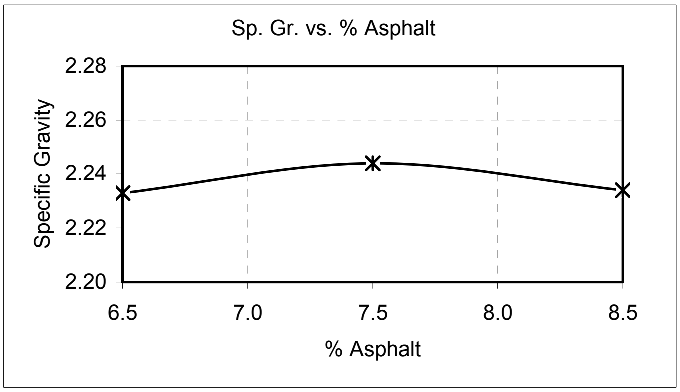
Volumetric Calculations Compaction Method: Marshall Calculation Method: ARIZ 815

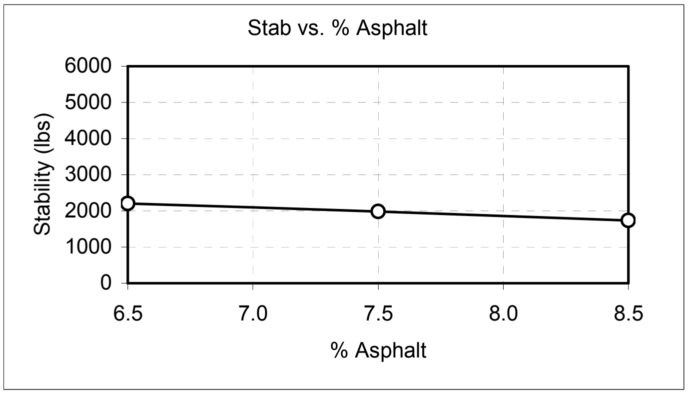
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.233	92.574	1.0	0.926	79.029	0.940	6.217	0.48	13.220	2204	17	20.03	66.00	6.8	2.396
7.5	2.244	91.584	1.0	0.916	78.569	0.934	7.220	0.41	15.429	1979	17	20.50	75.28	5.1	2.364
8.5	2.234	90.594	1.0	0.906	77.374	0.920	8.223	0.36	17.495	1734	19	21.71	80.60	4.2	2.332
7.3	**2.242**	**91.782**	**1.0**	**0.918**	**78.669**	**0.935**	**7.019**	**0.42**	**14.987**	**2024**	**17**	**20.40**	**73.48**	**5.4**	**2.370**
												Min 19		(4.5-6.5)	

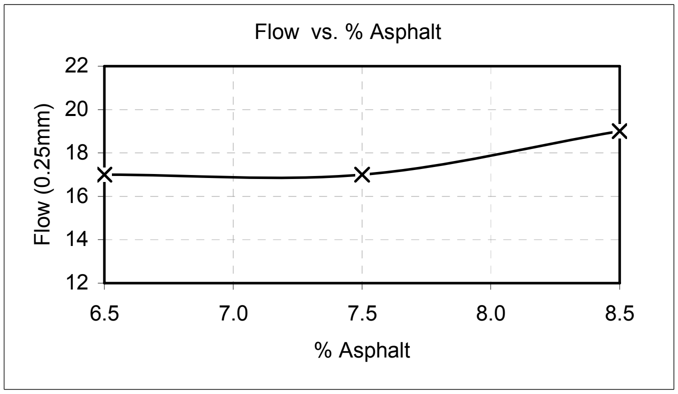












Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B1C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:
Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Paramount / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1089.0	600.8	1085.0	2.222	138.4	2.425	2250	1.05	2363	10.5	16
	2	1084.8	604.6	1080.6	2.250	140.2	2.423	2100	1.05	2205	9.8	16
	3	1085.3	601.6	1077.8	2.228	138.8	2.490	2025	1.01	2045	9.1	18
				Average:	2.233	139.1			Average:	2204	9.8	17
				Range:	0.028	1.8						
7.5	4	1086.5	598.8	1093.5	2.242	139.7	2.437	2025	1.04	2106	9.4	17
	5	1093.9	608.5	1092.3	2.250	140.2	2.440	1950	1.04	2028	9.0	16
	6	1092.8	605.4	1091.8	2.240	139.6	2.455	1750	1.03	1803	8.0	18
				Average:	2.244	139.8			Average:	1979	8.8	17
				Range:	0.010	0.6						
8.5	7	1090.1	603.2	1087.6	2.234	139.2	2.459	1700	1.03	1751	7.8	18
	8	1098.6	608.1	1096.8	2.236	139.3	2.460	1650	1.03	1700	7.6	19
	9	1105.2	611.1	1102.6	2.232	139.1	2.452	1700	1.03	1751	7.8	20
				Average:	2.234	139.2			Average:	1734	7.7	19
				Range:	0.004	0.2						

Salt River B1C3
Figure 11

MACTEC

ARAC Design Summary

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B2C1	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-28 / Type II
Project Loc.:		Type of Admix.:	Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31721	19.80
Crusher Fines	31720	10.89
3/8" Aggregate	31719	20.79
1/2" Aggregate	31718	47.52
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	98	(80-100)	98
3/8" / 9.5	74	(65-80)	74
1/4" / 6.3	41		41
#4 / 4.75	32	(28-42)	33
#8 / 2.36	21	(14-22)	22
#10 / 2.00	18		19
#16 / 1.18	13		14
#30 / .600	9		10
#40 / .425	8		9
#50 / .300	6		7
#100 / .150	4		5
#200 / .075	2.0	(0-2.5)	3.0

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Recommended % Asphalt: 7.1 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	7.1		
Bulk Specific Gravity :	2.242		
Bulk Specific Density (kg/m3):	2237		
Bulk Specific Density (PCF):	139.7		
Theor. Max. Sp. Gr. (Gmm):	2.375		
Stability (lbs):	2229		
Flow (0.25 mm):	16		
Percent Air Voids:	5.6	(4.5-6.5)	
Percent VMA:	20.22	Min 19	
Percent Voids Filled:	72.3		
Percent Effective Asphalt:	6.849		
Dust to Eff. Asphalt Ratio:	0.43		
Effective Sp. Gr.(w/ Admix):	2.628		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.610	2.628	2.616	2.35-2.85
"SSD" Sp. Gravity:	2.637	2.648	2.640	
Apparent Sp. Gravity:	2.682	2.682	2.682	
Water Absorption(%):	1.02	0.77	0.95	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			68	Min 55
Fractured Face 2 Face (%):			88	Min 85
Fractured Face 1 Face (%):			94	
Asphalt Absorbed into Dry Aggregate (%):			0.27	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			4	Max 9
L.A. Abrasion @ 500 Rev.(%):			19	Max 40

Remarks:

Salt River B2C1
Figure 12

MACTEC

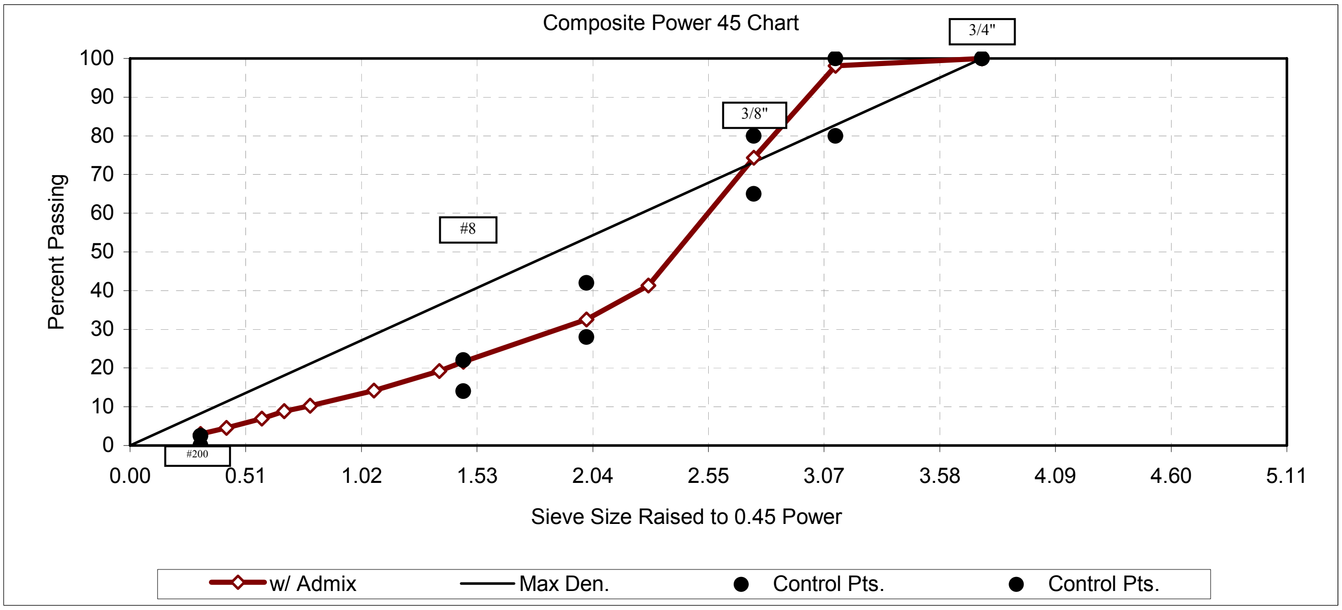
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31721	Aggregate #1:	Clean Crusher Fines	20.0	19.80
31720	Aggregate #2:	Crusher Fines	11.0	10.89
31719	Aggregate #3:	3/8" Aggregate	21.0	20.79
31718	Aggregate #4:	1/2" Aggregate	48.0	47.52
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31721	31720	31719	31718			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
20.0	11.0	21.0	48.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	100	96			100	1/2" / 12.5	98	(80-100)	98	
100	100	91	50			100	3/8" / 9.5	74	(65-80)	74	
100	100	35	5			100	1/4" / 6.3	41		41	
95	95	7	2			100	#4 / 4.75	32	(28-42)	33	
63	62	2	2			100	#8 / 2.36	21	(14-22)	22	
55	55	2	2			100	#10 / 2.00	18		19	
39	42	2	1			100	#16 / 1.18	13		14	
26	30	2	1			100	#30 / .600	9		10	
21	26	2	1			100	#40 / .425	8		9	
15	21	1	1			100	#50 / .300	6		7	
7	14	1	1			100	#100 / .150	4		5	
3.5	9.2	0.7	0.3			100.0	#200 / .075	2.0	(0-2.5)	3.0	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1063.9
	Flask 2	1063.3
	Flask 3	1060.7
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3855.9
	Flask 2	3870.3
	Flask 3	3815.1
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1063.9
	Flask 2	1063.3
	Flask 3	1060.7
Loss of binder from mixing:		3.6
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3855.9
	Flask 2	3870.3
	Flask 3	3815.1
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1064.9
	Flask 2	1064.4
	Flask 3	1061.8
Volume of Voidless Mix ("Vvm"):	Flask 1	440.4
	Flask 2	441.1
	Flask 3	438.5
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.416
	Flask 2	2.411
	Flask 3	2.419
Average Maximum Sp. Gravity ("Gmm"):		**2.415**
Average Maximum Density (PCF):		150.5
"Gmm" Range:		0.008

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.634
Asphalt Absorbed (%):	0.27

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
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Weight in Water(g):	1870.2
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Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
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Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B2C1	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-28 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1074.0
	Flask 2	1073.9
	Flask 3	1073.3
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3856.1
	Flask 2	3871.3
	Flask 3	3817.1
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1074.0
	Flask 2	1073.9
	Flask 3	1073.3
Loss of binder from mixing:		4.6
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3856.1
	Flask 2	3871.3
	Flask 3	3817.1
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1075.1
	Flask 2	1075.0
	Flask 3	1074.5
Volume of Voidless Mix ("Vvm"):	Flask 1	450.4
	Flask 2	450.7
	Flask 3	449.2
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.385
	Flask 2	2.383
	Flask 3	2.389
Average Maximum Sp. Gravity ("Gmm"):		**2.386**
Average Maximum Density (PCF):		148.6
"Gmm" Range:		0.006

Weights in grams. 0.0 = item was tared

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.638
Asphalt Absorbed (%):	0.34

MACTEC

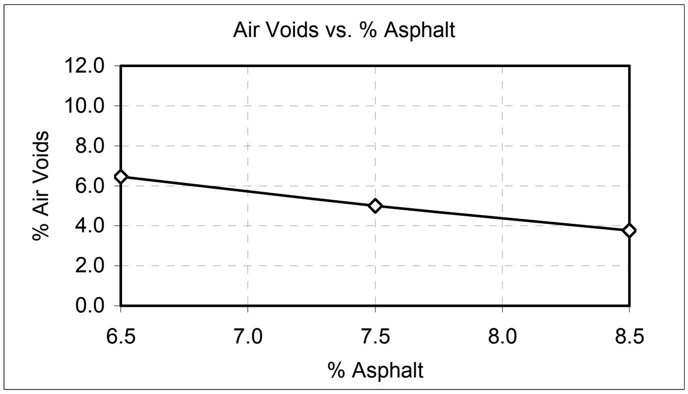
Volumetric Calculations

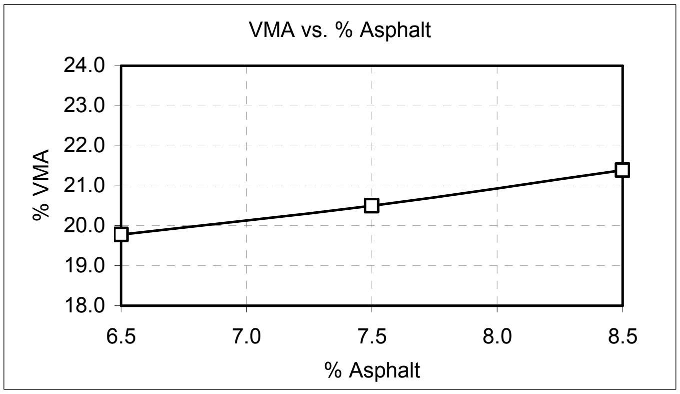
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

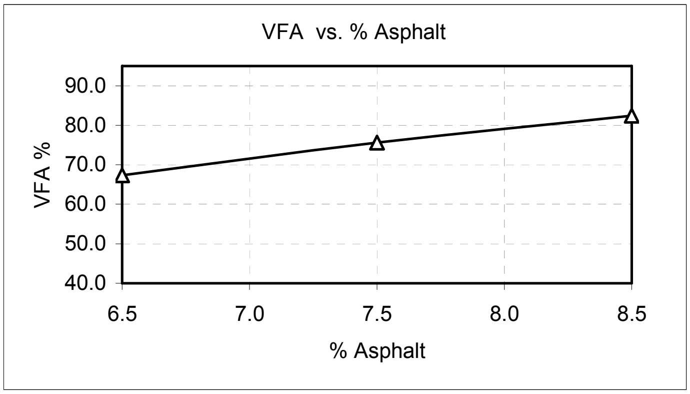
Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

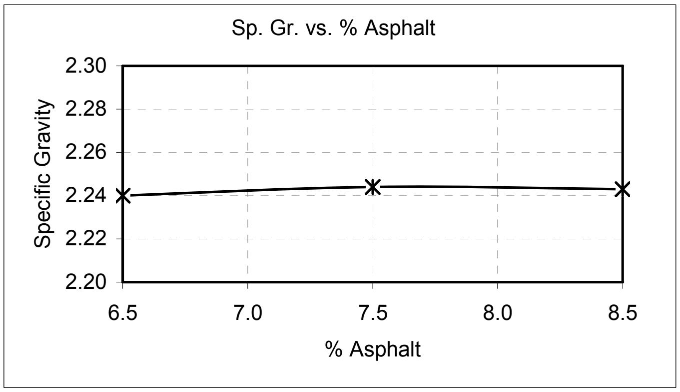
Volumetric Calculations Compaction Method: Marshall Calculation Method: ARIZ 815

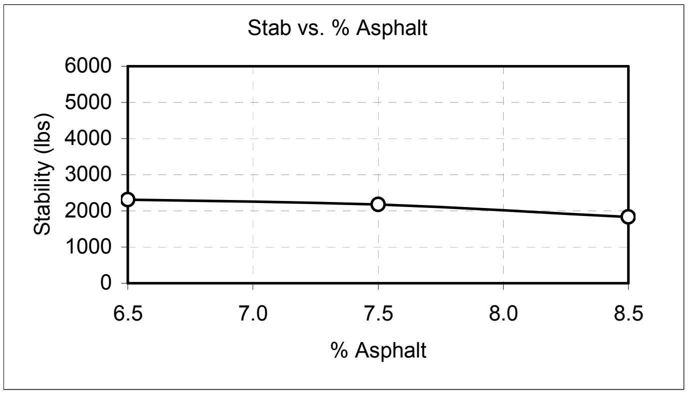
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.240	92.574	1.0	0.926	79.277	0.943	6.247	0.48	13.328	2312	15	19.78	67.38	6.5	2.395
7.5	2.244	91.584	1.0	0.916	78.569	0.934	7.250	0.41	15.494	2174	17	20.50	75.59	5.0	2.362
8.5	2.243	90.594	1.0	0.906	77.685	0.924	8.253	0.36	17.629	1835	20	21.39	82.41	3.8	2.331
7.1	**2.242**	**91.980**	**1.0**	**0.920**	**78.839**	**0.937**	**6.849**	**0.43**	**14.624**	**2229**	**16**	**20.22**	**72.31**	**5.6**	**2.375**
												Min 19		(4.5-6.5)	

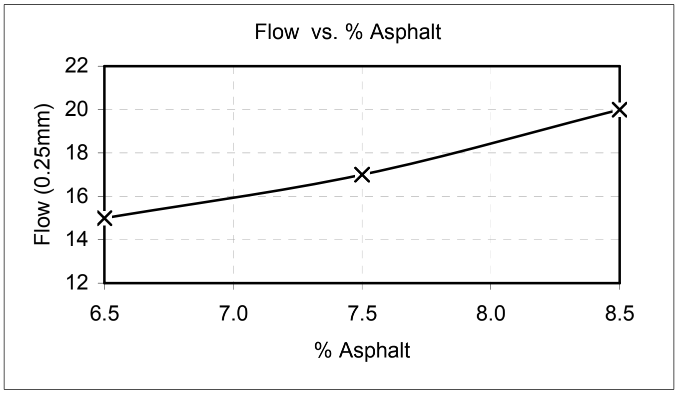












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C1
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Number of Blows: 75				Compaction / Mixing Temp: 325/325 F					Test Method: ARIZ 815			
% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1093.1	604.9	1087.0	2.227	138.7	2.490	2100	1.01	2121	9.4	14
	2	1085.5	606.1	1082.2	2.257	140.6	2.435	2400	1.04	2496	11.1	15
	3	1091.4	606.9	1082.8	2.235	139.2	2.454	2250	1.03	2318	10.3	16
				Average:	2.240	139.5			Average:	2312	10.3	15
				Range:	0.030	1.9						
7.5	4	1098.7	611.5	1095.9	2.249	140.1	2.461	2050	1.03	2112	9.4	15
	5	1100.3	610.0	1095.9	2.235	139.2	2.492	2225	1.01	2247	10.0	17
	6	1092.3	607.6	1089.1	2.247	140.0	2.450	2100	1.03	2163	9.6	18
				Average:	2.244	139.8			Average:	2174	9.7	17
				Range:	0.014	0.9						
8.5	7	1097.9	606.2	1096.1	2.229	138.9	2.480	1650	1.01	1667	7.4	21
	8	1104.0	612.5	1102.3	2.243	139.7	2.483	1975	1.01	1995	8.9	19
	9	1107.6	617.9	1105.7	2.258	140.7	2.480	1825	1.01	1843	8.2	19
				Average:	2.243	139.8			Average:	1835	8.2	20
				Range:	0.029	1.8						

Salt River B2C1
Figure 12

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ARAC Design Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation		
Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31721	19.80
Crusher Fines	31720	10.89
3/8" Aggregate	31719	20.79
1/2" Aggregate	31718	47.52
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	98	(80-100)	98
3/8" / 9.5	74	(65-80)	74
1/4" / 6.3	41		41
#4 / 4.75	32	(28-42)	33
#8 / 2.36	21	(14-22)	22
#10 / 2.00	18		19
#16 / 1.18	13		14
#30 / .600	9		10
#40 / .425	8		9
#50 / .300	6		7
#100 / .150	4		5
#200 / .075	2.0	(0-2.5)	3.0

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Recommended % Asphalt: 7.1 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt			
Property	Value	Spec.	
Percent of Asphalt:	7.1		
Bulk Specific Gravity :	2.244		
Bulk Specific Density (kg/m3):	2239		
Bulk Specific Density (PCF):	139.8		
Theor. Max. Sp. Gr. (Gmm):	2.374		
Stability (lbs):	2014		
Flow (0.25 mm):	16		
Percent Air Voids:	5.5	(4.5-6.5)	
Percent VMA:	20.15	Min 19	
Percent Voids Filled:	72.9		
Percent Effective Asphalt:	6.876		
Dust to Eff. Asphalt Ratio:	0.43		
Effective Sp. Gr.(w/ Admix):	2.627		

Aggregate / Admix Properties				
Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.610	2.628	2.616	2.35-2.85
"SSD" Sp. Gravity:	2.637	2.648	2.640	
Apparent Sp. Gravity:	2.682	2.682	2.682	
Water Absorption(%):	1.02	0.77	0.95	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			68	Min 55
Fractured Face 2 Face (%):			88	Min 85
Fractured Face 1 Face (%):			94	
Asphalt Absorbed into Dry Aggregate (%):			0.24	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			4	Max 9
L.A. Abrasion @ 500 Rev.(%):			19	Max 40

Remarks:

ADOT submitted the CRA blend material to MACTEC.

Salt River B2C2
Figure 13

MACTEC

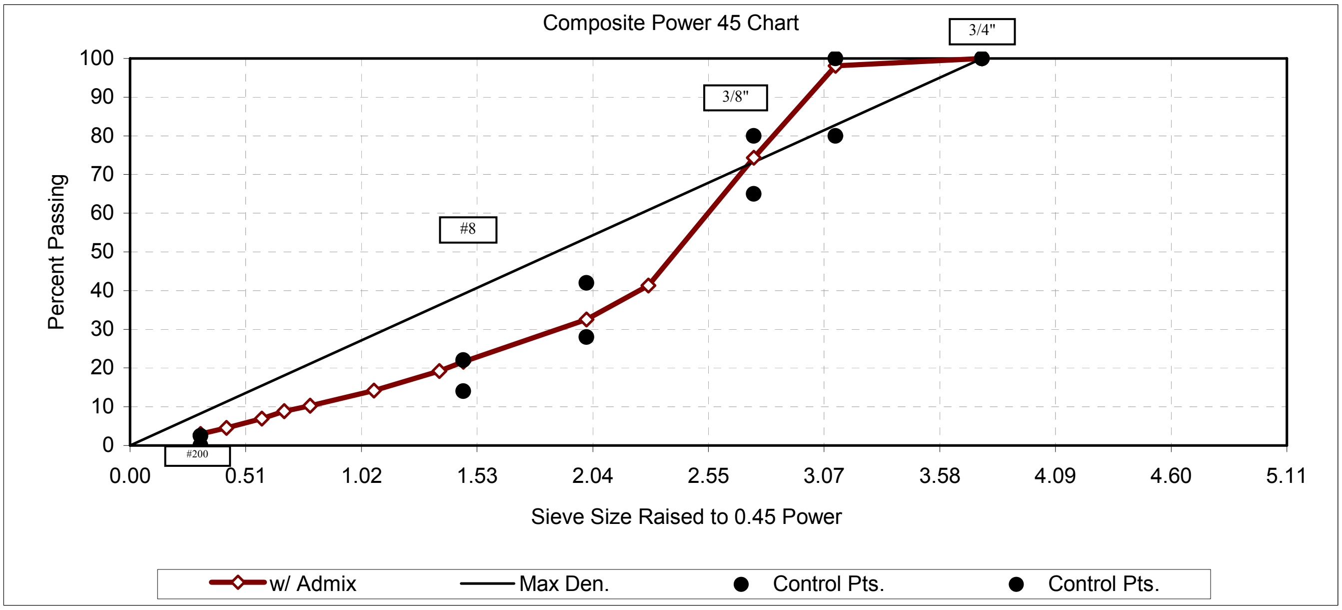
Aggregate Composite

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31721	Aggregate #1:	Clean Crusher Fines	20.0	19.80
31720	Aggregate #2:	Crusher Fines	11.0	10.89
31719	Aggregate #3:	3/8" Aggregate	21.0	20.79
31718	Aggregate #4:	1/2" Aggregate	48.0	47.52
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31721	31720	31719	31718			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
20.0	11.0	21.0	48.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	100	96			100	1/2" / 12.5	98	(80-100)	98	
100	100	91	50			100	3/8" / 9.5	74	(65-80)	74	
100	100	35	5			100	1/4" / 6.3	41		41	
95	95	7	2			100	#4 / 4.75	32	(28-42)	33	
63	62	2	2			100	#8 / 2.36	21	(14-22)	22	
55	55	2	2			100	#10 / 2.00	18		19	
39	42	2	1			100	#16 / 1.18	13		14	
26	30	2	1			100	#30 / .600	9		10	
21	26	2	1			100	#40 / .425	8		9	
15	21	1	1			100	#50 / .300	6		7	
7	14	1	1			100	#100 / .150	4		5	
3.5	9.2	0.7	0.3			100.0	#200 / .075	2.0	(0-2.5)	3.0	



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Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B2C2	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-28 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1063.0
	Flask 2	1062.4
	Flask 3	1062.4
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3856.0
	Flask 2	3869.3
	Flask 3	3816.0
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1063.0
	Flask 2	1062.4
	Flask 3	1062.4
Loss of binder from mixing:		3.7
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3856.0
	Flask 2	3869.3
	Flask 3	3816.0
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1064.1
	Flask 2	1063.5
	Flask 3	1063.1
Volume of Voidless Mix ("Vvm"):	Flask 1	439.5
	Flask 2	441.2
	Flask 3	440.1
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.419
	Flask 2	2.408
	Flask 3	2.414
Average Maximum Sp. Gravity ("Gmm"):		**2.414**
Average Maximum Density (PCF):		150.4
"Gmm" Range:		0.011

Weights in grams. 0.0 = item was tared

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.632
Asphalt Absorbed (%):	0.24

MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1071.1
	Flask 2	1073.5
	Flask 3	1076.7
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3853.8
	Flask 2	3869.6
	Flask 3	3816.6
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1071.1
	Flask 2	1073.5
	Flask 3	1076.7
Loss of binder from mixing:		4.5
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3193.0
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3853.8
	Flask 2	3869.6
	Flask 3	3816.6
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1072.3
	Flask 2	1074.1
	Flask 3	1077.5
Volume of Voidless Mix ("Vvm"):	Flask 1	449.9
	Flask 2	451.5
	Flask 3	453.9
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.381
	Flask 2	2.378
	Flask 3	2.372
Average Maximum Sp. Gravity ("Gmm"):		**2.377**
Average Maximum Density (PCF):		148.1
"Gmm" Range:		0.009

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.627
Asphalt Absorbed (%):	0.17

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

MACTEC

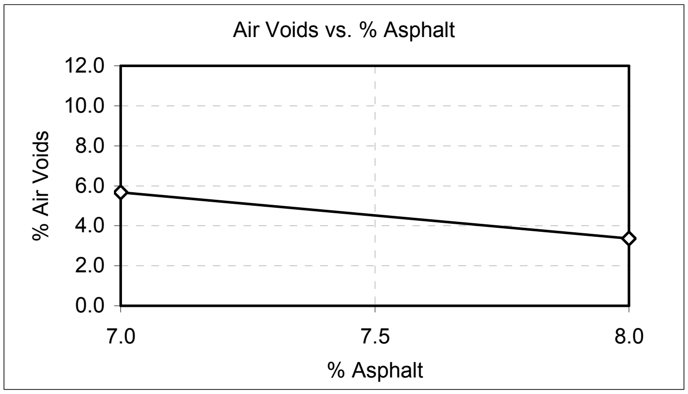
Volumetric Calculations

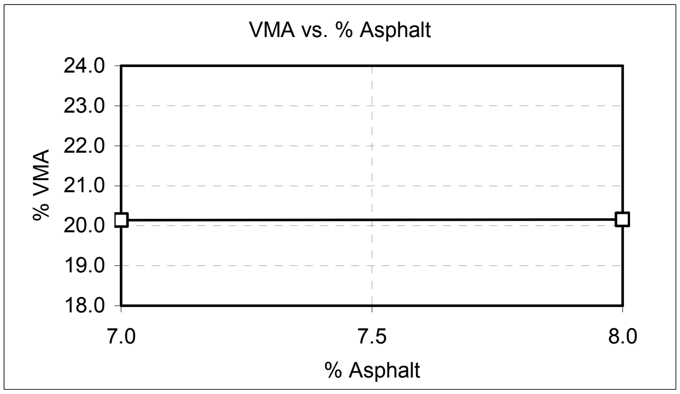
MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

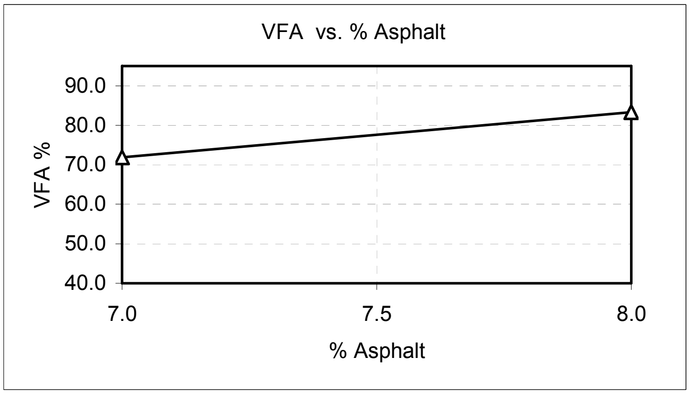
Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

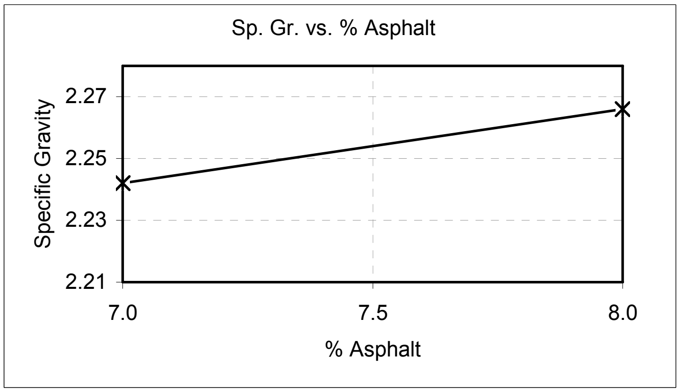
Volumetric Calculations Compaction Method: Marshall Calculation Method: ARIZ 815

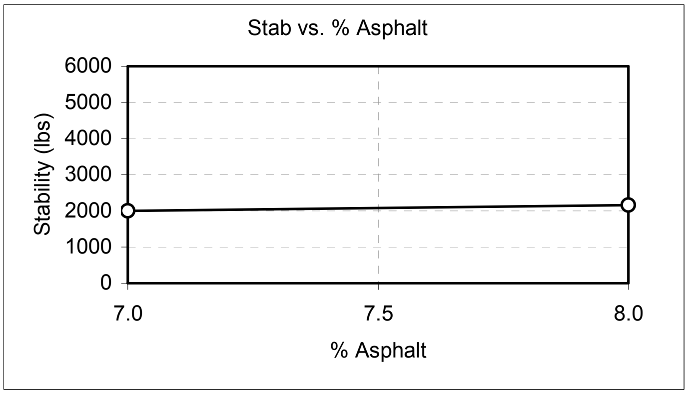
% Asph.	Sp. Gr.	% Aggr.	% Admix	Total	Agg. Vol.	Admix Vol	Eff % Asph	Dust to	Eff Asph	Stability	Flow	VMA	VFA	Eff. Voids	
Tot Wt.	Gmb	Pma	(%)	% Admix	Vol. (%)	Vol. (%)	(Tot Wt.)	Eff. Asph	Vol. (%)	(lbs)	(0.25mm)	(%)	(%)	(%)	Gmm
7.0	2.242	92.079	1.0	0.921	78.924	0.938	6.776	0.44	14.468	1998	16	20.14	71.84	5.7	2.377
8.0	2.266	91.089	1.0	0.911	78.911	0.938	7.778	0.38	16.786	2155	18	20.15	83.30	3.4	2.345
7.1	**2.244**	**91.980**	**1.0**	**0.920**	**78.909**	**0.938**	**6.876**	**0.43**	**14.695**	**2014**	**16**	**20.15**	**72.92**	**5.5**	**2.374**
												Min 19		(4.5-6.5)	

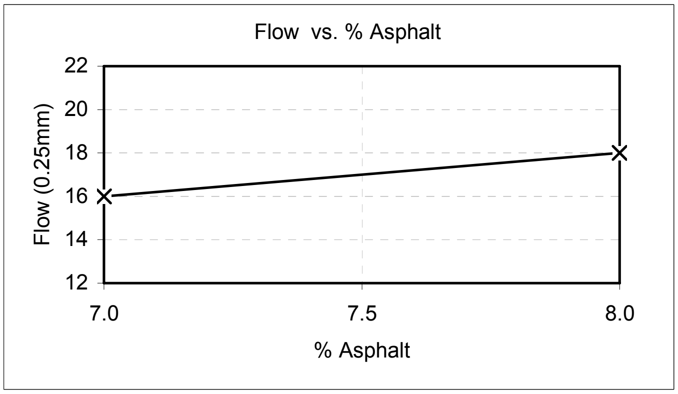












Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C2
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
7.0	1	1093.7	605.2	1089.8	2.231	139.0	2.456	1950	1.03	2009	8.9	16
	2	1097.0	611.5	1090.7	2.247	140.0	2.458	1900	1.03	1957	8.7	17
	3	1093.4	609.2	1089.1	2.249	140.1	2.439	1950	1.04	2028	9.0	16
				Average:	2.242	139.7			Average:	1998	8.9	16
				Range:	0.018	1.1						
8.0	4	1104.5	616.6	1102.1	2.259	140.7	2.442	1975	1.04	2054	9.1	18
	5	1102.6	616.8	1100.2	2.265	141.1	2.440	2050	1.04	2132	9.5	19
	6	1098.6	616.0	1097.1	2.273	141.6	2.413	2150	1.06	2279	10.1	17
				Average:	2.266	141.1			Average:	2155	9.6	18
				Range:	0.014	0.9						
	7											
	8											
	9											
				Average:					Average:			
				Range:								

Salt River B2C2
Figure 13

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ARAC Design Summary

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	31721	19.80
Crusher Fines	31720	10.89
3/8" Aggregate	31719	20.79
1/2" Aggregate	31718	47.52
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	98	(80-100)	98
3/8" / 9.5	74	(65-80)	74
1/4" / 6.3	41		41
#4 / 4.75	32	(28-42)	33
#8 / 2.36	21	(14-22)	22
#10 / 2.00	18		19
#16 / 1.18	13		14
#30 / .600	9		10
#40 / .425	8		9
#50 / .300	6		7
#100 / .150	4		5
#200 / .075	2.0	(0-2.5)	3.0

Recommended % Asphalt: 6.8 ***

ARAC Supplier:
ADOT Lab No.:
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 325 F
Compaction Temperature: 325 F

Design Data at Recommended % Asphalt

Property	Value	Spec.	
Percent of Asphalt:	6.8		
Bulk Specific Gravity :	2.257		
Bulk Specific Density (kg/m3):	2252		
Bulk Specific Density (PCF):	140.6		
Theor. Max. Sp. Gr. (Gmm):	2.385		
Stability (lbs):	2537		
Flow (0.25 mm):	16		
Percent Air Voids:	5.4	(4.5-6.5)	
Percent VMA:	19.43	Min 19	
Percent Voids Filled:	72.4		
Percent Effective Asphalt:	6.545		
Dust to Eff. Asphalt Ratio:	0.45		
Effective Sp. Gr.(w/ Admix):	2.629		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.610	2.628	2.616	2.35-2.85
"SSD" Sp. Gravity:	2.637	2.648	2.640	
Apparent Sp. Gravity:	2.682	2.682	2.682	
Water Absorption(%):	1.02	0.77	0.95	0-2.5
Admixture Sp. Gravity:	2.200	Asphalt Sp. Gravity:		1.050
Sand Equivalent value:			68	Min 55
Fractured Face 2 Face (%):			88	Min 85
Fractured Face 1 Face (%):			94	
Asphalt Absorbed into Dry Aggregate (%):			0.28	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			4	Max 9
L.A. Abrasion @ 500 Rev.(%):			19	Max 40

MACTEC Engineering and Consulting, Inc.

James Carusone
Assist. Vice President

Anne Stonex, PE
Sr. Engineer

Remarks:

Salt River B2C3
Figure 14

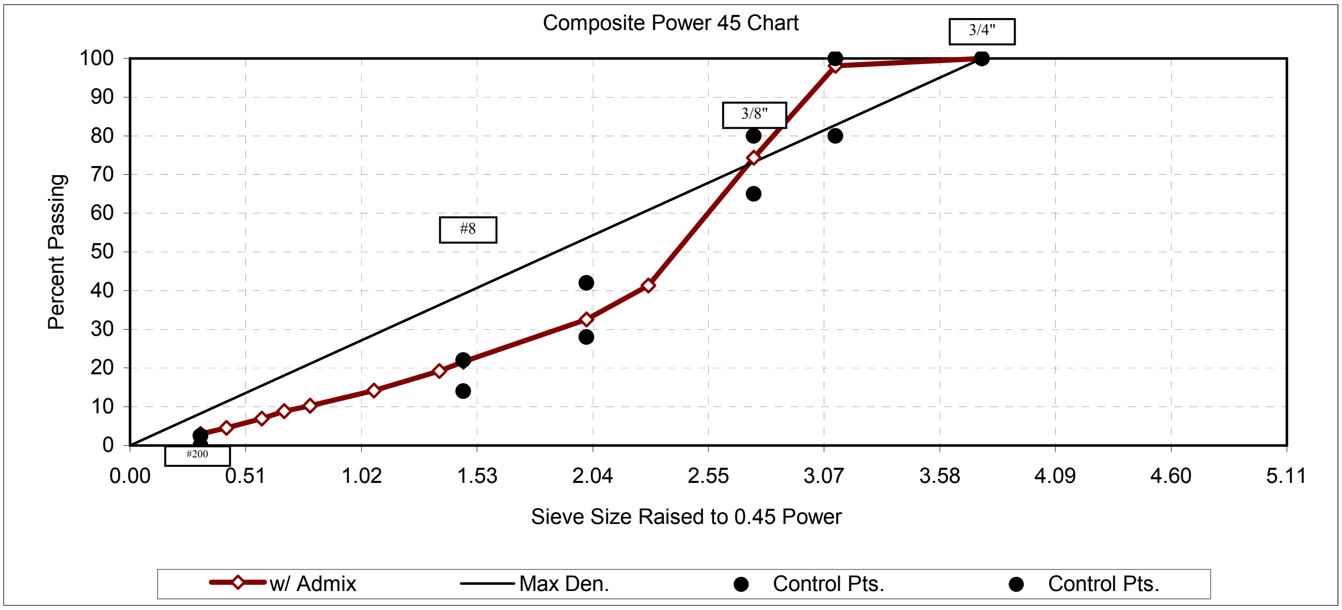
MACTEC

Aggregate Composite

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B2C3	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-28 / Type II
Project Loc.:		Type of Admix.:	Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
31721	Aggregate #1:	Clean Crusher Fines	20.0	19.80
31720	Aggregate #2:	Crusher Fines	11.0	10.89
31719	Aggregate #3:	3/8" Aggregate	21.0	20.79
31718	Aggregate #4:	1/2" Aggregate	48.0	47.52
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method: ADOT 201 & 815		Difference:	1.0	0.0

31721	31720	31719	31718			Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
20.0	11.0	21.0	48.0			1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3	Agg. #4			Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100	100			100	1.5" / 37.5	100		100	
100	100	100	100			100	1.25 / 31.5	100		100	
100	100	100	100			100	1" / 25	100		100	
100	100	100	100			100	3/4" / 19	100	(100)	100	
100	100	100	96			100	1/2" / 12.5	98	(80-100)	98	
100	100	91	50			100	3/8" / 9.5	74	(65-80)	74	
100	100	35	5			100	1/4" / 6.3	41		41	
95	95	7	2			100	#4 / 4.75	32	(28-42)	33	
63	62	2	2			100	#8 / 2.36	21	(14-22)	22	
55	55	2	2			100	#10 / 2.00	18		19	
39	42	2	1			100	#16 / 1.18	13		14	
26	30	2	1			100	#30 / .600	9		10	
21	26	2	1			100	#40 / .425	8		9	
15	21	1	1			100	#50 / .300	6		7	
7	14	1	1			100	#100 / .150	4		5	
3.5	9.2	0.7	0.3			100.0	#200 / .075	2.0	(0-2.5)	3.0	



MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1064.0
	Flask 2	1064.5
	Flask 3	1062.8
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3855.7
	Flask 2	3871.0
	Flask 3	3815.1
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1064.0
	Flask 2	1064.5
	Flask 3	1062.8
Loss of binder from mixing:		0.2
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3855.7
	Flask 2	3871.0
	Flask 3	3815.1
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1064.6
	Flask 2	1065.0
	Flask 3	1063.3
Volume of Voidless Mix ("Vvm"):	Flask 1	440.3
	Flask 2	441.0
	Flask 3	440.0
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.417
	Flask 2	2.414
	Flask 3	2.415
Average Maximum Sp. Gravity ("Gmm"):		**2.415**
Average Maximum Density (PCF):		150.5
"Gmm" Range:		0.003

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.634
Asphalt Absorbed (%):	0.28

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3008	Date:	August, 2003
MACTEC Lab No.:	Salt River B2C3	Mix Type:	ADOT 413
Project Name:	Gap Graded Study	Source of Aggregate:	Rinker Pit
Project No.:	ADOT SPR 524	Asphalt / Rubber Source:	Ergon / CRM
TRACS:		Asphalt Grade / Blend Type:	PG 58-28 / Type II
Project Loc.:		Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		7.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1075.2
	Flask 2	1075.4
	Flask 3	1073.6
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3856.5
	Flask 2	3871.3
	Flask 3	3815.2
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1075.2
	Flask 2	1075.4
	Flask 3	1073.6
Loss of binder from mixing:		1.6
Wt. of Flask ,and Water,(B):	Flask 1	3231.4
	Flask 2	3247.0
	Flask 3	3191.8
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3856.5
	Flask 2	3871.3
	Flask 3	3815.2
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1075.5
	Flask 2	1075.9
	Flask 3	1074.1
Volume of Voidless Mix ("Vvm"):	Flask 1	450.4
	Flask 2	451.6
	Flask 3	450.7
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.387
	Flask 2	2.381
	Flask 3	2.382
Average Maximum Sp. Gravity ("Gmm"):		**2.383**
Average Maximum Density (PCF):		148.5
"Gmm" Range:		0.006

Weights in grams. 0.0 = item was tared

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2982.1
"SSD" Weight(g):	3012.6
Weight in Water(g):	1870.2
Bulk (Dry) Sp. Gravity:	2.610
"SSD" Sp. Gravity:	2.637
Apparent Sp. Gravity:	2.682
Water Absorption(%):	1.02

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	496.2
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	663.9
Weight of Flask, Water & Sample(g):	975.1
Bulk (Dry) Sp. Gravity:	2.628
"SSD" Sp. Gravity:	2.648
Apparent Sp. Gravity:	2.682
Water Absorption(%):	0.77

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.616
Comp. "SSD"(W/O Admix):	2.640
Comp. Apparent(W/O Admix):	2.682
Comp Water Absorb. (%)	0.95
Comp. Bulk(Dry)(with Admix):	2.611
Comp. "SSD"(with Admix):	2.635
Comp. Apparent(with Admix):	2.676

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	68	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	88	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	94	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	4	Max 9
L.A. Abrasion @ 500 Rev.(%):	19	Max 40

Maximum Theoretical Gravity (Rice) Test Design Calculations

Asphalt Specific Gravity:	1.050
Effective Specific Gravity:	2.635
Asphalt Absorbed (%):	0.30

Volumetric Calculations

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

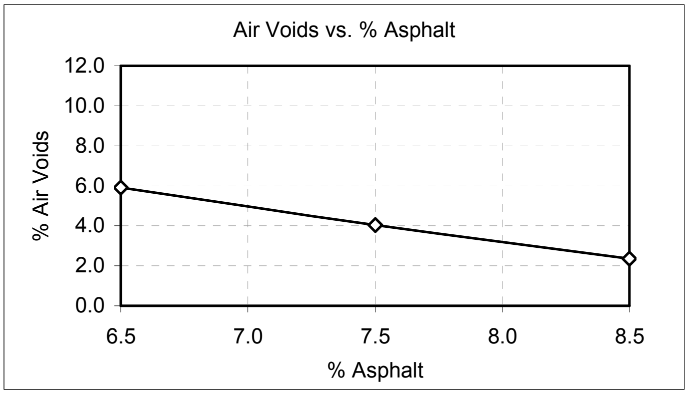
Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

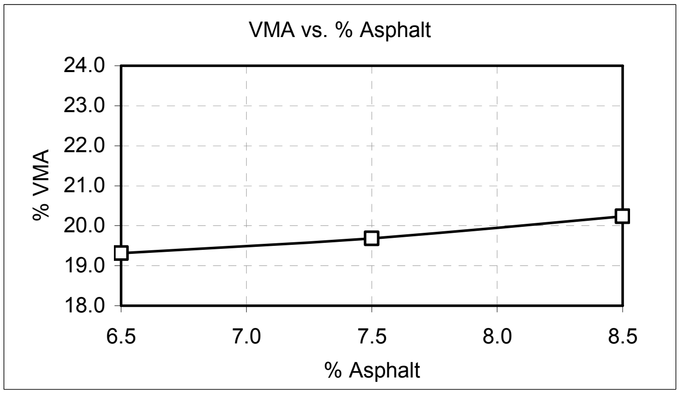
Volumetric Calculations

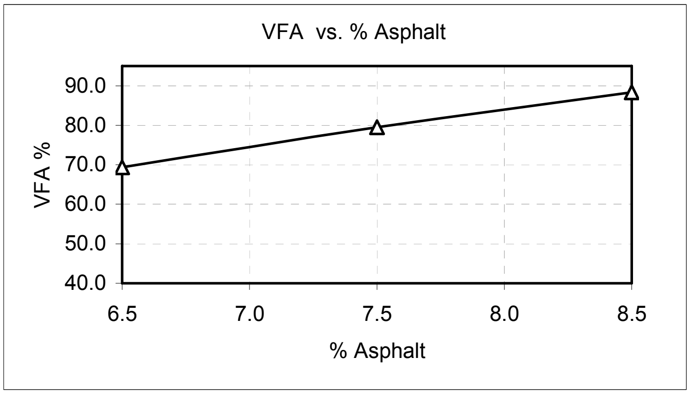
Compaction Method: Marshall

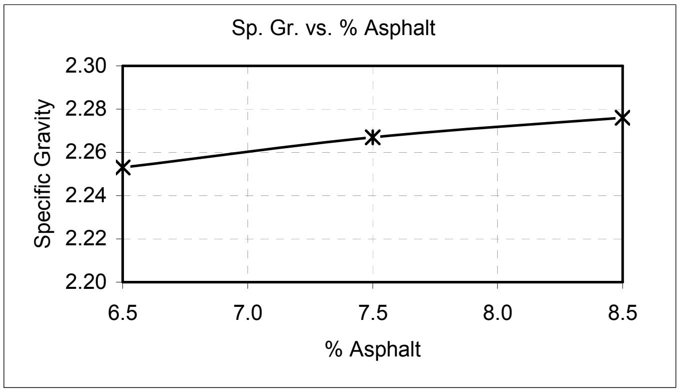
Calculation Method: ARIZ 815

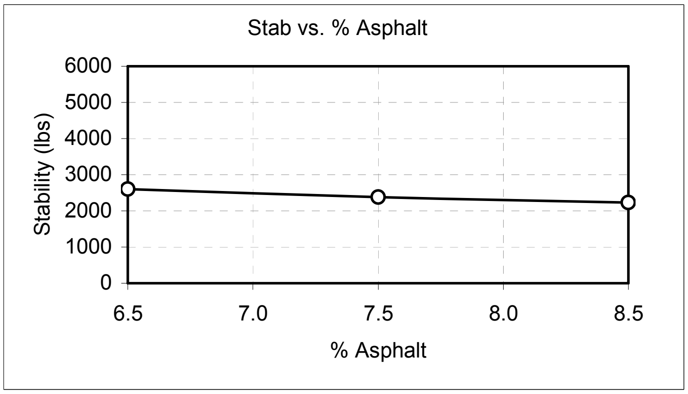
% Asph. Tot Wt.	Sp. Gr. Gmb	% Aggr. Pma	% Admix (%)	Total % Admix	Agg. Vol. Vol. (%)	Admix Vol Vol. (%)	Eff % Asph (Tot Wt.)	Dust to Eff. Asph	Eff Asph Vol. (%)	Stability (lbs)	Flow (0.25mm)	VMA (%)	VFA (%)	Eff. Voids (%)	Gmm
6.5	2.253	92.574	1.0	0.926	79.737	0.948	6.244	0.48	13.397	2605	16	19.31	69.36	5.9	2.395
7.5	2.267	91.584	1.0	0.916	79.375	0.944	7.247	0.41	15.646	2379	16	19.68	79.49	4.0	2.362
8.5	2.276	90.594	1.0	0.906	78.828	0.937	8.249	0.36	17.881	2226	17	20.23	88.37	2.4	2.331
6.8	**2.257**	**92.277**	**1.0**	**0.923**	**79.623**	**0.947**	**6.545**	**0.45**	**14.068**	**2537**	**16**	**19.43**	**72.40**	**5.4**	**2.385**
												Min 19		(4.5-6.5)	

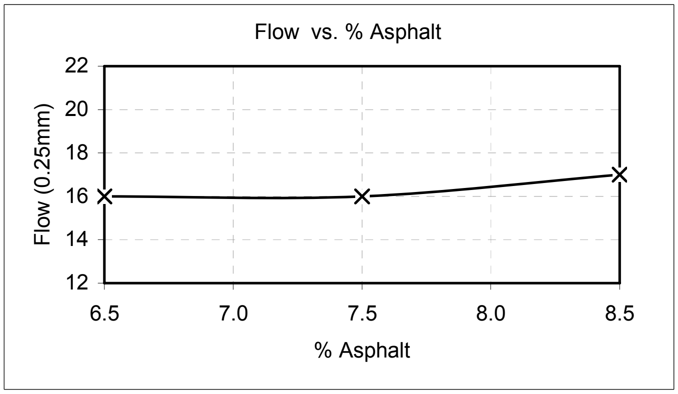












MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3008
MACTEC Lab No.: Salt River B2C3
Project Name: Gap Graded Study
Project No.: ADOT SPR 524
TRACS:
Project Loc.:

Date: August, 2003
Mix Type: ADOT 413
Source of Aggregate: Rinker Pit
Asphalt / Rubber Source: Ergon / CRM
Asphalt Grade / Blend Type: PG 58-28 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% Asphalt (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1088.7	606.6	1085.9	2.252	140.3	2.399	2500	1.07	2675	11.9	15
	2	1086.6	606.0	1083.6	2.255	140.5	2.395	2350	1.07	2515	11.2	15
	3	1094.0	610.3	1088.9	2.251	140.2	2.436	2525	1.04	2626	11.7	17
				Average:	2.253	140.3			Average:	2605	11.6	16
				Range:	0.004	0.3						
7.5	4	1095.0	614.2	1095.6	2.279	142.0	2.356	2300	1.11	2553	11.4	15
	5	1097.9	614.2	1094.2	2.262	140.9	2.387	2025	1.08	2187	9.7	16
	6	1094.3	612.0	1089.7	2.259	140.7	2.380	2200	1.09	2398	10.7	16
				Average:	2.267	141.2			Average:	2379	10.6	16
				Range:	0.020	1.3						
8.5	7	1101.5	618.4	1100.3	2.278	141.9	2.413	2200	1.06	2332	10.4	18
	8	1104.4	619.3	1103.3	2.274	141.7	2.420	2050	1.05	2153	9.6	17
	9	1104.2	619.7	1103.1	2.277	141.9	2.397	2050	1.07	2194	9.8	17
				Average:	2.276	141.8			Average:	2226	9.9	17
				Range:	0.004	0.2						

Salt River B2C3
Figure 14

APPENDIX C
INITIAL VERSION 1 MIX DESIGN DATA SUMMARIES

Compiled AR-AC Version 1 Mix Design Data
CKC Aggregate
Table 19

CKC Mixes	ARB	Effective Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Gradation A Mod													
	7.5		13.747		23.3		59.00		9.6		1682		19
Version 1	8.5		16.166		22.1		73.03		6.0		2064		21
NOTES													
Binder 1: Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC													
Binder 2: Ergon 58-28 with 22.7% fine CRM rubber by weight of AC													

Compiled AR-AC Version 1 Mix Design Data
Grey Mountain Aggregate
Table 20

Grey Mtn. Mixes	ARB	Effective Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Version 1	7.5		15.727		21.9		71.79		6.2		2142		19
	8.5		17.937		22.8		78.72		4.8		1908		21
with Mixed	6.5	13.384		22.0		60.82		8.6		1709		17	
Crusher Fines	7.5	15.633		22.6		69.26		6.9		1597		20	
NOTES													
Binder 1: Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC													
Binder 2: Ergon 58-28 with 22.7% fine CRM rubber by weight of AC													

Compiled MACTEC AR-AC Version 1 Mix Design Data
Round 1 Salt River Aggregate with Binders 1 and 2
Table 21

Salt River Mix	ARB	Effect. Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Version 1													
Mix Designs	6.5	12.999	13.368	20.73	19.69	62.71	67.89	7.7	6.3	1907	2160	19	15
V1-1	7.5	15.113	15.674	21.58	19.70	70.04	79.57	6.5	4.0	1600	2394	21	16
	8.5	17.313	---	22.04	---	78.55	---	4.7	---	1605	---	24	---
	7.0	13.790		21.10		65.30		7.3		1754		19	
	8.0	16.044		21.30		75.34		5.3		1482		20	
Repeat 1	6.5	12.805	13.229	20.48	19.08	62.52	69.33	7.7	5.9	1614	2643	18	15
V1-2	7.5	14.941	15.490	21.26	19.42	70.28	79.78	6.3	3.9	1504	2374	20	16
	8.5	17.028	17.639	22.29	20.39	76.41	86.50	5.3	2.8	1075	1926	23	17
Repeat 2	6.5	13.272	13.440	20.98	19.26	63.26	69.78	7.7	5.8	1581	2289	17	16
V1-3	7.5	15.418	15.688	21.61	19.63	71.33	79.93	6.2	3.9	1408	2035	18	17
	8.5	17.456	17.782	22.78	20.81	76.64	85.44	5.3	3.0	1400	2033	19	17
	NOTES												
	Binder 1 (**B1**): Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC												
	Binder 2 (**B2**): Ergon 58-28 with 22.7% fine CRM rubber by weight of AC												
	V1-1, V1-2, V1-3: Version 1 mix designations used in graph legends												

APPENDIX D
REBOUND AND RICE DATA

Rebound Experiment Using 2000 Gram Weight
First Round of Control and Version 1 Mix Designs
Table 22

Lab Number	Agg. Source/Binder	Binder Content	*Weight Used (g)	**Initial Reading (in.)	***Final Reading (in.)	Rebound (in.)	% Rebound
B1V1-1	Salt River / Binder 1	6.5	2000	0.0262	0.0262	0.0000	0.00
B1V1-1	Salt River / Binder 1	7.5	2000	0.2482	0.2448	-0.0034	-0.14
B1C1	Salt River / Binder 1	7.5	0	0.0454	0.0455	0.0001	0.00
B1V1-1	Salt River / Binder 1	8.5	2000	0.0428	0.0424	-0.0004	-0.02
	CKC / Binder 2	6.5	2000	0.0701	0.0697	-0.0004	-0.02
	CKC / Binder 2	7.5	2000	0.1610	0.1593	-0.0017	-0.07
	CKC / Binder 2	7.5	0	0.0640	0.0628	-0.0012	-0.05
	CKC / Binder 2	8.5	2000	0.1219	0.1185	-0.0034	-0.14
	Grey Mtn/ Binder 2	6.5	2000	0.0379	0.0375	-0.0004	-0.02
	Grey Mtn/ Binder 2	7.5	2000	0.1251	0.1168	-0.0083	-0.33
	Grey Mtn/ Binder 2	7.5	0	0.0527	0.0522	-0.0005	-0.02
	Grey Mtn/ Binder 2	8.5	2000	0.0460	0.0455	-0.0005	-0.02

Positive rebound values indicate rebound and negative values indicate that the surface is receding

* Weight = 0 for existing ADOT method (control mix designs) or 2000 +/- 10 grams for Version 1 method.

** Initial Reading taken immediately after paper discs removed

*** Final Reading taken when sample was cooled to room temperature

Binder 1 = Paramount 58-22 with 24.2% coarse CRM rubber by weight of asphalt
Binder 2 = Ergon 58-28 with 22.7% fine CRM rubber by weight of asphalt

Rebound Experiment Using 2000 Gram Weight
Repeats 1 2 of Control and Version 1 Mix Designs
Table 23

Lab Number	Agg. Source/Binder	Binder Content	*Weight Used (g)	**Initial Reading (in.)	***Final Reading (in.)	Rebound (in.)	% Rebound
B1V1-2	Salt River / Binder 1	6.5	2000	0.1800	0.1776	-0.0024	-0.10
B1V1-2	Salt River / Binder 1	7.5	2000	0.0603	0.0599	-0.0004	-0.02
B1V1-2	Salt River / Binder 1	8.5	2000	0.0812	0.0797	-0.0015	-0.06
B1V1-3	Salt River / Binder 1	6.5	2000	0.7750	0.7710	-0.0040	-0.16
B1V1-3	Salt River / Binder 1	7.5	2000	0.1502	0.1455	-0.0047	-0.19
B1V1-3	Salt River / Binder 1	8.5	2000	0.6430	0.6380	-0.0050	-0.20
					Average	-0.0030	-0.12
B1C2	Salt River / Binder 1	6.5	0	0.1043	0.0940	-0.0103	-0.41
B1C2	Salt River / Binder 1	7.5	0	0.1210	0.1140	-0.0070	-0.28
B1C2	Salt River / Binder 1	8.5	0	0.1200	0.1096	-0.0104	-0.42
B1C3	Salt River / Binder 1	6.5	0	0.0825	0.0786	-0.0039	-0.16
B1C3	Salt River / Binder 1	7.5	0	0.1164	0.1101	-0.0063	-0.25
B1C3	Salt River / Binder 1	8.5	0	0.1211	0.1149	-0.0062	-0.25
					Average	-0.0074	-0.29
B2V1-2	Salt River / Binder 2	6.5	2000	0.5600	0.5570	-0.0030	-0.12
B2V1-2	Salt River / Binder 2	7.5	2000	0.7010	0.6980	-0.0030	-0.12
B2V1-2	Salt River / Binder 2	8.5	2000	0.8230	0.8120	-0.0110	-0.44
B2V1-3	Salt River / Binder 2	6.5	2000	0.0847	0.0837	-0.0010	-0.04
B2V1-3	Salt River / Binder 2	7.5	2000	0.5560	0.5541	-0.0019	-0.08
B2V1-3	Salt River / Binder 2	8.5	2000	0.6690	0.6650	-0.0040	-0.16
					Average	-0.0040	-0.16
B2C2	Salt River / Binder 2	6.5	0	0.1817	0.1785	-0.0032	-0.13
B2C2	Salt River / Binder 2	7.5	0	0.3020	0.2940	-0.0080	-0.32
B2C2	Salt River / Binder 2	8.5	0	0.1908	0.1937	0.0029	0.12
B2C3	Salt River / Binder 2	6.5	0	0.2093	0.2028	-0.0065	-0.26
B2C3	Salt River / Binder 2	7.5	0	0.2680	0.2650	-0.0030	-0.12
B2C3	Salt River / Binder 2	8.5	0	0.1760	0.1751	-0.0009	-0.04
					Average	-0.0031	-0.12

Positive rebound values indicate rebound and negative values indicate that the surface is receding

* Weight = 0 for existing ADOT method (control mix designs) or 2000 +/- 10 grams for Version 1 method.

** Initial Reading taken immediately after paper discs removed

*** Final Reading taken when sample was cooled to room temperature

Binder 1 = Paramount 58-22 with 24.2% coarse CRM rubber by weight of asphalt
Binder 2 = Ergon 58-28 with 22.7% fine CRM rubber by weight of asphalt

Rebound Experiment Using 2000 Gram Weight
Soufflé Mix
Table 24

Specimen No.	Agg. Source/Binder	Binder Content	*Weight Used (g)	**Initial Reading (in.)	***Final Reading (in.)	Rebound (in.)	% Rebound
1		7.0	2000	0.907	0.904	-0.003	-0.12
2		7.0	2000	0.386	0.372	-0.014	-0.56
3		7.0	0	0.029	0.039	0.010	0.40
1		8.0	2000	0.685	0.681	-0.004	-0.16
2		8.0	2000	0.346	0.335	-0.011	-0.44
3		8.0	0	0.227	0.241	0.014	0.56

Positive rebound values indicate rebound and negative values indicate that the surface is receding

* Weight = 0 for existing ADOT method (control mix designs) or 2000 +/- 10 grams for Version 1 method.

** Initial Reading taken immediately after paper discs removed

*** Final Reading taken when sample was cooled to room temperature

This mix was selected for use in this study because it had rebounded noticeably during mix design testing.

Aggregate source: Black Angus Pit, Sierra Vista area
Asphalt grade and source: Koch PG 58-22 for ADOT Type 2 AR binder
Rubber source: RTG

Observations: Observers indicated that rebound was observed immediately after compaction stopped while the mold was being disassembled (removal of top collar, base plate, and end papers, followed by replacement of the base plate). to allow the specimen to air cool.

Statistical Analysis of MACTEC's Measured Rice Values (Gmm)
Salt River Aggregate at 6.0 and 7.0% AR Binder
Table 25

	Control Mixes				**Control Mixes**			
Round	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**
Binder	**1**	**1**	**2**	**2**	**1**	**1**	**2**	**2**
Binder Content,%	**6.0**	**7.0**	**6.0**	**7.0**	**6.0**	**7.0**	**6.0**	**7.0**
	2.414	2.380	2.414	2.377	2.412	2.377	2.412	2.380
Rice Values	2.412	2.382	2.415	2.386	2.414	2.378	2.413	2.385
	2.417	2.380	2.414	2.380	2.415	2.376	2.415	2.380
			2.415	2.383				
Average	2.414	2.381	2.415	2.382	2.414	2.377	2.413	2.382
Std Deviation	0.0025	0.0012	0.0006	0.0039	0.0015	0.0010	0.0015	0.0029
	Version 1 Mixes				**Version 1 Mixes**			
Round	1	1	1	1	2	2	2	2
Binder	1	1	2	2	1	1	2	2
Binder Content,%	6.0	7.0	6.0	7.0	6.0	7.0	6.0	7.0
	2.412	2.381		2.376	2.412	2.390	2.410	2.377
Rice Values	2.411	2.387	2.413	2.382	2.412	2.377	2.406	2.384
	2.403	2.373	2.407	2.376	2.413	2.389	2.418	2.384
Average	2.409	2.380	2.410	2.378	2.412	2.385	2.411	2.382
Std Deviation (1s)	0.0049	0.0070	0.0042	0.0035	0.0006	0.0072	0.0061	0.0040
Coeff of Variation (1s%)	0.2048	0.2951	0.1760	0.1457	0.0239	0.3033	0.2534	0.1697
d2s	0.0140	0.0199	0.0120	0.0098	0.0016	0.0205	0.0173	0.0114
d2s%	0.5796	0.8351	0.4982	0.4123	0.0677	0.8583	0.7171	0.4802
	6%		6%		7%		7%	
	Binder 1		Binder 2		Binder 1		Binder 2	
	2.414		2.414		2.380		2.377	
	2.412		2.415		2.382		2.386	
	2.417		2.414		2.380		2.380	
	2.412		2.412		2.377		2.380	
	2.414		2.413		2.378		2.385	
	2.415		2.415		2.376		2.380	
	2.412		2.410		2.381		2.376	
	2.411		2.413		2.387		2.382	
	2.403		2.407		2.373		2.376	
	2.412		2.410		2.390		2.377	
	2.412		2.406		2.377		2.384	
	2.413		2.418		2.389		2.384	
Average	2.412		2.412		2.381		2.381	
Std. Deviation	0.0034		0.0035		0.0053		0.0036	
Tcrit, n=12, @2.5%	2.412		2.412		2.412		2.412	
Lower Outlier Limit	2.404		2.404		2.368		2.372	
Upper Outlier Limit	2.420		2.421		2.394		2.389	
	Outlier		Dummy Value=Mean					

Single Factor ANOVA for MACTEC AR-AC Rice Data
Comparison of Results of Rounds 1 and 2
Table 26

Control Mixes: Rice @ 6.0% Binder 1

Round 1	Round 2
2.414	2.412
2.412	2.414
2.417	2.415

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.243	2.414333333	6.33333E-06
Round 2	3	7.241	2.413666667	2.33333E-06

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.66667E-07	1	6.66667E-07	0.153846152	0.714889	7.70865
Within Groups	1.73333E-05	4	4.33333E-06			
Total	1.8E-05	5				

Hypothesis Supported

Control Mixes: Rice @ 7.0% Binder 1

Round 1	Round 2
2.380	2.377
2.382	2.378
2.380	2.376

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.142	2.380666667	1.33333E-06
Round 2	3	7.131	2.377	1E-06

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.01667E-05	1	2.01667E-05	17.28571431	0.014173	7.70865
Within Groups	4.66667E-06	4	1.16667E-06			
Total	2.48333E-05	5				

Hypothesis Rejected at 95% level of confidence, but not at 99% level of confidence (see next ANOVA)

Anova: Single Factor Upper 1%
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.142	2.380666667	1.33333E-06
Round 2	3	7.131	2.377	1E-06

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.01667E-05	1	2.01667E-05	17.28571431	0.014173	21.19759
Within Groups	4.66667E-06	4	1.16667E-06			
Total	2.48333E-05	5				

Hypothesis Supported at 99% level of confidence

Single Factor ANOVA for MACTEC AR-AC Rice Data
Comparison of Results of Rounds 1 and 2
Table 26

Control Mixes Rice @ 6% Binder 2

Round 1	Round 2
2.414	2.412
2.415	2.413
2.414	2.415

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.243	2.414333333	3.33333E-07
Round 2	3	7.24	2.413333333	2.33333E-06

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.5E-06	1	1.5E-06	1.12499999	0.348641	7.70865
Within Groups	5.33333E-06	4	1.33333E-06			
Total	6.83333E-06	5				

Hypothesis Supported

Control Mixes Rice @ 7% Binder 2

Round 1	Round 2
2.377	2.380
2.386	2.385
2.380	2.380
2.383	

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	4	9.526	2.3815	1.5E-05
Round 2	3	7.145	2.381666667	8.33333E-06

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.7619E-08	1	4.7619E-08	0.003861004	0.952861	6.607877
Within Groups	6.16667E-05	5	1.23333E-05			
Total	6.17143E-05	6				

Hypothesis Supported

Single Factor ANOVA for MACTEC AR-AC Rice Data
Comparison of Results of Rounds 1 and 2
Table 26

Version 1 Mixes @ 6% Binder 1

	Round 1	Round 2
	2.412	2.412
	2.411	2.412
Outlier	2.403	2.413

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5% (outlier included)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.226	2.408666667	2.43333E-05
Round 2	3	7.237	2.412333333	3.33333E-07

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.01667E-05	1	2.01667E-05	1.635135135	0.270144	7.70865
Within Groups	4.93333E-05	4	1.23333E-05			
Total	6.95E-05	5				

Hypothesis Supported with outlier included

Version 1 Mixes @ 7% Binder 1

Round 1	Round 2
2.381	2.390
2.387	2.377
2.373	2.389

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.141	2.380333333	4.93333E-05
Round 2	3	7.156	2.385333333	5.23333E-05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.75E-05	1	3.75E-05	0.737704918	0.438821	7.70865
Within Groups	0.000203333	4	5.08333E-05			
Total	0.000240833	5				

Hypothesis Supported

Single Factor ANOVA for MACTEC AR-AC Rice Data
Comparison of Results of Rounds 1 and 2
Table 26

Version 1 Mixes @ 6% Binder 2

Round 1	Round 2
	2.410
2.413	2.406
2.407	2.418

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	2	4.82	2.41	1.8E-05
Round 2	3	7.234	2.411333333	3.73333E-05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.13333E-06	1	2.13333E-06	0.069064748	0.809718	10.12796
Within Groups	9.26667E-05	3	3.08889E-05			
Total	9.48E-05	4				

Hypothesis Supported

Version 1 Mixes @ 7% Binder 2

Round 1	Round 2
2.376	2.377
2.382	2.384
2.376	2.384

Hypothesis: Rice Results of Round 1 = Results of Round 2

Anova: Single Factor Upper 5%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Round 1	3	7.134	2.378	1.2E-05
Round 2	3	7.145	2.381666667	1.63333E-05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.01667E-05	1	2.01667E-05	1.423529412	0.298754	7.70865
Within Groups	5.66667E-05	4	1.41667E-05			
Total	7.68333E-05	5				

Hypothesis Supported

AR-AC Rice Data: Two-Way ANOVA for
Relative Effects of Binder and Design Method
Table 27

Rice Values Measured @ 6.0% ARB

		Binder 1	Binder 2
Controls		2.414	2.414
		2.412	2.415
		2.417	2.414
		2.412	2.412
		2.414	2.413
		2.415	2.415
Prop. Changes		2.412	2.410
		2.411	2.413
	*	2.403	2.407
		2.412	2.410
		2.412	2.406
		2.413	2.418

*Outlier

Used mean as dummy value to permit analysis - software cannot handle missing value

Hypothesis 1: Means of Rices made with 6% Binder 1 = means of Rices made with 6% Binder 2
Hypothesis 2: Means of Rices @ 6% for control mixes = Means of Rices @ 6% for proposed changes mixes

Anova: Two-Factor With Replication　　　　　Upper 5%

SUMMARY	Binder 1	Binder 2	Total
Controls			
Count	6	6	12
Sum	14.484	14.483	28.967
Average	2.414	2.413833333	2.413916667
Variance	3.6E-06	1.36667E-06	2.26515E-06
Prop. Changes			
Count	6	6	12
Sum	14.463	14.464	28.927
Average	2.4105	2.410666667	2.410583333
Variance	1.39E-05	1.90667E-05	1.49924E-05
Total			
Count	12	12	
Sum	28.947	28.947	
Average	2.41225	2.41225	
Variance	1.12955E-05	1.20227E-05	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	6.66667E-05	1	6.66667E-05	7.029877	0.01532	4.35125003
Columns	0	1	0	0	1	4.35125003
Interaction	1.66667E-07	1	1.66667E-07	0.017575	0.895859	4.35125003
Within	0.000189667	20	9.48333E-06			
Total	0.0002565	23				

Hypothesis 1 is supported
Hypothesis 2 is rejected at 95% level of confidence, but supported at 99% confidence level

AR-AC Rice Data: Two-Way ANOVA for Relative Effects of Binder and Design Method
Table 27

Hypothesis 2: Means of Rices @ 6% for control mixes = Means of Rices @ 6% for proposed changes mixes

Anova: Two-Factor With Replication Upper 1%

SUMMARY	Binder 1	Binder 2	Total
Controls			
Count	6	6	12
Sum	14.484	14.483	28.967
Average	2.414	2.413833333	2.413916667
Variance	3.6E-06	1.36667E-06	2.26515E-06
Prop. Changes			
Count	6	6	12
Sum	14.463	14.464	28.927
Average	2.4105	2.410666667	2.410583333
Variance	1.39E-05	1.90667E-05	1.49924E-05
Total			
Count	12	12	
Sum	28.947	28.947	
Average	2.41225	2.41225	
Variance	1.12955E-05	1.20227E-05	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	6.66667E-05	1	6.66667E-05	7.029877	0.01532	8.09598077
Columns	0	1	0	0	1	8.09598077
Interaction	1.66667E-07	1	1.66667E-07	0.017575	0.895859	8.09598077
Within	0.000189667	20	9.48333E-06			
Total	0.0002565	23				

Hypothesis 2 is supported at 99% level of confidence

AR-AC Rice Data: Two-Way ANOVA for Relative Effects of Binder and Design Method
Table 27

Rice Values Measured @ 7.0% ARB

	Binder 1	Binder 2
Controls	2.380	2.377
	2.382	2.386
	2.380	2.380 *
	2.377	2.380
	2.378	2.385
	2.376	2.380
Prop. Changes	2.381	2.376
	2.387	2.382
	2.373	2.376
	2.390	2.377
	2.377	2.384
	2.389	2.384

*Omitted 4th value that nearlyequals average of B2 control to permit analysis by Excel

Hypothesis 1: Means of Rices made with 7% Binder 1 = means of Rices made with 7% Binder 2
Hypothesis 2: Means of Rices @ 7% for control mixes = Means of Rices @ 7% for proposed changes mixes

Anova: Two-Factor With Replication Upper 5%

SUMMARY	Binder 1	Binder 2	Total
Controls			
Count	6	6	12
Sum	14.273	14.288	28.561
Average	2.378833333	2.381333333	2.380083333
Variance	4.96667E-06	1.18667E-05	9.35606E-06
Prop. Changes			
Count	6	6	12
Sum	14.297	14.279	28.576
Average	2.382833333	2.379833333	2.381333333
Variance	4.81667E-05	1.53667E-05	3.13333E-05
Total			
Count	12	12	
Sum	28.57	28.567	
Average	2.380833333	2.380583333	
Variance	2.85152E-05	1.29924E-05	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	9.375E-06	1	9.375E-06	0.466611	0.502387	4.35125003
Columns	3.75E-07	1	3.75E-07	0.018664	0.892699	4.35125003
Interaction	4.5375E-05	1	4.5375E-05	2.258399	0.148518	4.35125003
Within	0.000401833	20	2.00917E-05			
Total	0.000456958	23				

Hypotheses 1 and 2 are supported.
Interaction between binder and design method apparently had more effect than either factor alone.

APPENDIX E
ROUND 2 MIX DESIGN DATA

Combined ADOT MACTEC AR-AC Mix Data Rounds 1 and 2 Salt River Aggregate with Binders 1 and

Source Data for Plots

Table 28

Mix	ARB	Effect. Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Control	6.5	13.30	13.33	20.28	19.78	65.56	67.38	7.0	6.5	2268	2312	17	15
Designs	7.5	15.44	15.49	21.06	20.50	73.28	75.59	5.6	5.0	2010	2174	18	17
C1	8.5	17.67	17.63	21.43	21.39	82.49	82.41	3.8	3.8	1751	1835	20	20
Repeat 1	6.5	13.35	13.36	20.32	19.78	65.68	67.52	7.0	6.4	1477	2475	17	15
C2	7.5	15.56	15.54	20.71	20.43	75.13	76.06	5.2	4.9	1304	2326	20	16
	8.5	17.62	17.69	21.88	21.25	80.54	83.23	4.3	3.6	1484	2402	17	18
Repeat 2	6.5	13.22	13.40	20.03	19.31	66.00	69.36	6.8	5.9	2204	2605	17	16
C3	7.5	15.43	15.65	20.50	19.68	75.28	79.49	5.1	4.0	1979	2379	17	16
	8.5	17.50	17.88	21.71	20.23	80.60	88.37	4.2	2.4	1734	2226	19	17
Round 2	6.5	13.16	13.61	21.43	18.88	61.43	72.05	8.3	5.3	1797	2747	21	15
Run 1	7.5	15.38	15.85	21.67	19.33	70.97	82.02	6.3	3.5	1800	2615	21	16
C4	8.5	17.50	17.99	22.44	20.34	77.99	88.46	4.9	2.3	1689	2755	20	18
Run 2	6.5	13.19	13.34	20.89	20.25	63.13	65.88	7.7	6.9	1518	1894	17	17
C5	7.5	15.30	15.57	21.74	20.53	70.38	75.85	6.4	5.0	1334	1837	19	18
	8.5	17.52	17.75	22.09	21.25	79.29	83.51	4.6	3.5	1408	1697	21	18
Run 3	6.5	13.21	13.39	20.53	19.49	64.35	68.71	7.3	6.1	1819	2626	19	17
C6	7.5	15.36	15.69	21.24	19.61	72.31	79.99	5.9	3.9	1728	2599	22	17
	8.5	17.47	17.76	22.16	20.90	78.81	84.96	4.7	3.1	1502	2228	23	19
Round 2	6.5	13.29	13.35	20.72	19.61	64.13	68.10	7.4	6.3	2130	2780	21	15
AC4	7.5	15.46	15.58	21.25	20.08	72.78	77.57	5.8	4.5	2270	2550	26	20
	8.5	17.51	17.90	22.45	20.21	77.97	88.55	4.9	2.3	1930	2770	25	16
	6.5	13.51	13.31	21.15	19.54	63.90	68.11	7.6	6.2	1980	2670	23	18
AC5	7.5	15.64	15.59	21.85	19.69	71.57	79.18	6.2	4.1	1980	2620	25	20
	8.5	17.93	17.69	21.89	20.84	81.90	84.90	4.0	3.1	2270	2480	23	19
	6.5	13.20	13.17	20.54	19.83	64.26	66.43	7.3	6.6	2110	2560	18	15
AC6	7.5	15.18	15.37	22.14	20.36	68.56	75.48	7.0	5.0	1830	2460	22	14
	8.5	17.38	17.57	22.49	20.98	77.31	83.77	5.1	3.4	1930	2320	24	19

NOTES

Binder 1 (**B1**): Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC

Binder 2 (**B2**): Ergon 58-28 with 22.7% fine CRM rubber by weight of AC

Descriptions starting with A such as AC4 and AV1-5 designate ADOT results

Volumetric calculations for Control mixes were based on Rice at 6.0% ARB

Combined ADOT MACTEC AR-AC Mix Data Rounds 1 and 2 Salt River Aggregate with Binders 1 and
Source Data for Plots
Table 29

Mix	ARB	Effect. Binder Volume,%		VMA, %		VFA, %		Effect. Air Voids,%		Stability, lbs		Flow	
Description	Content	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2	Binder 1	Binder 2
Version 1	6.5	13.00	13.37	20.73	19.69	62.71	67.89	7.7	6.3	1907	2160	19	15
V1-1	7.5	15.11	15.67	21.58	19.70	70.04	79.57	6.5	4.0	1600	2394	21	16
	8.5	17.31	---	22.04	---	78.55	---	4.7	---	1605	---	24	---
Repeat 1	6.5	12.81	13.23	20.48	19.08	62.52	69.33	7.7	5.9	1614	2643	18	15
V1-2	7.5	14.94	15.49	21.26	19.42	70.28	79.78	6.3	3.9	1504	2374	20	16
	8.5	17.03	17.64	22.29	20.39	76.41	86.50	5.3	2.8	1075	1926	23	17
Repeat 2	6.5	13.27	13.44	20.98	19.26	63.26	69.78	7.7	5.8	1581	2289	17	16
V1-3	7.5	15.42	15.69	21.61	19.63	71.33	79.93	6.2	3.9	1408	2035	18	17
	8.5	17.46	17.78	22.78	20.81	76.64	85.44	5.3	3.0	1400	2033	19	17
Round 2	6.5	12.79	13.43	19.83	19.08	64.49	70.38	7.0	5.7	1790	2332	17	16
Run 1	7.5	14.95	15.80	20.62	18.85	72.48	83.83	5.7	3.0	1792	2119	20	14
V1-4	8.5	17.13	17.92	21.30	20.04	80.40	89.39	4.2	2.1	1581	2140	22	17
Run 2	6.5	13.31	13.13	19.83	19.22	67.08	68.28	6.5	6.1	1941	2279	17	17
V1-5	7.5	15.55	15.38	20.16	19.59	77.11	78.48	4.6	4.2	1850	2215	17	19
	8.5	17.60	17.55	21.44	20.43	82.08	85.93	3.8	2.9	1759	2120	19	18
Run 3	6.5	12.74	13.15	20.41	19.08	62.42	68.91	7.7	5.9	1814	2228	18	17
V1-6	7.5	15.02	15.42	20.44	19.38	73.46	79.55	5.4	4.0	1794	2267	19	19
	8.5	16.99	17.57	22.11	20.36	76.84	86.30	5.1	2.8	1581	2133	20	20
	6.5	12.98	12.90	20.11	18.93	64.52	68.14	7.1	6.0	2170	3140	18	13
AV1-4	7.5	15.21	15.08	20.43	19.73	74.44	76.44	5.2	4.6	2390	3120	19	16
	8.5	17.40	17.24	21.12	20.63	82.38	83.56	3.7	3.4	2170	2600	22	19
	6.5	12.99	13.11	20.58	19.47	63.12	67.34	7.6	6.4	2200	2730	17	20
AV1-5	7.5	15.21	15.37	20.43	19.76	71.71	77.78	6.0	4.4	2180	2610	19	15
	8.5	17.40	17.52	22.00	20.73	78.61	84.46	4.7	3.2	2050	2440	23	19
	6.5	13.15	13.31	19.93	20.08	65.98	66.28	6.8	6.8	2540	2820	18	18
AV1-6	7.5	15.36	15.67	20.43	19.73	75.15	79.46	5.1	4.1	2240	2790	17	18
	8.5	17.45	17.74	21.54	21.01	81.01	84.43	4.1	3.3	2030	2240	24	16

NOTES

Binder 1 (**B1**): Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC

Binder 2 (**B2**): Ergon 58-28 with 22.7% fine CRM rubber by weight of AC

Descriptions starting with A such as AC4 and AV1-5 designate ADOT results

Volumetric calculations for Proposed Changes mixes were based on Rice at 7.0% ARB

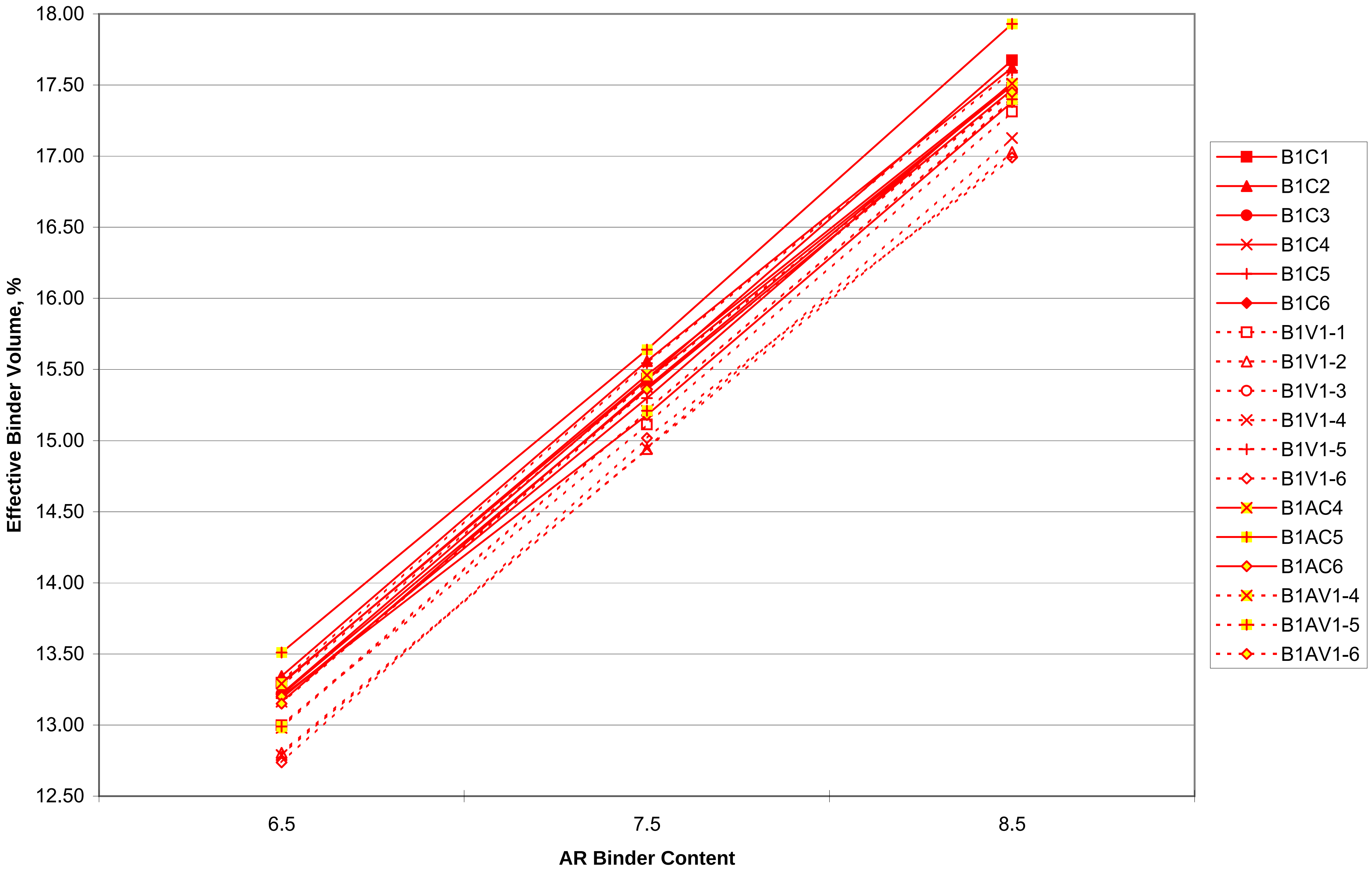
Legend Key for Plots of AR-AC Test Results
Table 30

Legend Key for Plots

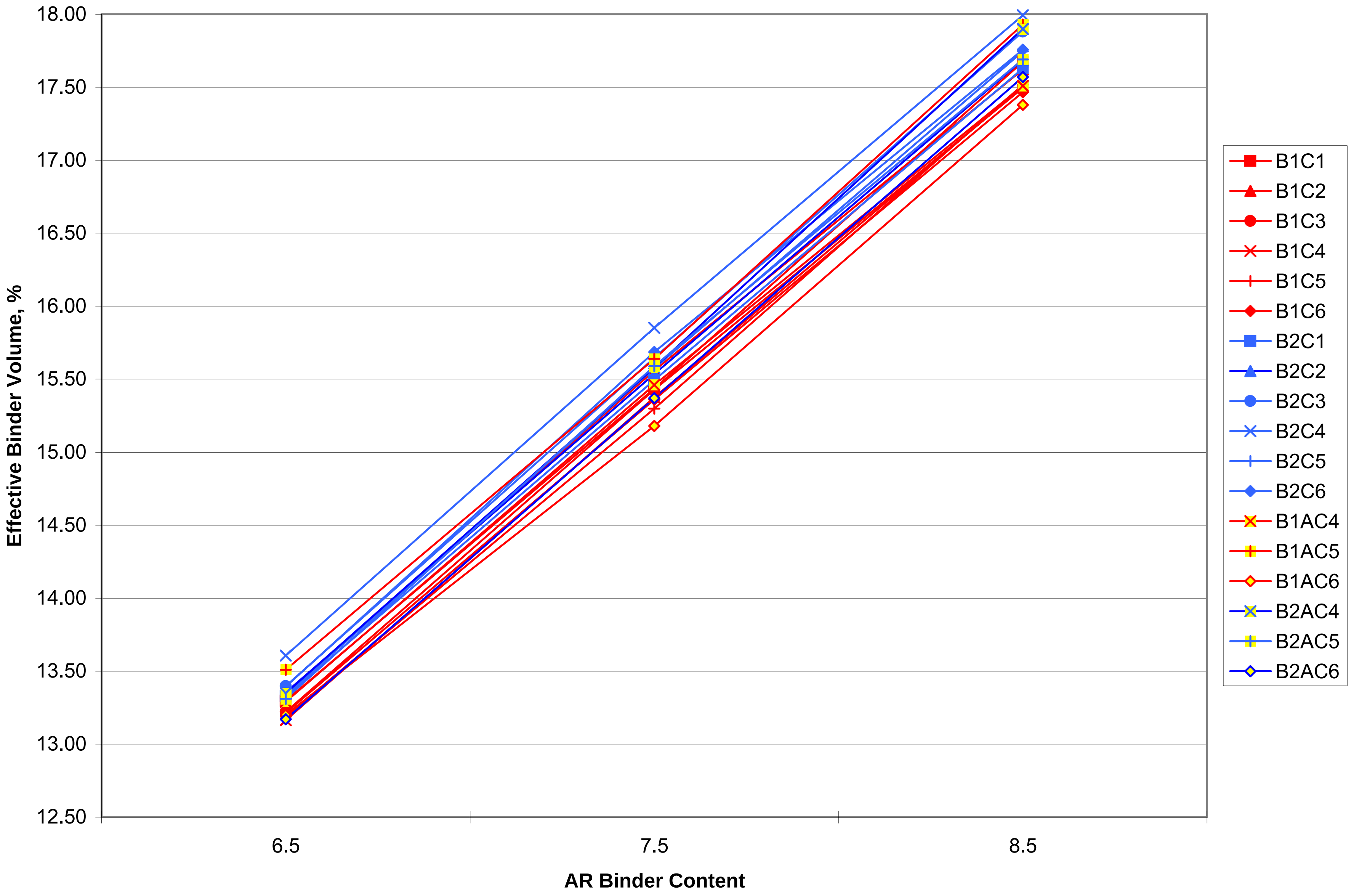
Identifying Codes used in the respective graphs of mix properties vs. binder content include binder ID and mix ID codes (see Example below)
The graphing conventions presented herein have been applied to plots that include Round 2 test results.

Code	Description	
B1	Binder 1 (Red graph lines and symbols)	Paramount 58-22 with 24.2% coarse CRM rubber by weight of AC
B2	Binder 2 (Blue graph lines and symbols)	Ergon 58-28 with 22.7% fine CRM rubber by weight of AC
C1-C3	Control Mixes batched and tested by MACTEC for Round 1	
C4-C6	Control Mixes batched and tested by MACTEC for Round 2 Graphing Conventions: Solid lines, solid (filled) symbols in red or blue for Binder 1 or 2, respectively	
AC4-AC6	Control Mixes batched by MACTEC for Round 2, and tested by ADOT Graphing Conventions: Solid Lines in red or blue for Binder 1 and 2, respectively Symbols are infilled or highlighted with yellow.	
V1-1 toV1-3	Version 1 mixes batched and tested by MACTEC for Round 1	
V1-4 to V1-6	Proposed Changes mixes batched and tested by MACTEC for Round 2 Graphing Conventions: Dotted lines, symbol outlines (unfilled) in red or blue for Binder 1 or 2, respectively	
AV1-4 to AV1-6	Proposed Changes mixes batched by MACTEC for Round 2, and tested by ADOT Graphing Conventions for ADOT results: fill symbols with yellow, add yellow highlight to those that can't be filled.. Still use red & blue to distinguish binders, solid vs dashed lines to distinguish method.	

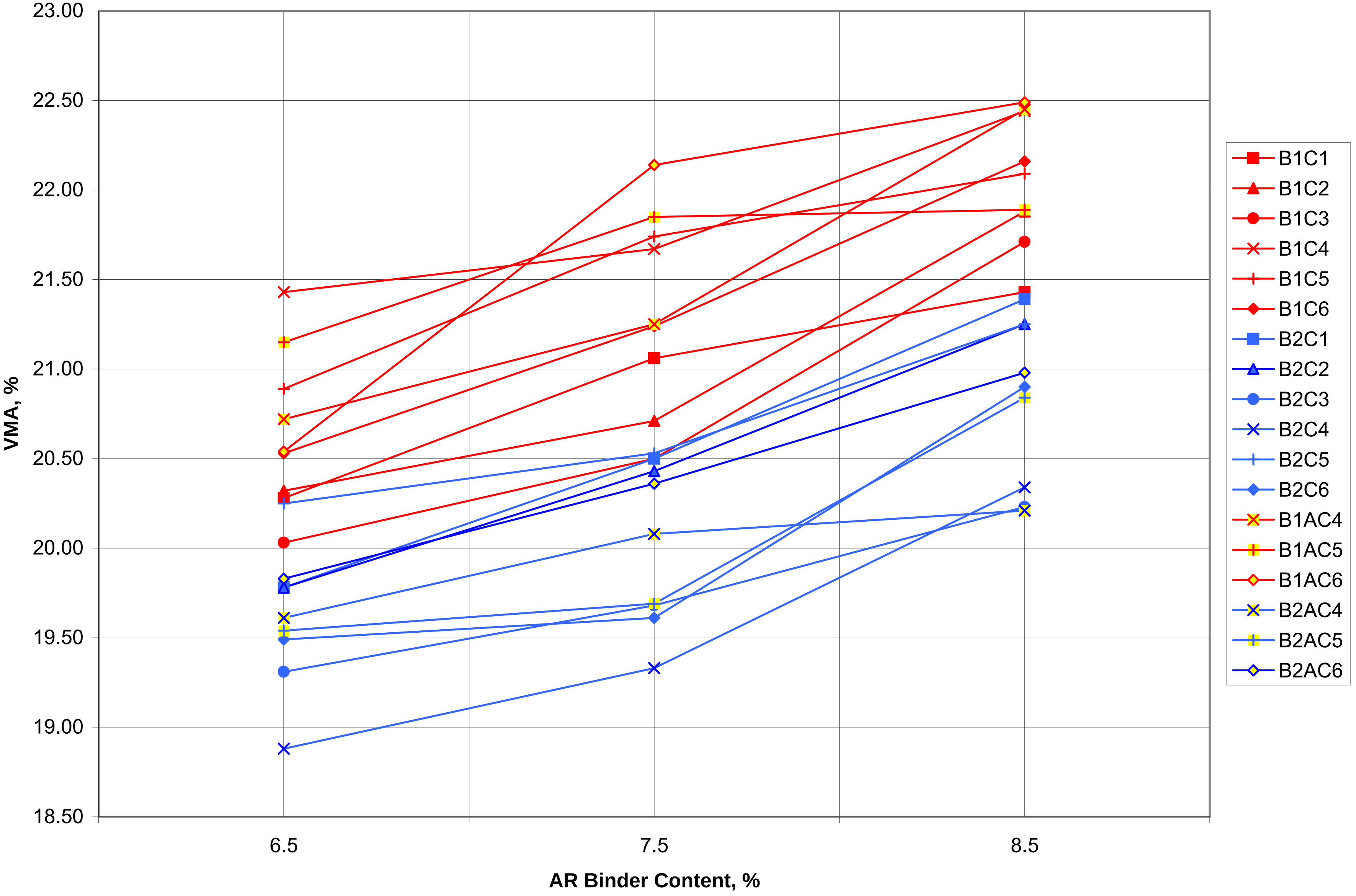
Example:	B1C1	First set of control mix specimens made by MACTEC in Round 1 with Binder 1 (at three AR binder contents)
	B2V1-5	Second set of proposed changes mix specimens made by MACTEC in Round 2 with Binder 2 (3 AR binder contents)
	B1AC4	First set of control mix specimens mixed with 3 content levels of Binder 1and tested by ADOT in Round 2



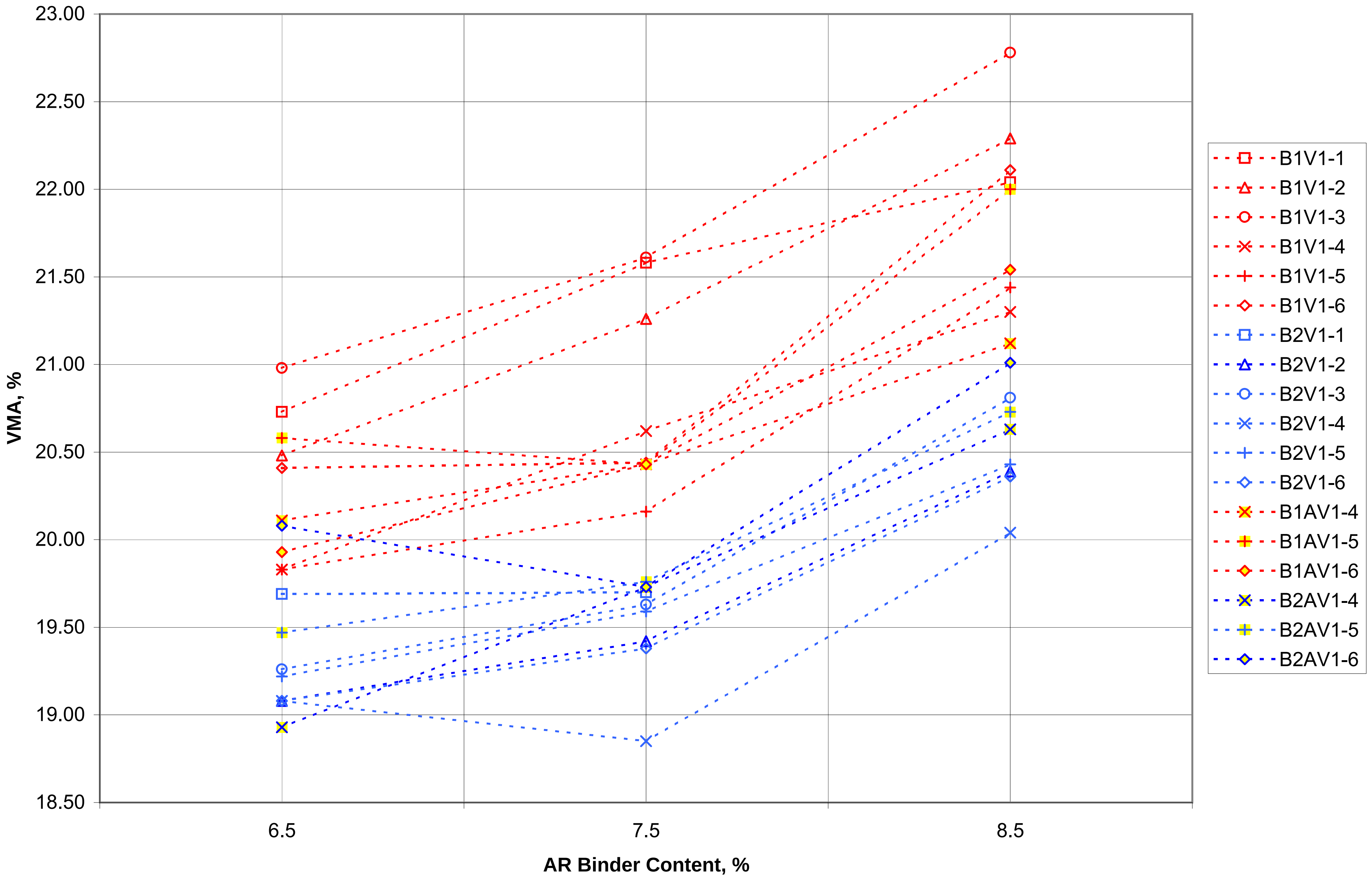
MACTEC Rounds 1 2 and ADOT Round 2
Effective Binder Volume Salt River B1 Control and Version 1
Figure 15



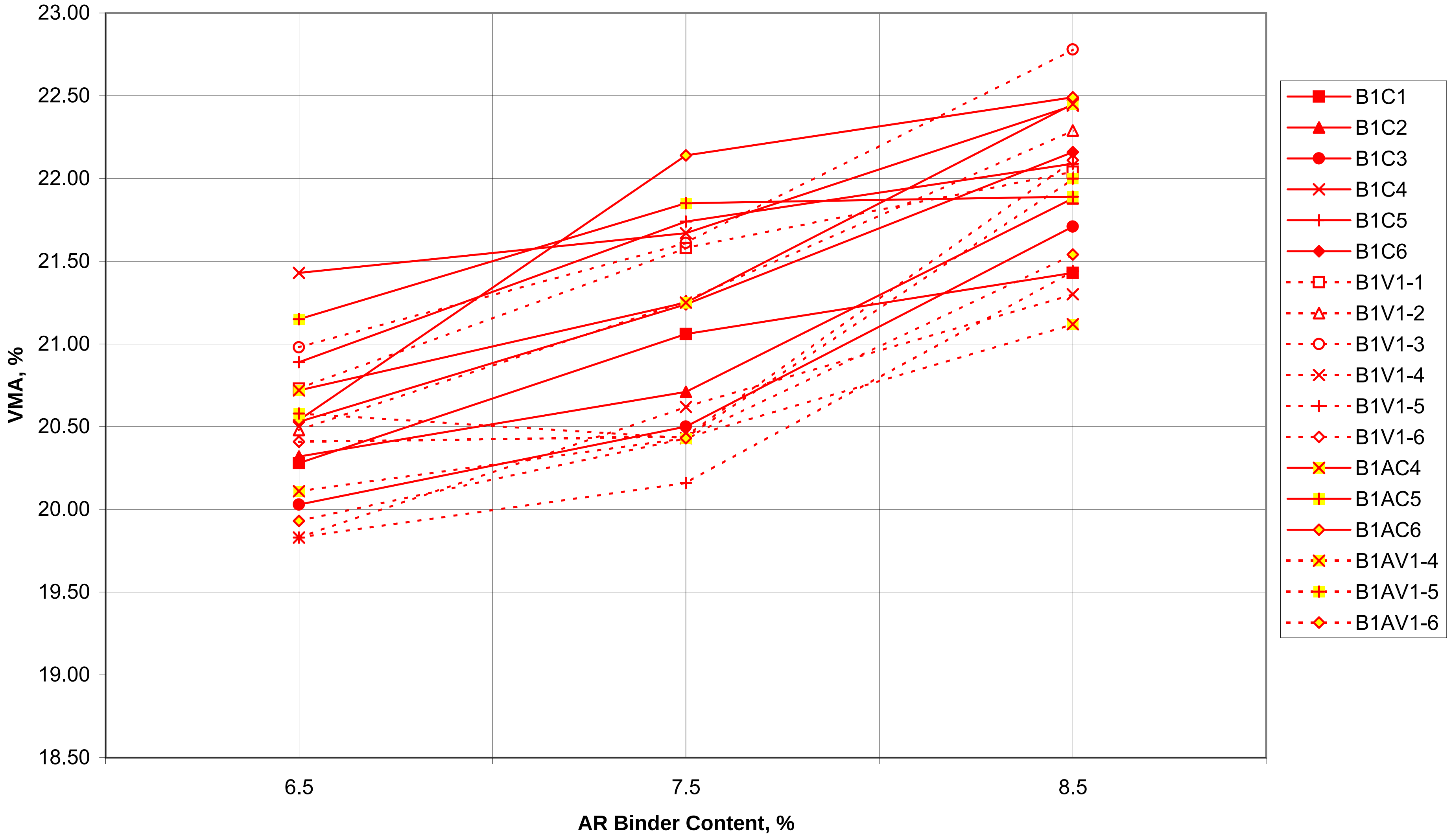
MACTEC Rounds 1 and 2 and ADOT Round 2
Effective Binder Volume Salt River Controls B1 and B2
Figure 16



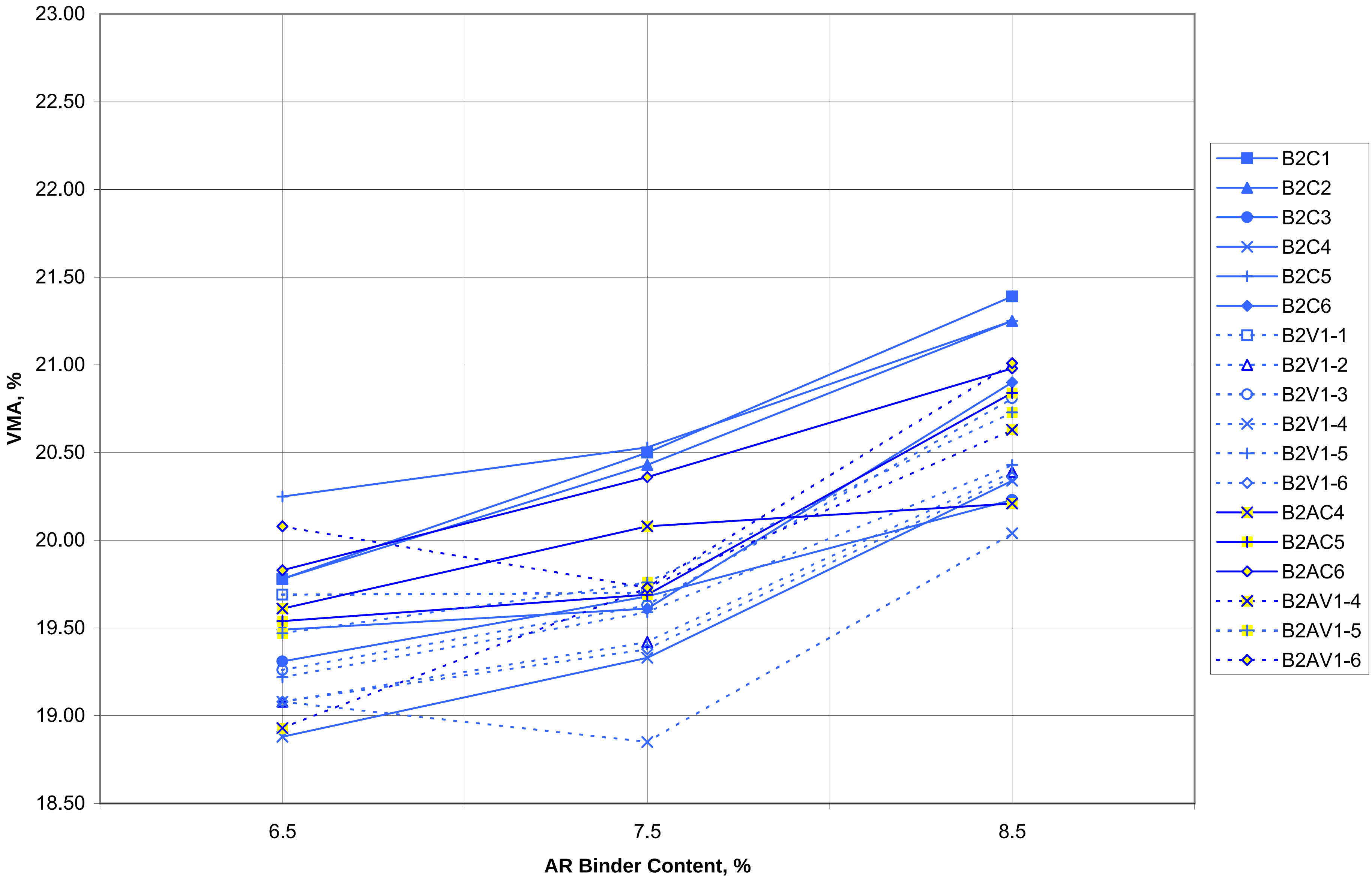
MACTEC Rounds 1 and 2 and ADOT Round 2 VMA Salt River Control Binders 1 and 2
Figure 17



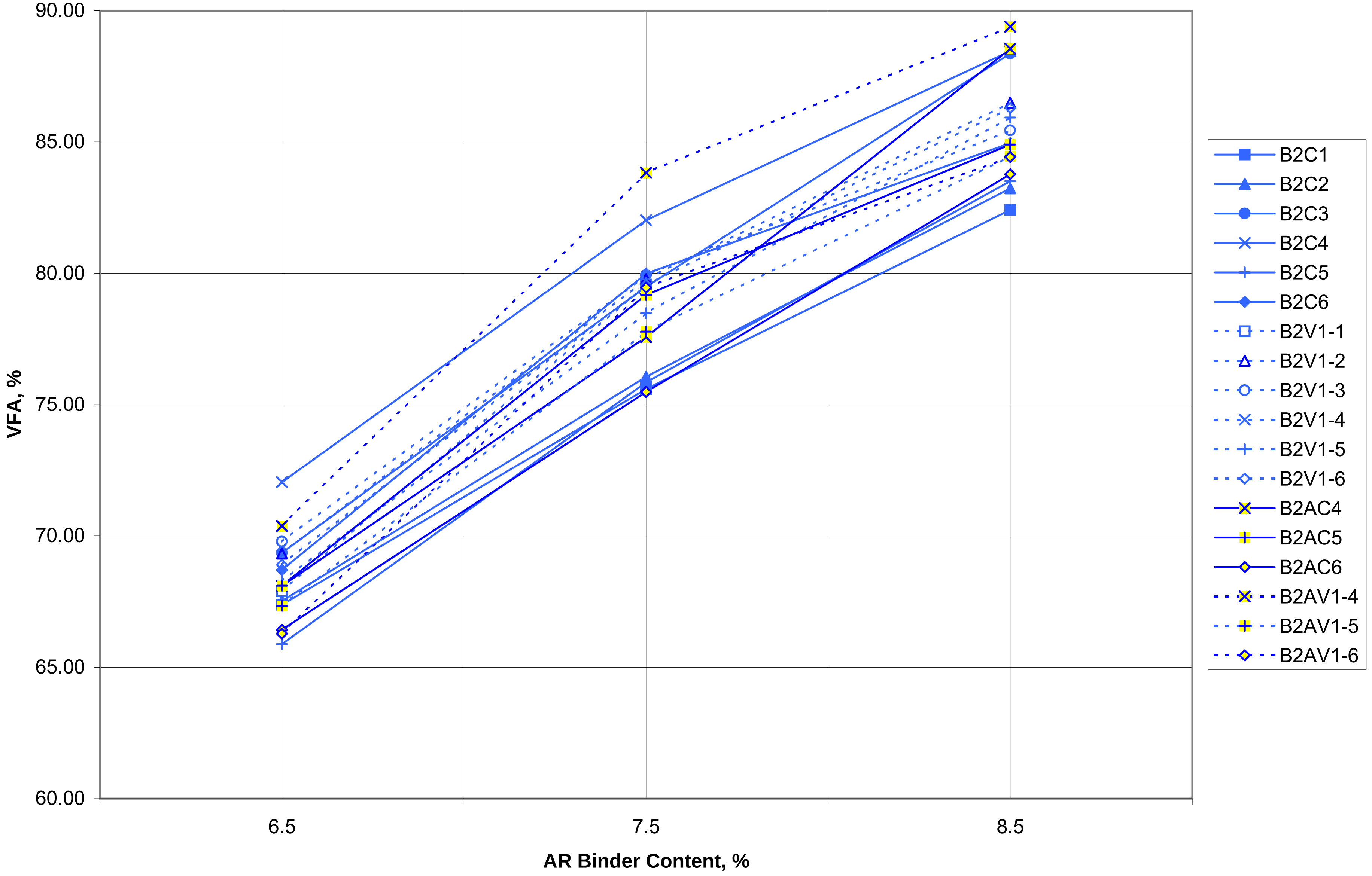
MACTEC Rounds 1 and 2 and ADOT Round 2 VMA Salt River Version 1 Binders 1 and 2
Figure 18



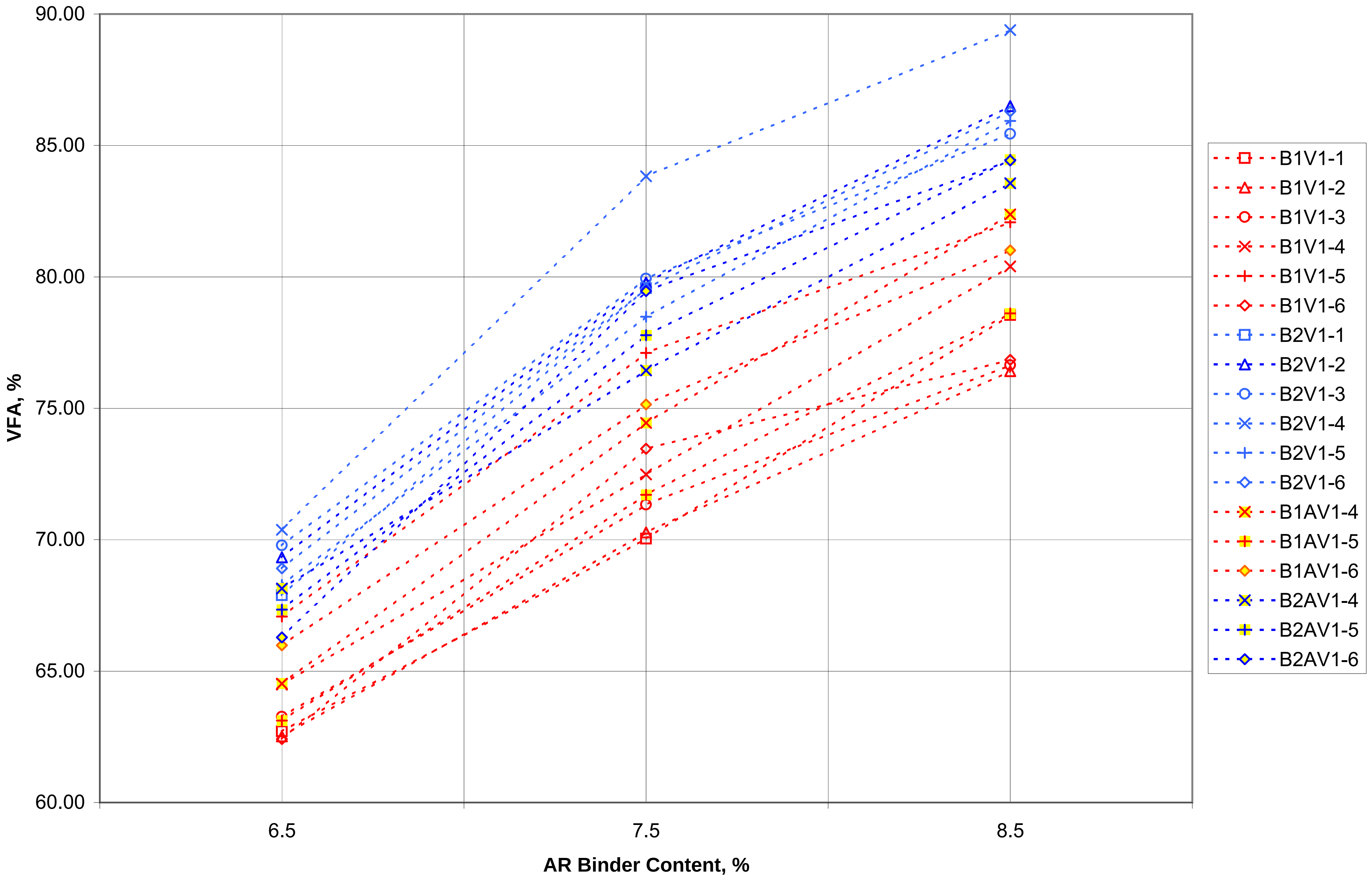
MACTEC Rounds 1 and 2 and ADOT Round 2 VMA Salt River B1 Control and Version 1
Figure 19



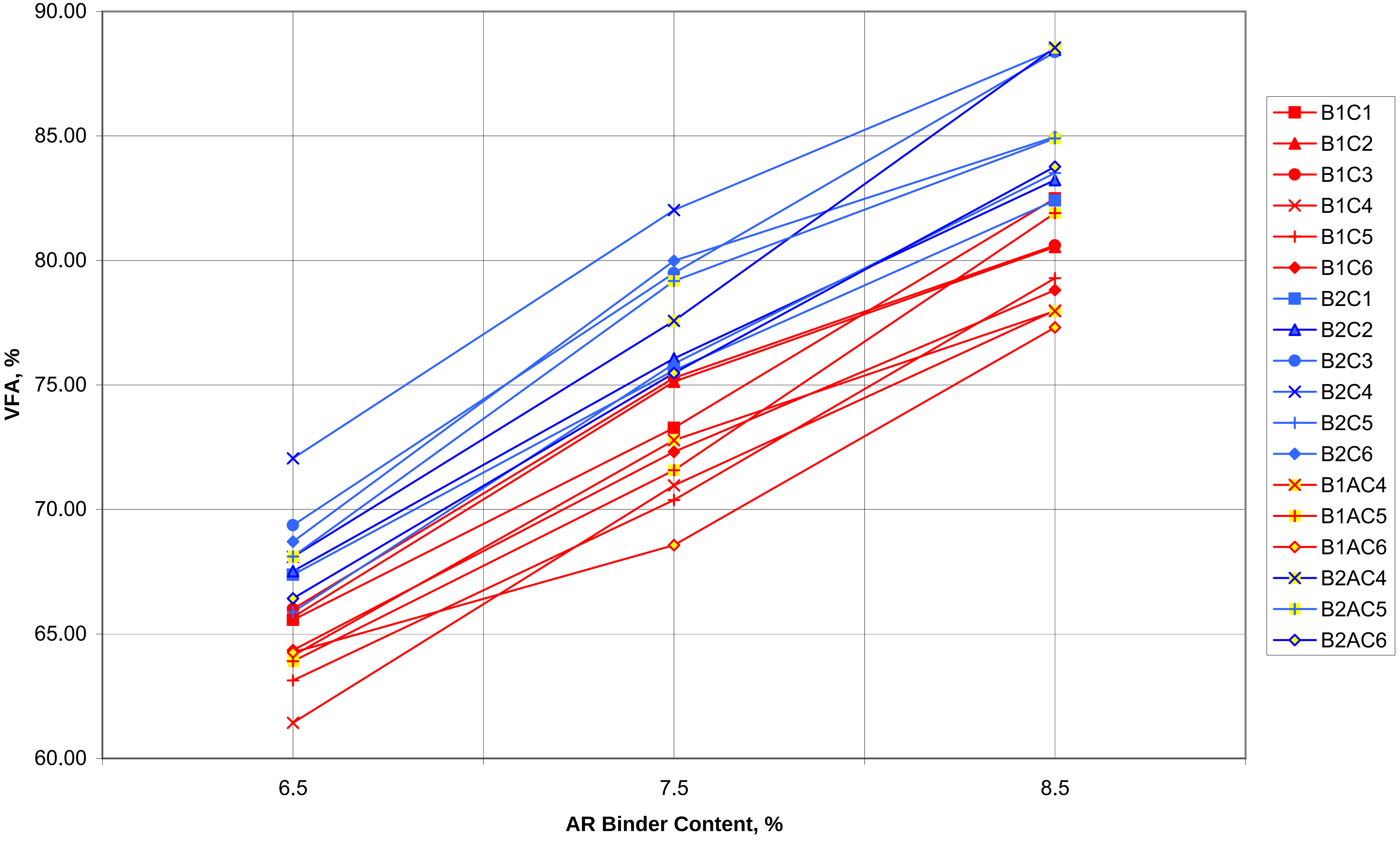
MACTEC Rounds 1 and 2 and ADOT Round 2 VMA Salt River B2 Controls and Version 1
Figure 20



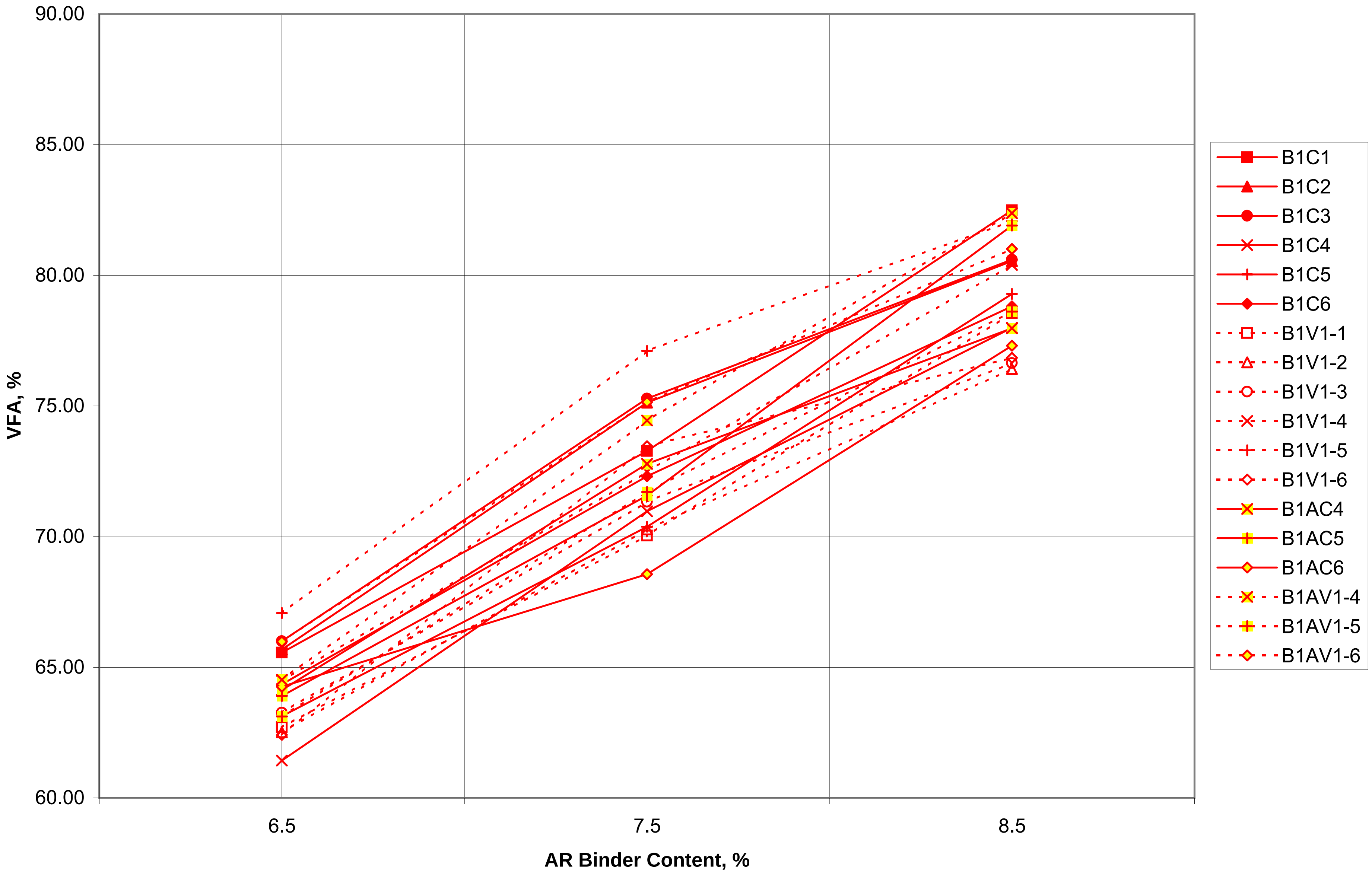
MACTEC Rounds 1 and 2 and ADOT Round 2 VFA Salt River B2 Control and Version 1
Figure 21



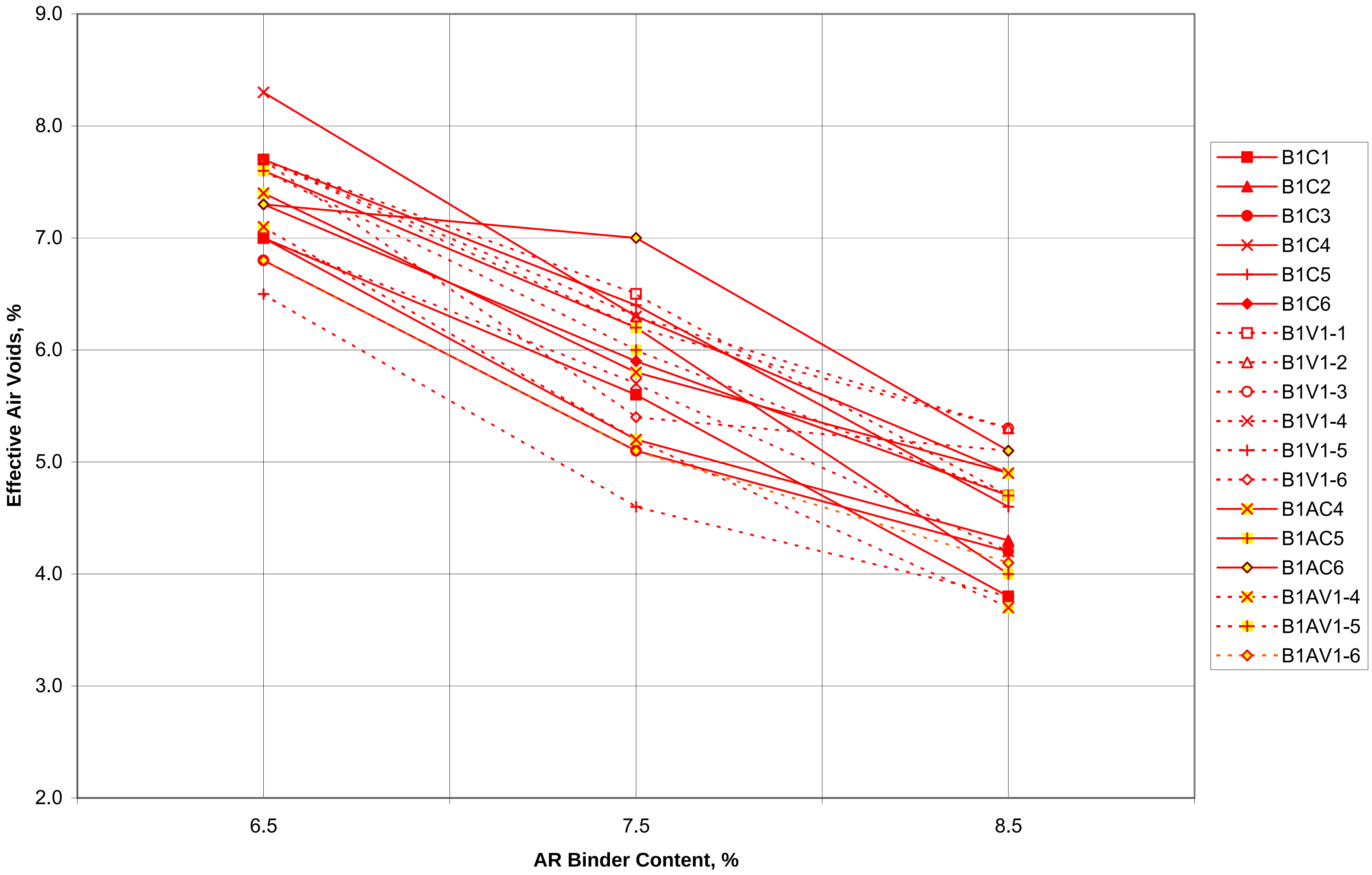
MACTEC Rounds 1 and 2 and ADOT Round 2 VFA Salt River Version 1 Binders 1 and 2
Figure 22



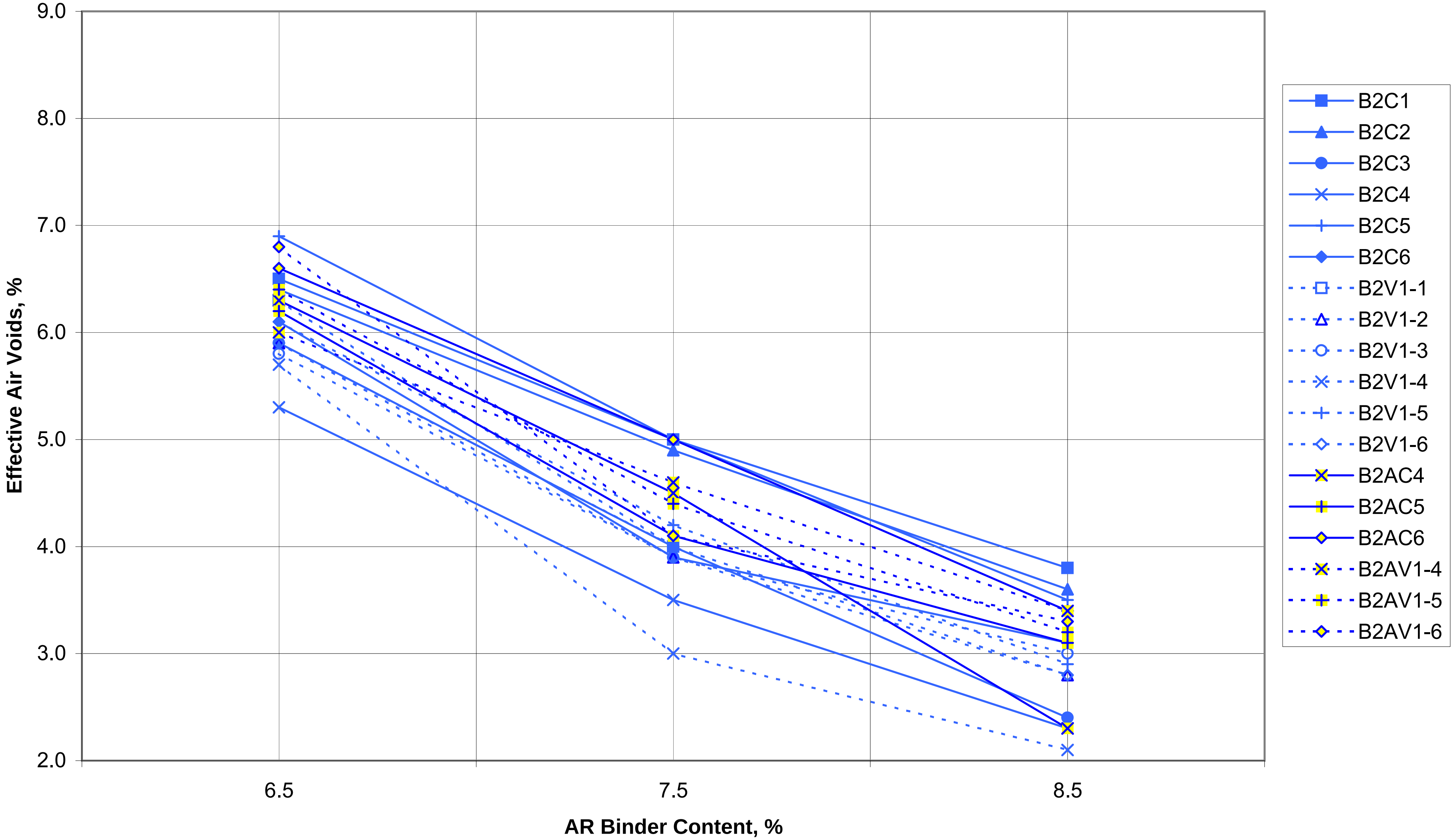
MACTEC Rounds 1 and 2 and ADOT Round 2 VFA Salt River Control Binders 1 and 2
Figure 23



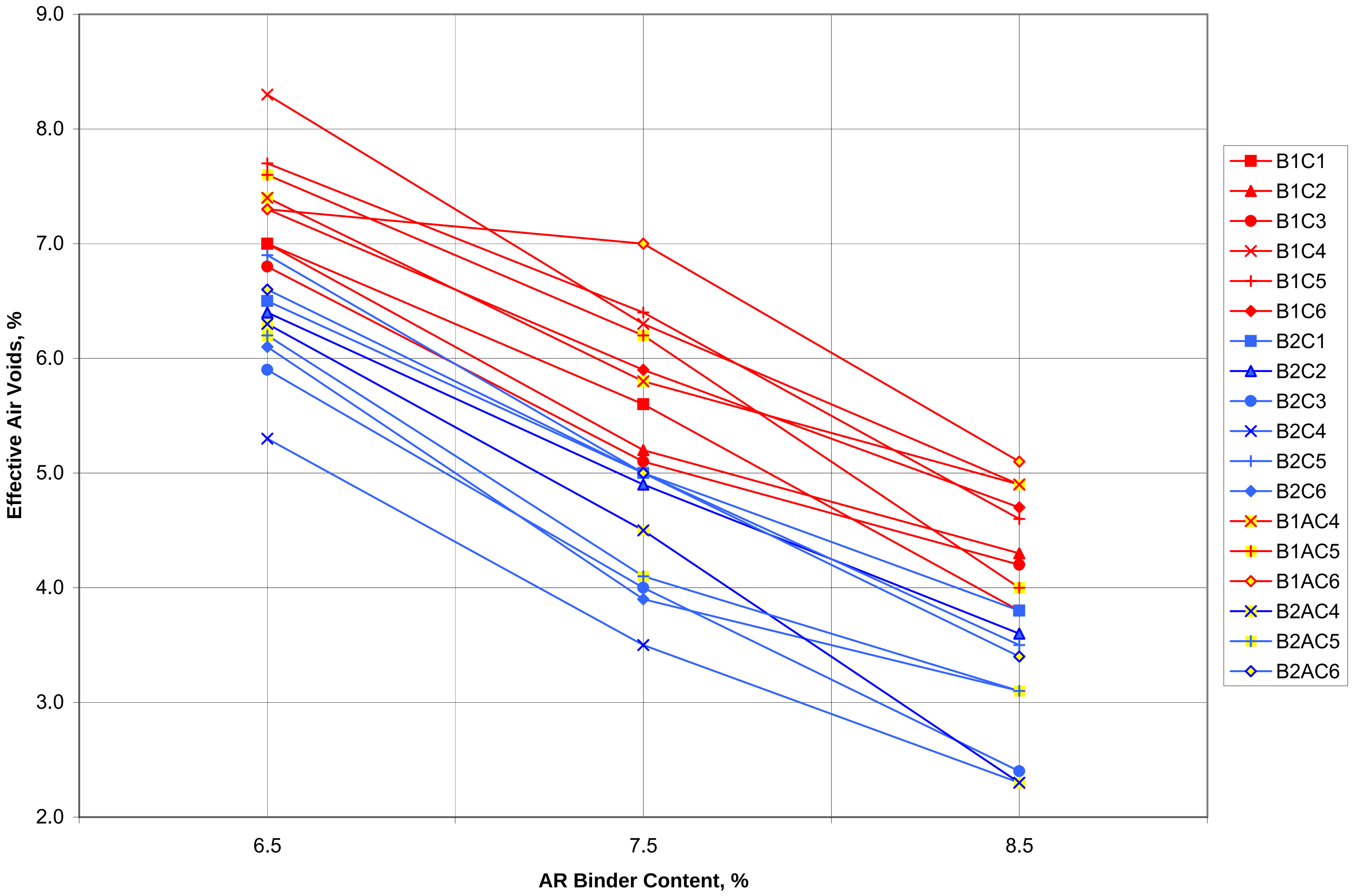
MACTEC Rounds 1 and 2 and ADOT Round 2 VFA Salt River B1 Control and Version 1
Figure 24



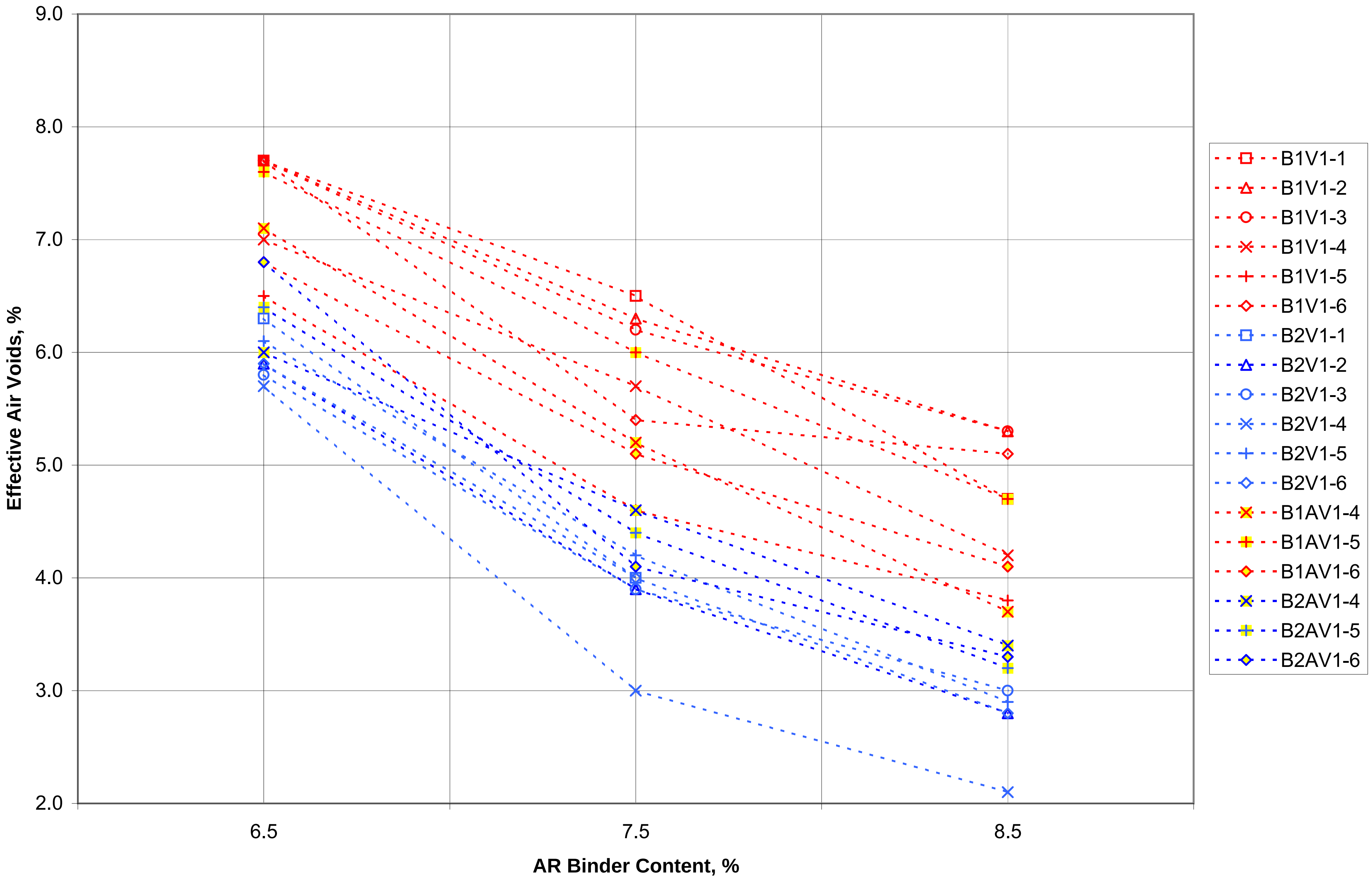
MACTEC Rounds 1 and 2 and ADOT Round 2 Air Voids Salt River B1 Control and Version 1
Figure 25



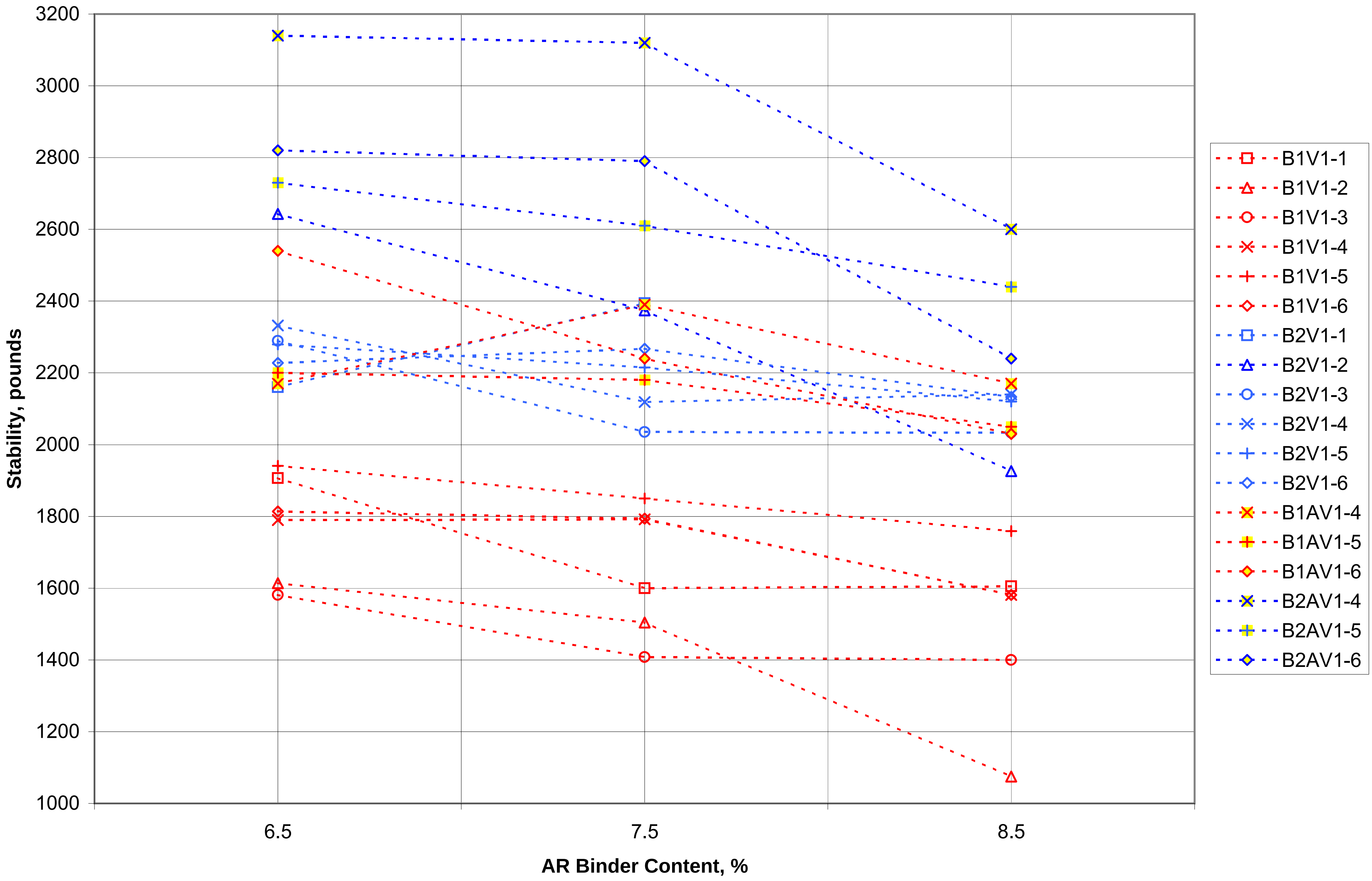
MACTEC Round 1 and 2 and ADOT Round 2 Air Voids Salt River B2 Control and Version 1
Figure 26



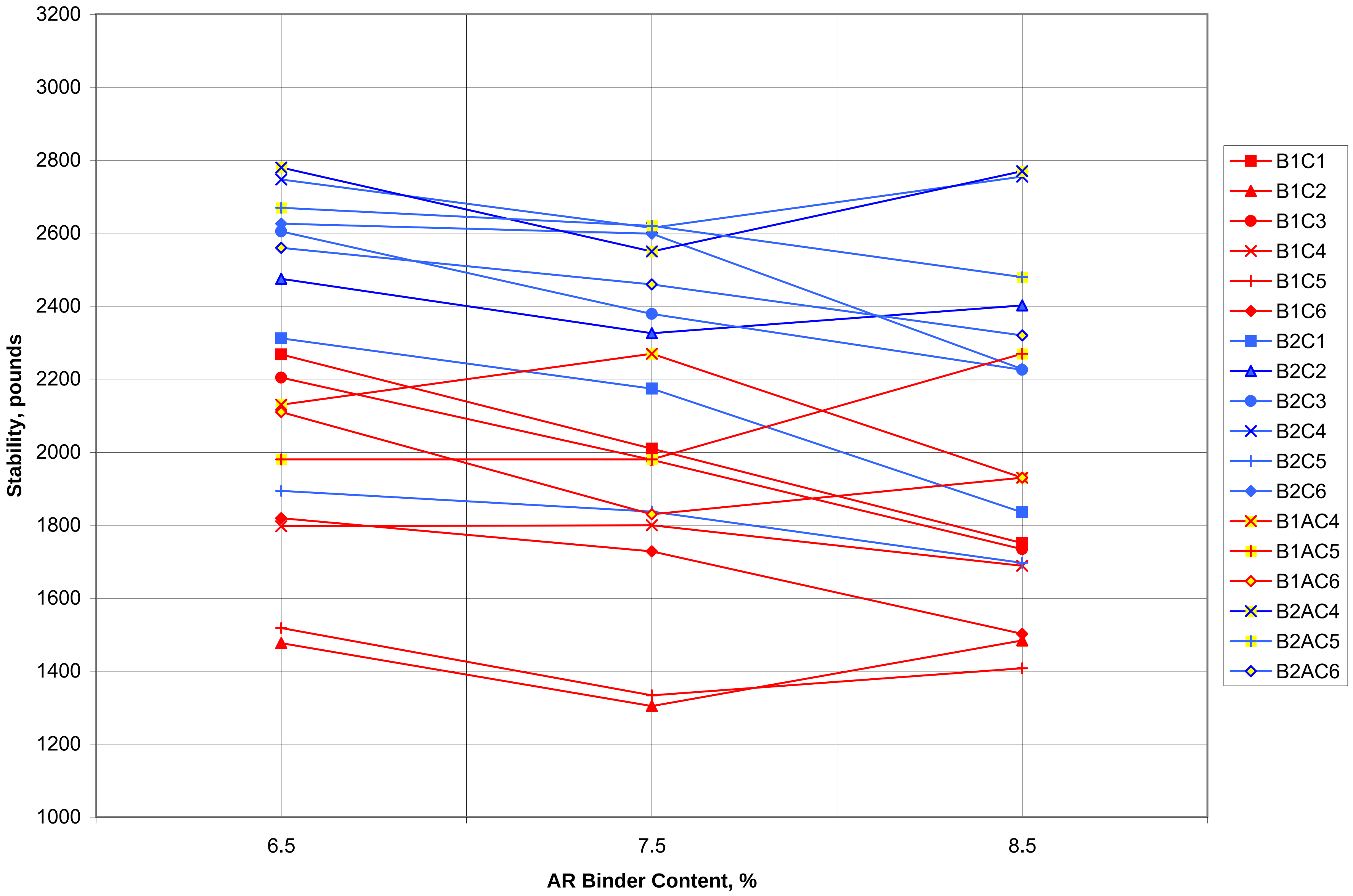
MACTEC Rounds 1 and 2 and ADOT Round 2 Air Voids Salt River Control Binders 1 and 2
Figure 27



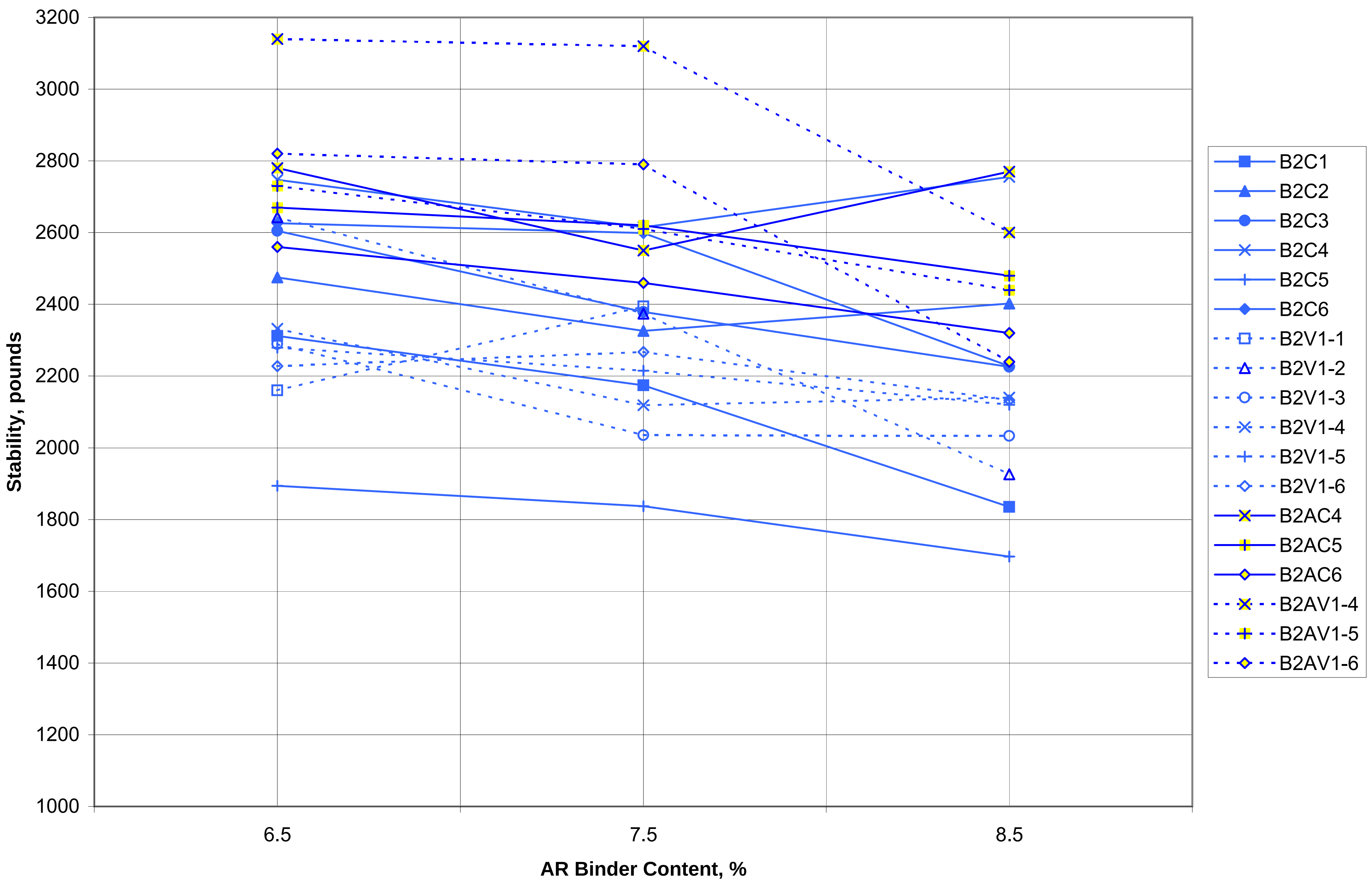
MACTEC Rounds 1 and 2 and ADOT Round 2 Air Voids Salt River Version 1 Binders 1 and 2
Figure 28



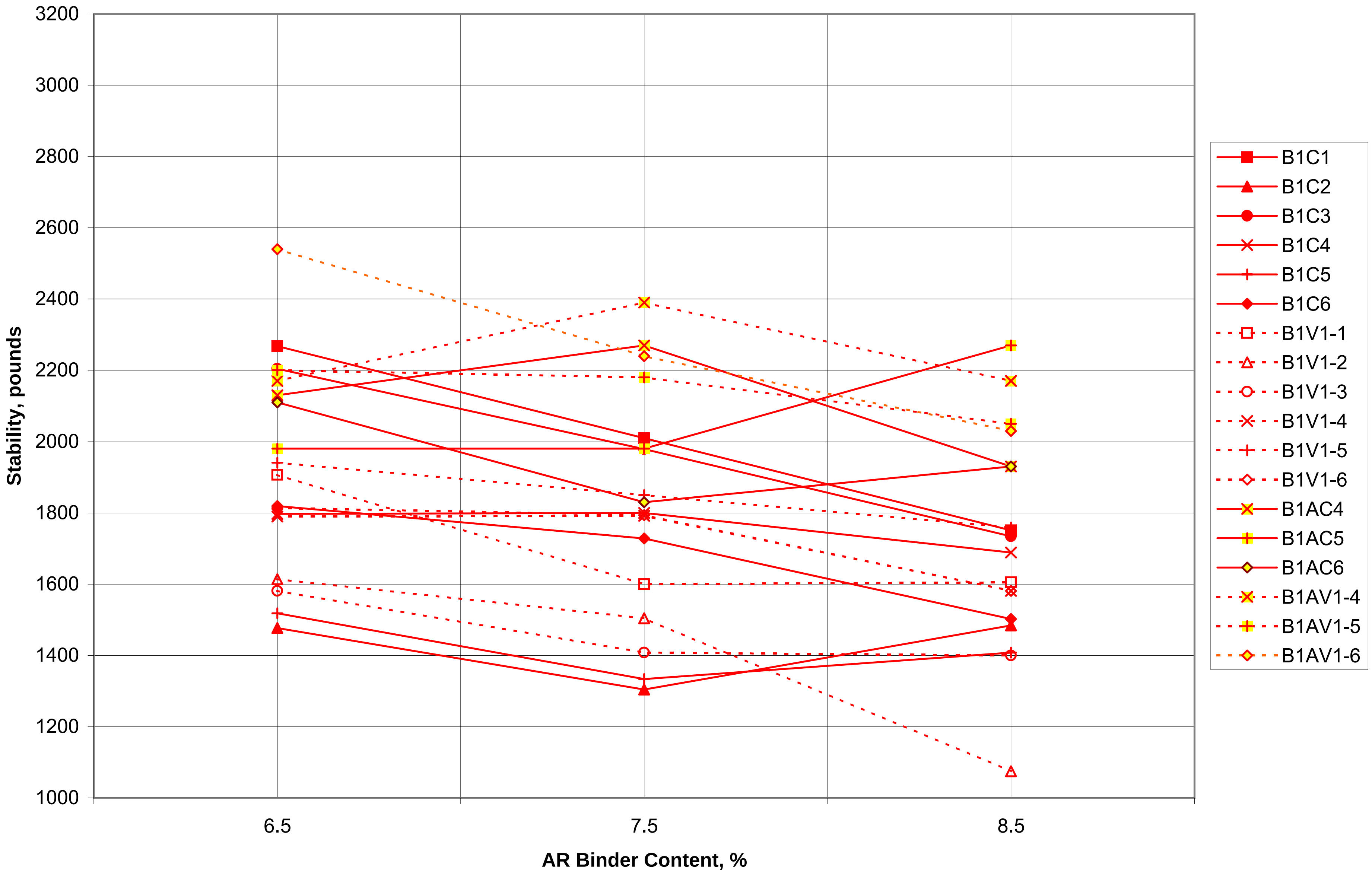
MACTEC Rounds 1 and 2 and ADOT Round 2 Stability Salt River Version 1 Binders 1 and 2
Figure 29



MACTEC Rounds 1 and 2 and ADOT Round 2 Stability Salt River Controls Binders 1 and 2
Figure 30



MACTEC Rounds 1 and 2 and ADOT Round 2 Stability Salt River B2 Control and Version 1
Figure 31



MACTEC Rounds 1 and 2 and ADOT Round 2 Stability Salt River B1 Control and Version 1
Figure 32

One-Way Analysis of Variance Results Matrix
ADOT and MACTEC AR-AC Test Results (Rounds 1 and 2)
Table 31

Cell entries show the level of confidence at which means of results are statistically equal, or if assumption of equality is rejected by analysis of variance.

Description	MACTEC Round 1 vs. Round 2	MACTEC vs. ADOT Round 2	MACTEC Round 1 vs. ADOT Round 2
Control B1 @ 6.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	97.5%
VFA	97.5%	95.0%	X - Rejected @99%[1]
Air Voids	97.5%	95.0%	99.0%
Stability	95.0%	97.5%	95.0%
Flow	95.0%	95.0%	95.0%
Control B1 @ 7.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	99.0%	95.0%	97.5%
VFA	99.0%	95.0%	95.0%
Air Voids	99.0%	95.0%	95.0%
Stability	95.0%	95.0%	95.0%
Flow	95.0%	95.0%	99.0%
Control B1 @ 8.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	97.5%	95.0%	95.0%
VFA	97.5%	95.0%	95.0%
Air Voids	99.0%	95.0%	95.0%
Stability	95.0%	99.0%	95.0%
Flow	95.0%	95.0%	X - Rejected @99%[2]
Version 1 B1 @ 6.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	97.5%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	95.0%
Stability	95.0%	99.0%	99.0%
Flow	95.0%	95.0%	95.0%
Version 1 B1 @ 7.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	X - Rejected @ 99%	95.0%	X - Rejected @99%
VFA	95.0%	95.0%	97.5%
Air Voids	97.0%	95.0%	97.5%
Stability	X - Rejected @ 99%	X - Rejected @99%	X - Rejected @99%
Flow	95.0%	95.0%	95.0%
Version 1 B1 @ 8.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	95.0%
Stability	95.0%	X - Rejected @99%	99%[3]
Flow	95.0%	95.0%	95.0%

Note 1. Average of MACTEC Rounds 1 and 2 equal @ 95% confidence level

Note 2. Average of MACTEC Rounds 1 and 2 equal @ 95% confidence level

Note 3. Equality supported at 99% confidence level due solely to high variability among results.

One-Way Analysis of Variance Results Matrix
ADOT and MACTEC AR-AC Test Results (Rounds 1 and 2)
Table 31

Description	MACTEC Round 1 vs. Round 2	MACTEC vs. ADOT Round 2	MACTEC Round 1 vs. ADOT Round 2
Control B2 @ 6.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	95.0%
Stability	95.0%	95.0%	95.0%
Flow	95.0%	95.0%	95.0%
Control B2 @ 7.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	95.0%
Stability	95.0%	95.0%	97.5%
Flow	95.0%	95.0%	95.0%
Control B2 @ 8.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	95.0%
Stability	95.0%	95.0%	95.0%
Flow	95.0%	95.0%	95.0%
Version 1 B2 @ 6.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	95.0%
Stability	95.0%	X - Rejected @ 99%	97.5%[4]
Flow	97.5%	95.0%	95.0%
Version 1 B2 @ 7.5%			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	95.0%	95.0%
VFA	95.0%	95.0%	95.0%
Air Voids	95.0%	95.0%	97.5%
Stability	95.0%	99.0%	97.5%
Flow	95.0%	95.0%	95.0%
****Version 1 B2 @ 8.5%**			
Effective Binder Vol.	95.0%	95.0%	95.0%
VMA	95.0%	97.5%	95.0%
VFA	95.0%	95.0%	97.5%
Air Voids	95.0%	95.0%	97.5%
Stability	97.5%	97.5%	97.5%
Flow	95.0%	95.0%	95.0%

Note 4. Average of Rounds 1 and 2 Rejected

**Round 1 MACTEC Proposed changes mixes @ 8.5% Binder 2 included 2 sets instead of 3 sets of Marshall Specimens

Two-Way Analysis of Variance Results Matrix
ADOT and MACTEC AR-AC Test Results (Rounds 1 and 2)
Binder 1 vs. Binder 2, Control vs. Version 1 Mixes
Table 32

Hypothesis 1: Mean of Results with Binder 1 = Mean of Results with Binder 2

If Hypothesis 1 is rejected, it means that the binder strongly effects the results of mix property tests.

Hypothesis 2: Mean of Results of Control Mixes = Mean of Results of Version 1 Mixes

If Hypothesis 2 is rejected, it means that the mix design method strongly effects results of mix tests.

Description	**ADOT (Round 2)**		**MACTEC (Rounds 1 and 2)**	
	Hypothesis 1	**Hypothesis 2**	**Hypothesis 1**	**Hypothesis 2**
6.5% Binder				
Effective Binder Vol.	95.0%	97.5%	X - Rejected @ 99%	X - Rejected @ 99%
VMA	X - Rejected @ 99%	95.0%	X - Rejected @ 99%	95.0%
VFA	X - Rejected @ 99%	95.0%	X - Rejected @ 99%	95.0%
Air Voids	X - Rejected @ 99%	95.0%	X - Rejected @ 99%	95.0%
Stability	X - Rejected @ 99%	97.5%	X - Rejected @ 99%	95.0%
Flow	95.0%	95.0%	X - Rejected @ 99%	95.0%
7.5% Binder				
Effective Binder Vol.	95.0%	95.0%	X - Rejected @ 99%	97.5%
VMA	X - Rejected @ 99%	X - Rejected @ 99%	X - Rejected @ 99%	95.0%
VFA	X - Rejected @ 99%	95.0%	X - Rejected @ 99%	95.0%
Air Voids	X - Rejected @ 99%	95.0%	X - Rejected @ 99%	95.0%
Stability	X - Rejected @ 99%	97.5%	X - Rejected @ 99%	95.0%
Flow	99.0%	99.0%	X - Rejected @ 99%	95.0%
8.5% Binder				
Effective Binder Vol.	95.0%	95.0%	*	*
VMA	X - Rejected @ 99%	95.0%	*	*
VFA	X - Rejected @ 99%	95.0%	*	*
Air Voids	X - Rejected @ 99%	95.0%	*	*
Stability	X - Rejected @ 99%	95.0%	*	*
Flow	X - Rejected @ 99%	95.0%	*	*

* Excel cannot perform ANOVA with unbalanced data due to missing values for Version 1 mixes with 8.5% Binder 2.

APPENDIX F
BIG BUG ROUND ROBIN
PRELIMINARY DATA AND ANALYSES

MACTEC

ARAC Design Summary

MACTEC Job No.: 4975-03-3015.11
MACTEC Lab No.: 41759
Project Name: Cordes Jct.-Flagstaff Hwy
Project No.: IM-017-B(005)A
TRACS: 017 YV 256 H611501C
Project Loc.: Badger Springs - Big Bug

Date: June, 2004
Mix Type: ADOT 413
Source of Aggregate: Big Bug
Asphalt / Rubber Source: Chevron / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Composite Aggregate Gradation

Aggregate	MACTEC Lab No.	Percentage w/ Admix
Clean Crusher Fines	41762	26.73
3/8" Aggregate	41761	34.65
3/4" Aggregate	41760	37.62
Hydrated Lime (wet prep)	Lime	0.99

Sieve (US/mm)	Composite w/o Admix	Specs w/o Admix	Composite w/ Admix
2" / 50	100		100
1.25" / 31.5	100		100
1" / 25	100		100
3/4" / 19	100	(100)	100
1/2" / 12.5	82	(80-100)	82
3/8" / 9.5	69	(65-80)	70
1/4" / 6.3	49		49
#4 / 4.75	37	(28-42)	38
#8 / 2.36	21	(14-22)	21
#10 / 2.00	18		19
#16 / 1.18	11		12
#30 / .600	6		7
#40 / .425	4		5
#50 / .300	3		4
#100 / .150	2		3
#200 / .075	1.5	(0-2.5)	2.4

Target % ARB: 7.8 ***

ARAC Supplier: FNF Construction, Inc.
ADOT Lab No.:
Asphalt / Rubber Source: Chevron / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Admix Source: Chemical Lime Co.
Mixing Temperature: 330 F
Compaction Temperature: 330 F

Design Data at Target % ARB

Property	Value	Spec.	
Percent of ARB:	7.8		
Bulk Specific Gravity :	2.313		
Bulk Specific Density (kg/m3):	2308		
Bulk Specific Density (PCF):	144.1		
Theor. Max. Sp. Gr. (Gmm):	2.453		
Stability (lbs):	2012		
Flow (0.25 mm):	20		
Percent Air Voids:	5.7	(4.5-6.5)	
Percent VMA:	21.83	Min 19	
Percent Voids Filled:	73.8		
Percent Effective ARB:	7.399		
Dust to Eff. ARB Ratio:	0.33		
Effective Sp. Gr.(w/ Admix):	2.766		

Aggregate / Admix Properties

Property	Coarse	Fine	Comb w/o Adm.	Spec
Bulk (Dry) Sp. Gravity:	2.744	2.719	2.735	2.35-2.85
"SSD" Sp. Gravity:	2.786	2.778	2.783	
Apparent Sp. Gravity:	2.866	2.889	2.874	
Water Absorption(%):	1.55	2.17	1.77	0-2.5
Admixture Sp. Gravity:	2.200	ARB Sp. Gravity:		1.050
Sand Equivalent value:			89	Min 55
Fractured Face 2 Face (%):			99	Min 85
Fractured Face 1 Face (%):			100	
ARB Absorbed into Dry Aggregate (%):			0.43	Max 1.0
L.A. Abrasion @ 100 Rev.(%):			6	Max 9
L.A. Abrasion @ 500 Rev.(%):			23	Max 40

MACTEC Engineering and Consulting, Inc.

Carusone

James Carusone
Vice President

Anne Stonex, PE
Sr. Engineer

Registered Professional Engineer (Civil)
Certificate No. 26470
ANNE STONEX
Date Signed 7-15-04
Arizona, U.S.A.

Remarks:

MACTEC

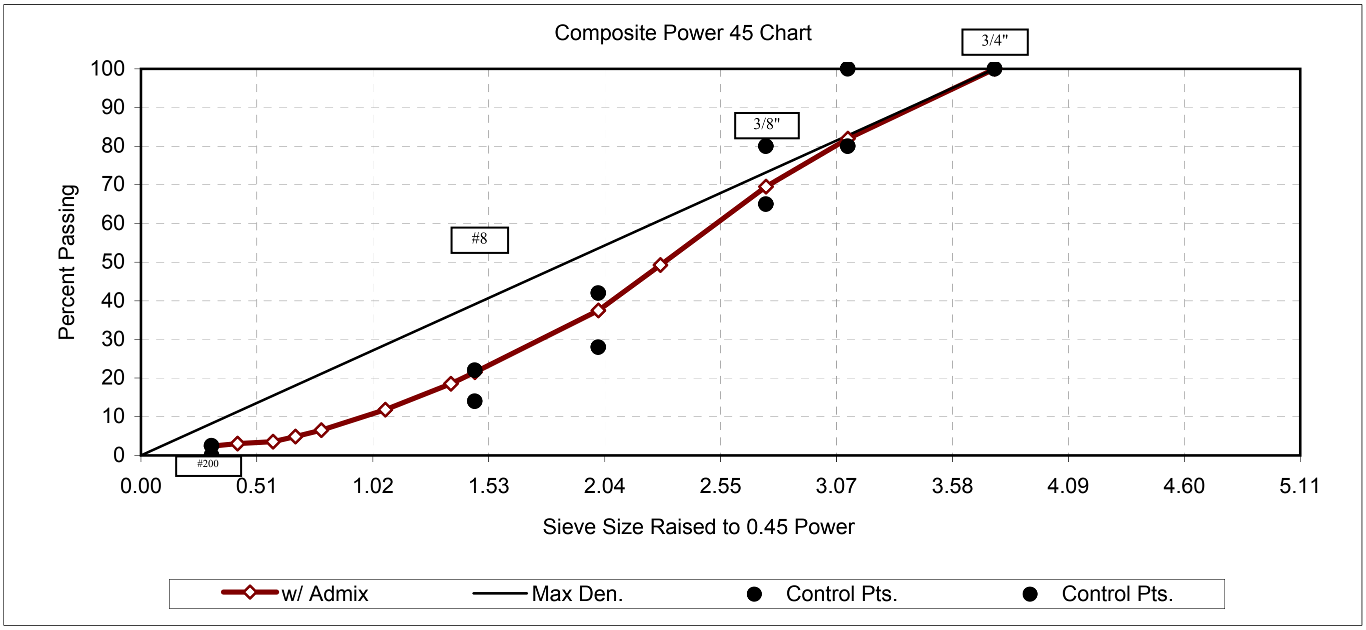
Aggregate Composite

MACTEC Job No.: 4975-03-3015.11
MACTEC Lab No.: 41759
Project Name: Cordes Jct.-Flagstaff Hwy
Project No.: IM-017-B(005)A
TRACS: 017 YV 256 H611501C
Project Loc.: Badger Springs - Big Bug

Date: June, 2004
Mix Type: ADOT 413
Source of Aggregate: Dugas Pit
Asphalt / Rubber Source: Chevron / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Lab No.		Aggregate Name	Percentage	Adjusted %
41762	Aggregate #1:	Clean Crusher Fines	27.0	26.73
41761	Aggregate #2:	3/8" Aggregate	35.0	34.65
41760	Aggregate #3:	3/4" Aggregate	38.0	37.62
Lime	Admixture:	Hydrated Lime (wet prep)	1.0	0.99
		Total:	101.0	100.0
Test Method:	ADOT 201 & 815	Difference:	1.0	0.0

41762	41761	41760				Lime	Lab No.	ADOT	ADOT	ADOT	ADOT
27.0	35.0	38.0				1.0	Percent	413 ARAC	413 ARAC	413 ARAC	413 ARAC
Agg. #1	Agg. #2	Agg. #3				Admix	Sieve	Composite	Control Pts	Composite	Control Pts
Percent Passing							(US/mm)	w/o Admix	w/o Admix	w/ Admix	w/ Admix
100	100	100				100	1.5" / 37.5	100		100	
100	100	100				100	1.25 / 31.5	100		100	
100	100	100				100	1" / 25	100		100	
100	100	100				100	3/4" / 19	100	(100)	100	
100	100	52				100	1/2" / 12.5	82	(80-100)	82	
100	100	19				100	3/8" / 9.5	69	(65-80)	70	
100	61	1				100	1/4" / 6.3	49		49	
99	28	1				100	#4 / 4.75	37	(28-42)	38	
74	1	1				100	#8 / 2.36	21	(14-22)	21	
63	1	1				100	#10 / 2.00	18		19	
38	1	1				100	#16 / 1.18	11		12	
18	1	1				100	#30 / .600	6		7	
12	1	1				100	#40 / .425	4		5	
7	1	1				100	#50 / .300	3		4	
5	1	1				100	#100 / .150	2		3	
3.9	0.6	0.5				100.0	#200 / .075	1.5	(0-2.5)	2.4	



Weigh Card - Stockpiles

MACTEC

Max Theor. Gravity & Agg. Data

MACTEC Job No.:	4975-03-3015.11	Date:	June, 2004
MACTEC Lab No.:	41759	Mix Type:	ADOT 413
Project Name:	Cordes Jct.-Flagstaff Hwy	Source of Aggregate:	Dugas Pit
Project No.:	IM-017-B(005)A	Asphalt / Rubber Source:	Chevron / CRM
TRACS:	017 YV 256 H611501C	Asphalt Grade / Blend Type:	PG 58-22 / Type II
Project Loc.:	Badger Springs - Big Bug	Type of Admix.:	Lime

Maximum Theoretical Gravity (Rice) Test

Test Method: ARIZ 806

Percent of binder in Sample:		6.0
Weight of Flask:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample and Flask:	Flask 1	1073.7
	Flask 2	1072.9
	Flask 3	1071.7
Wt. of Sample, Flask ,Water, & Glass Plate:	Flask 1	3856.4
	Flask 2	3894.9
	Flask 3	3841.2
Weight of Glass Plate:	Flask 1	0.0
	Flask 2	0.0
	Flask 3	0.0
Weight of Sample in Air("Wmm"):	Flask 1	1073.7
	Flask 2	1072.9
	Flask 3	1071.7
Loss of binder from mixing:		5.1
Wt. of Flask ,and Water,(B):	Flask 1	3207.1
	Flask 2	3245.6
	Flask 3	3191.6
Wt. of Sample, Flask ,& Water,(C):	Flask 1	3856.4
	Flask 2	3894.9
	Flask 3	3841.2
Surface Dry Wt. SSD ("Wsd"):	Flask 1	1076.1
	Flask 2	1075.3
	Flask 3	1074.4
Volume of Voidless Mix ("Vvm"):	Flask 1	426.8
	Flask 2	426.0
	Flask 3	424.8
Maximum Sp. Gravity ("Gmm"):	Flask 1	2.516
	Flask 2	2.519
	Flask 3	2.523
Average Maximum Sp. Gravity ("Gmm"):		**2.519**
Average Maximum Density (PCF):		156.9
"Gmm" Range:		0.007

Weights in grams. 0.0 = item was tared

Maximum Theoretical Gravity (Rice) Test Design Calculations

ARB Specific Gravity:	1.050
Effective Specific Gravity:	2.766
ARB Absorbed (%):	0.43

Coarse Specific Gravity

Test Method: ARIZ 210

Oven-Dry Weight(g):	2964.5
"SSD" Weight(g):	3010.6
Weight in Water(g):	1930.1
Bulk (Dry) Sp. Gravity:	2.744
"SSD" Sp. Gravity:	2.786
Apparent Sp. Gravity:	2.866
Water Absorption(%):	1.55

Fine Specific Gravity

Test Method: ARIZ 211

Oven-Dry Weight(g):	489.4
"SSD" Weight(g):	500.0
Weight of Flask & Water(g):	670.8
Weight of Flask, Water & Sample(g):	990.8
Bulk (Dry) Sp. Gravity:	2.719
"SSD" Sp. Gravity:	2.778
Apparent Sp. Gravity:	2.889
Water Absorption(%):	2.17

Combined Specific Gravity

Admixture Sp. Gravity:	2.200
Comp. Bulk(Dry)(W/O Admix):	2.735
Comp. "SSD"(W/O Admix):	2.783
Comp. Apparent(W/O Admix):	2.874
Comp Water Absorb. (%)	1.77
Comp. Bulk(Dry)(with Admix):	2.728
Comp. "SSD"(with Admix):	2.776
Comp. Apparent(with Admix):	2.866

Composite Mineral Aggregate Properties

Property	Value	Spec
Sand Equiv. (AASHTO T-176) (%):	89	Min 55
Fractured Agg. 2 Face(ARIZ 212) (%):	99	Min 85
Fractured Agg. 1 Face(ARIZ 212) (%):	100	---
L.A. Abrasion (AASHTO T-96)		
L.A. Abrasion @ 100 Rev.(%):	6	Max 9
L.A. Abrasion @ 500 Rev.(%):	23	Max 40

MACTEC

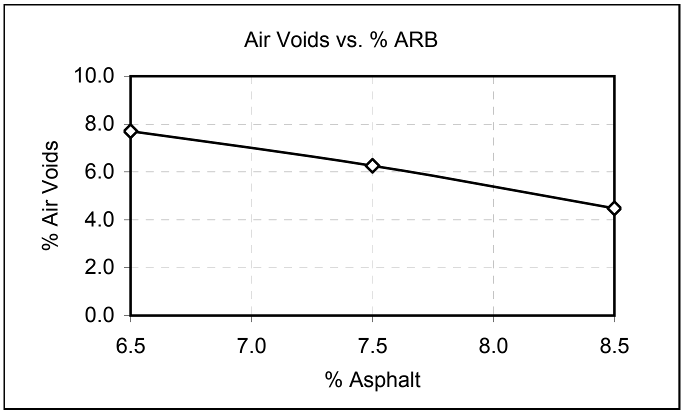
Volumetric Calculations

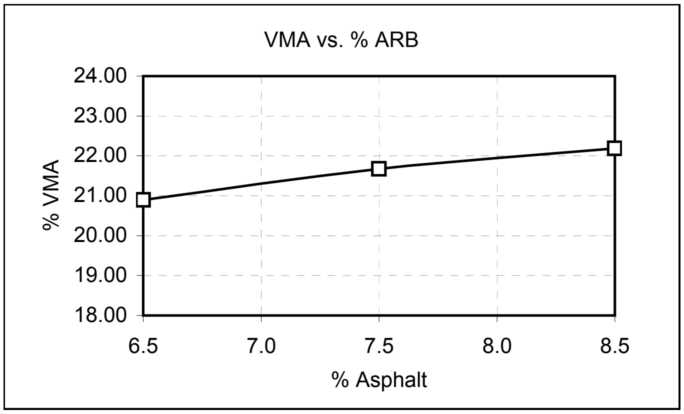
MACTEC Job No.: 4975-03-3015.11
MACTEC Lab No.: 41759
Project Name: Cordes Jct.-Flagstaff Hwy
Project No.: IM-017-B(005)A
TRACS: 017 YV 256 H611501C
Project Loc.: Badger Springs - Big Bug

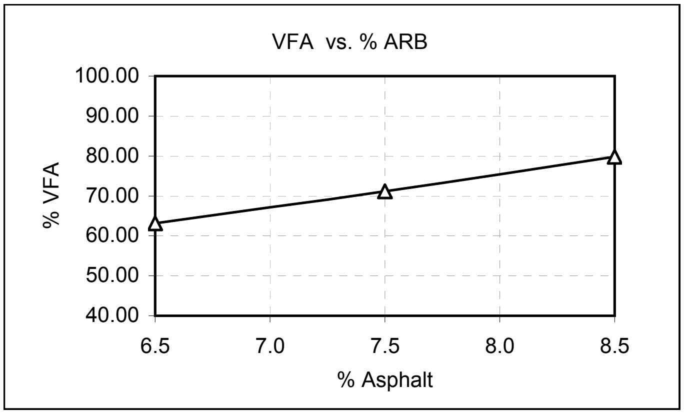
Date: June, 2004
Mix Type: ADOT 413
Source of Aggregate: Dugas Pit
Asphalt / Rubber Source: Chevron / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

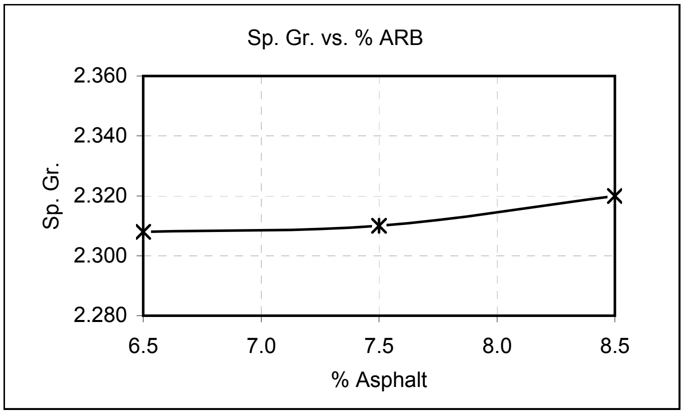
Volumetric Calculations Compaction Method: Marshall Calculation Method: A.I. SP-2 / MS-2

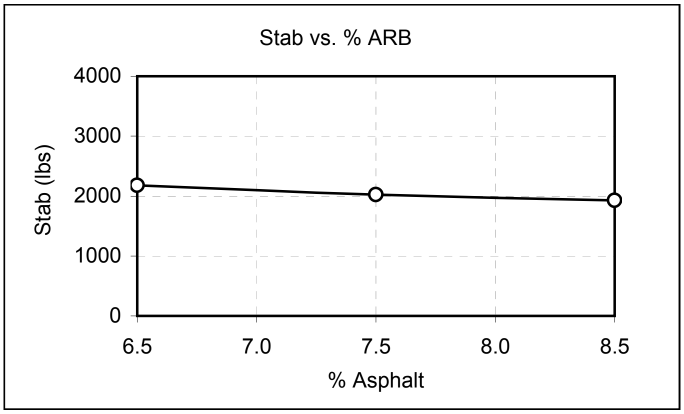
% Asph. (Tot Wt.)	Sp. Gr. (Gmb)	Agg. & Admix Vol. (%)	Admix Vol. (%)	Eff ARB Vol. (%)	Eff % ARB (Tot Wt.)	Dust to Eff. ARB Ratio	VMA (%)	VFA (%)	Eff. Voids (%)	Corrected Stab (lbs)	Flow (0.25 mm)	% Gmm	Gmm
6.5	2.308	79.100	1.039	13.394	6.094	0.40	20.90	63.18	7.7	2179	19	92.3	2.500
7.5	2.310	78.322	1.040	15.615	7.098	0.34	21.68	71.17	6.3	2022	20	93.7	2.464
8.5	2.320	77.811	1.044	17.902	8.102	0.30	22.19	79.84	4.5	1927	23	95.5	2.429
7.8	**2.313**	**78.170**	**1.041**	**16.299**	**7.399**	**0.33**	**21.8**	**73.80**	**5.7**	**2012**	**20**	**94.3**	**2.453**
							Min 19		(4.5-6.5)				

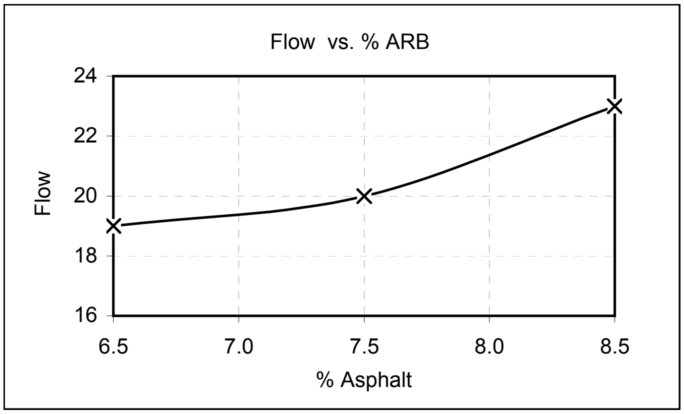

Air Voids vs. % ARB


VMA vs. % ARB


VFA vs. % ARB


Sp. Gr. vs. % ARB


Stab vs. % ARB


Flow vs. % ARB

MACTEC

Marshall Test Data

MACTEC Job No.: 4975-03-3015.11
MACTEC Lab No.: 41759
Project Name: Cordes Jct.-Flagstaff Hwy
Project No.: IM-017-B(005)A
TRACS: 017 YV 256 H611501C
Project Loc.: Badger Springs - Big Bug
Date: June, 2004
Mix Type: ADOT 413
Source of Aggregate: Dugas Pit
Asphalt / Rubber Source: Chevron / CRM
Asphalt Grade / Blend Type: PG 58-22 / Type II
Type of Admix.: Lime

Number of Blows: 75
Compaction / Mixing Temp: 325/325 F
Test Method: ARIZ 815

% ARB (Tot. Mix)	Spec. #	SSD Wt. (g)	H2O Wt. (g)	Air Wt. (g)	Specific Gravity	Unit Wt. (PCF)	Thickness (in.)	Stability (lbs)	Correction Factor	Corrected Stab (lbs)	Corrected Stab (kN)	Flow (0.25 mm)
6.5	1	1061.7	602.8	1059.1	2.308	143.8	2.325	1800	1.13	2034	9.0	17
	2	1065.3	603.0	1061.6	2.296	143.0	2.345	1950	1.11	2165	9.6	22
	3	1064.8	607.7	1060.2	2.319	144.5	2.315	2050	1.14	2337	10.4	17
				Average:	2.308	143.8			Average:	2179	9.7	19
				Range:	0.023	1.5						
7.5	4	1070.5	608.4	1068.8	2.313	144.1	2.357	1725	1.11	1915	8.5	19
	5	1073.0	609.3	1070.7	2.309	143.9	2.385	1925	1.08	2079	9.2	19
	6	1072.3	608.4	1070.2	2.307	143.7	2.344	1850	1.12	2072	9.2	22
				Average:	2.310	143.9			Average:	2022	9.0	20
				Range:	0.006	0.4						
8.5	7	1071.0	610.5	1069.8	2.323	144.7	2.355	1600	1.11	1776	7.9	23
	8	1078.1	612.6	1076.1	2.312	144.0	2.367	1775	1.10	1953	8.7	24
	9	1074.6	612.9	1073.6	2.325	144.8	2.346	1850	1.11	2054	9.1	22
				Average:	2.320	144.5			Average:	1927	8.6	23
				Range:	0.013	0.8						

Big Bug Version 2 Mix Design
Figure 33

Big Bug Round Robin
Compiled Preliminary AR-AC Round Robin Source Data for Plots
Table 33

Replicate	AR	Effect. Binder Volume,%			VMA, %			VFA, %			Effect. Air Voids,%		
Number	Content	B	C	D	B	C	D	B*	C	D	B	C	D
1	6.5	13.861	12.261	12.693	22.41	22.77	22.13	61.80	53.86	57.35	8.6	10.5	9.4
1	7.5	16.158	14.511	14.985	22.63	23.12	22.28	71.30	62.77	67.25	6.5	8.6	7.3
1	8.5	18.366	16.825	17.224	23.36	23.31	22.85	78.60	72.18	75.38	5.0	6.5	5.6
2	6.5	13.765	12.756	13.222	22.15	22.53	20.75	62.10	56.63	63.72	8.4	9.8	7.5
2	7.5	15.986	14.932	15.430	22.77	23.29	21.53	70.20	64.12	71.67	6.8	8.4	6.1
2	8.5	18.197	17.255	17.466	23.48	23.41	23.09	77.50	73.71	75.65	5.3	6.2	5.6
3	6.5	14.064	12.529	13.241	22.34	22.83	21.16	63.00	54.87	62.57	8.3	10.3	7.9
3	7.5	16.337	14.829	15.370	22.67	22.91	22.28	72.10	64.72	68.98	6.3	8.1	6.9
3	8.5	18.603	17.058	17.522	23.16	23.51	23.22	80.30	72.55	75.45	4.6	6.5	5.7

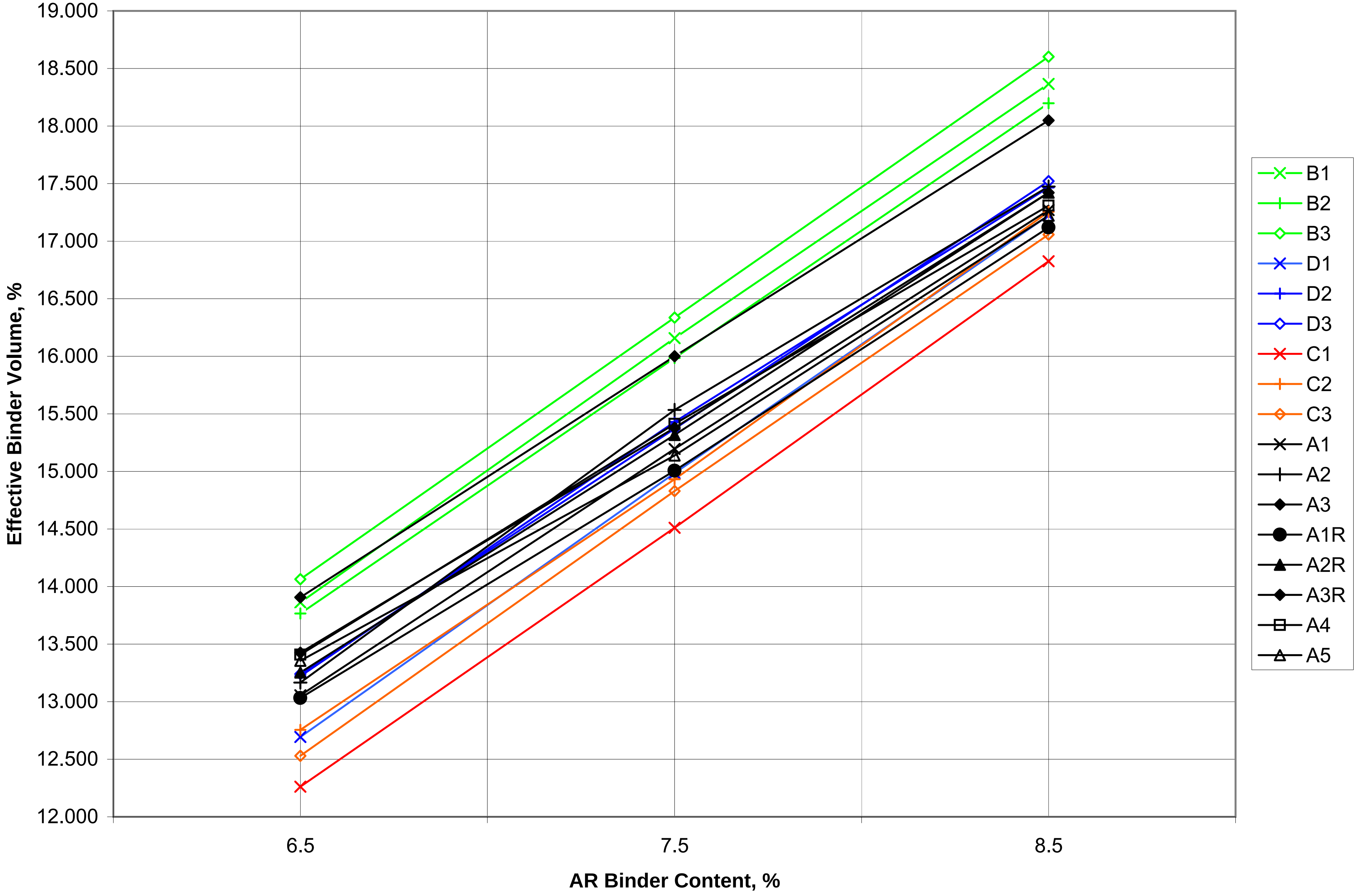
		Stability, lbs			Flow		
		B	C	D	B	C	D
1	6.5	2046	1888	1505	21	32	23
1	7.5	2030	1790	1352	21	35	19
1	8.5	1754	909	1355	20	38	20
2	6.5	1724	1297	1846	21	34	21
2	7.5	1669	1236	1842	16	35	22
2	8.5	1835	928	1679	22	37	23
3	6.5	2170	1317	1699	20	31	22
3	7.5	1843	1078	1725	23	31	22
3	8.5	1815	1145	1632	23	36	23

NOTES

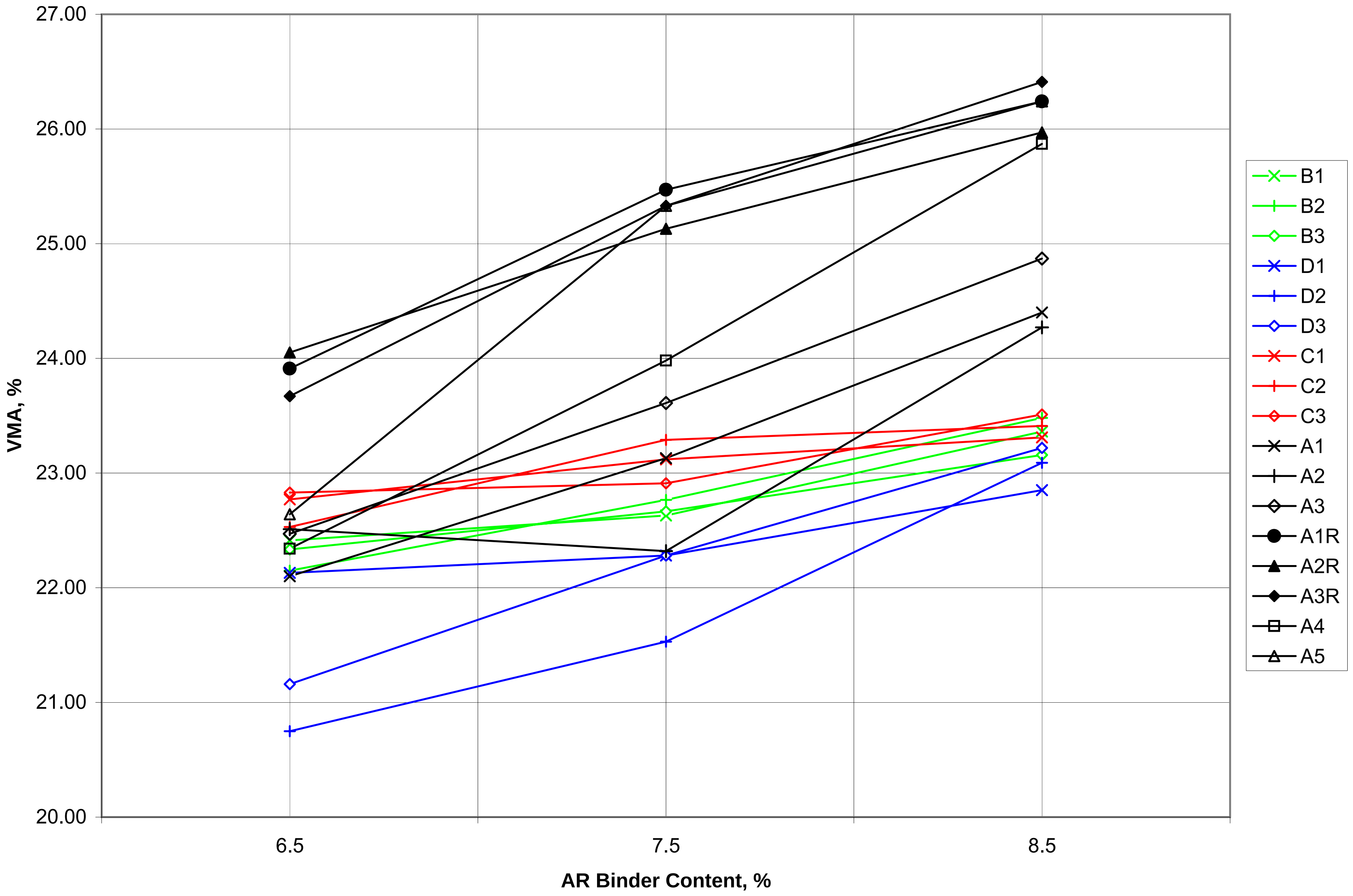
* Data provided had only one decimal place

Big Bug Round Robin
Compiled Preliminary AR-AC Round Robin Source Data for Plots
Table 33

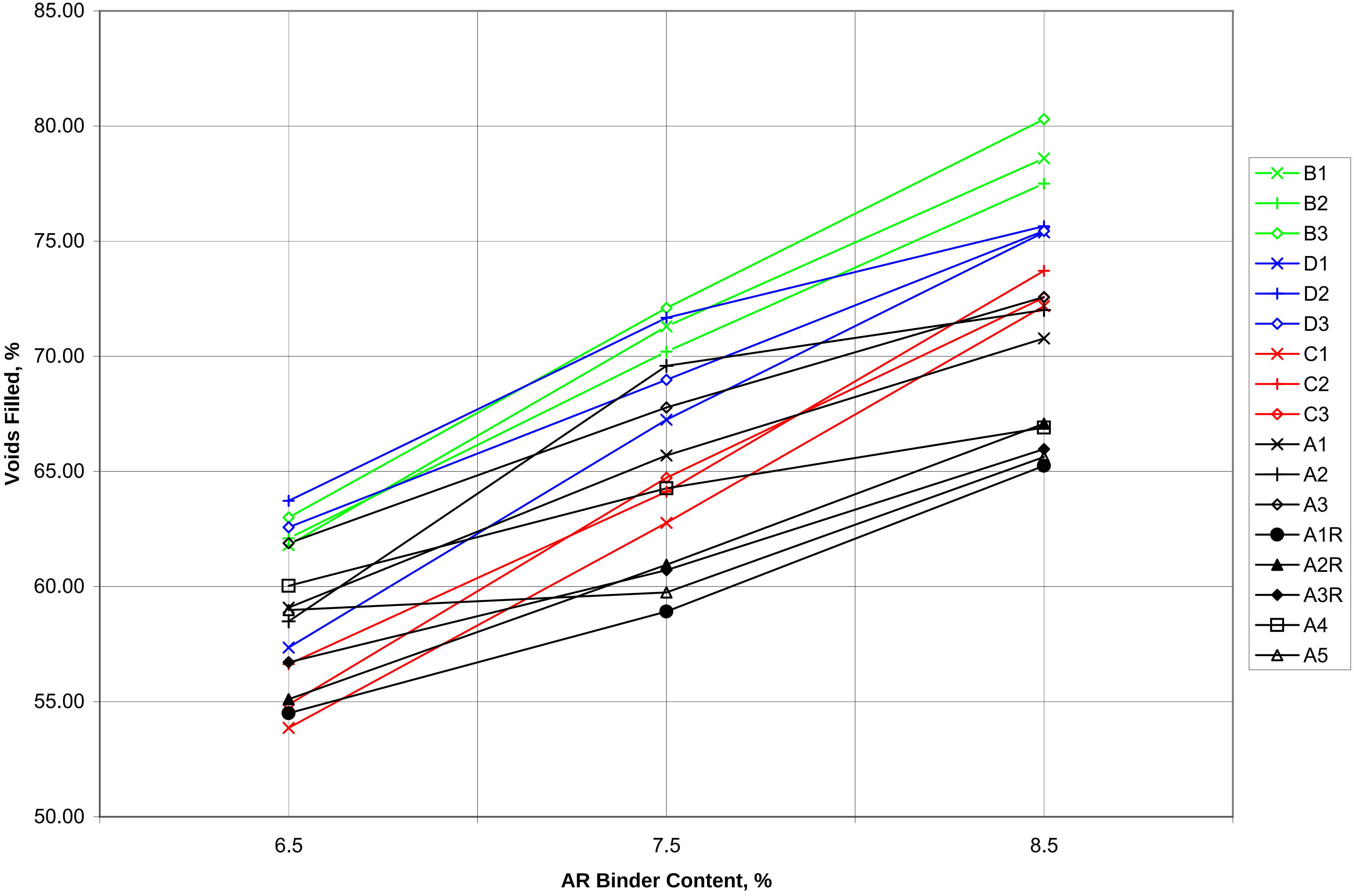
Replicate Number	AR Content	Effect. Binder Volume,%	VMA, %	VFA, %	Effect. Air Voids, %	Stability, lbs	Flow
		A	A	A	A	A	A
1	6.5	13.056	22.10	59.08	9.0	1596	15
1	7.5	15.195	23.13	65.69	7.9	1456	27
1	8.5	17.270	24.40	70.78	7.1	1425	30
2	6.5	13.165	22.51	58.49	9.3	1799	22
2	7.5	15.534	22.32	69.59	6.8	1794	25
2	8.5	17.474	24.27	72.01	6.8	1326	24
3	6.5	13.906	22.47	61.88	8.6	2022	29
3	7.5	16.001	23.61	67.78	7.6	2098	23
3	8.5	18.048	24.87	72.57	6.8	1428	30
1R	6.5	13.031	23.91	54.50	10.9	1094	28
1R	7.5	15.007	25.47	58.92	10.5	1104	28
1R	8.5	17.120	26.24	65.24	9.1	1062	28
2R	6.5	13.253	24.05	55.11	10.8	1132	30
2R	7.5	15.317	25.13	60.95	9.8	1067	32
2R	8.5	17.421	25.97	67.07	8.6	1143	34
3R	6.5	13.425	23.67	56.71	10.2	1303	29
3R	7.5	15.379	25.33	60.71	10.0	1191	34
3R	8.5	17.421	26.41	65.97	9.0	1048	36
4	6.5	13.408	22.34	60.03	8.9	1910	29
4	7.5	15.412	23.98	64.27	8.6	992	25
4	8.5	17.308	25.87	66.90	8.6	809	30
5	6.5	13.355	22.64	58.98	9.3	1353	28
5	7.5	15.138	25.33	59.75	10.2	1075	31
5	8.5	17.222	26.24	65.63	9.0	1157	38



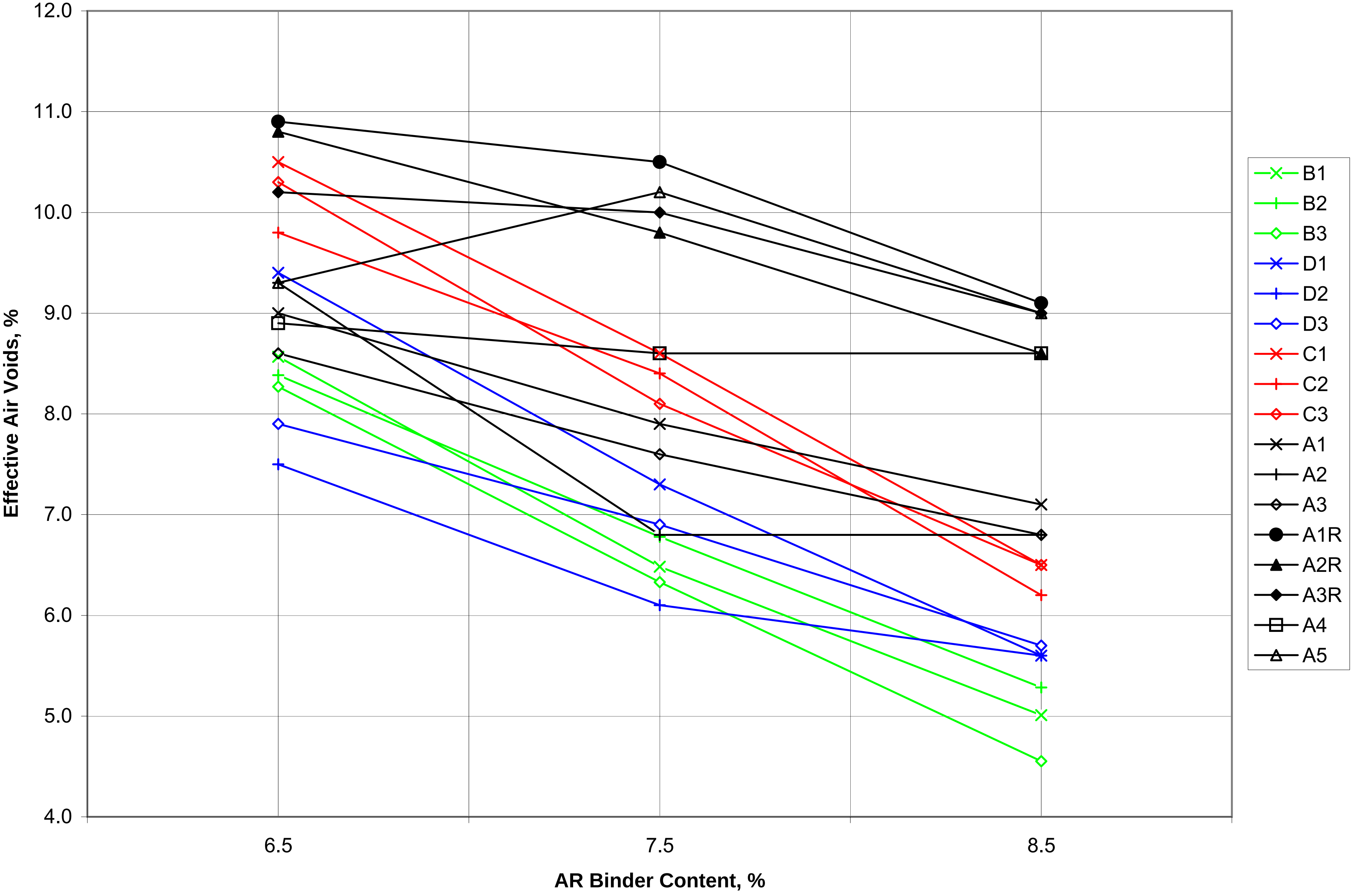
Preliminary Big Bug Effective AR Binder Volume
Figure 34



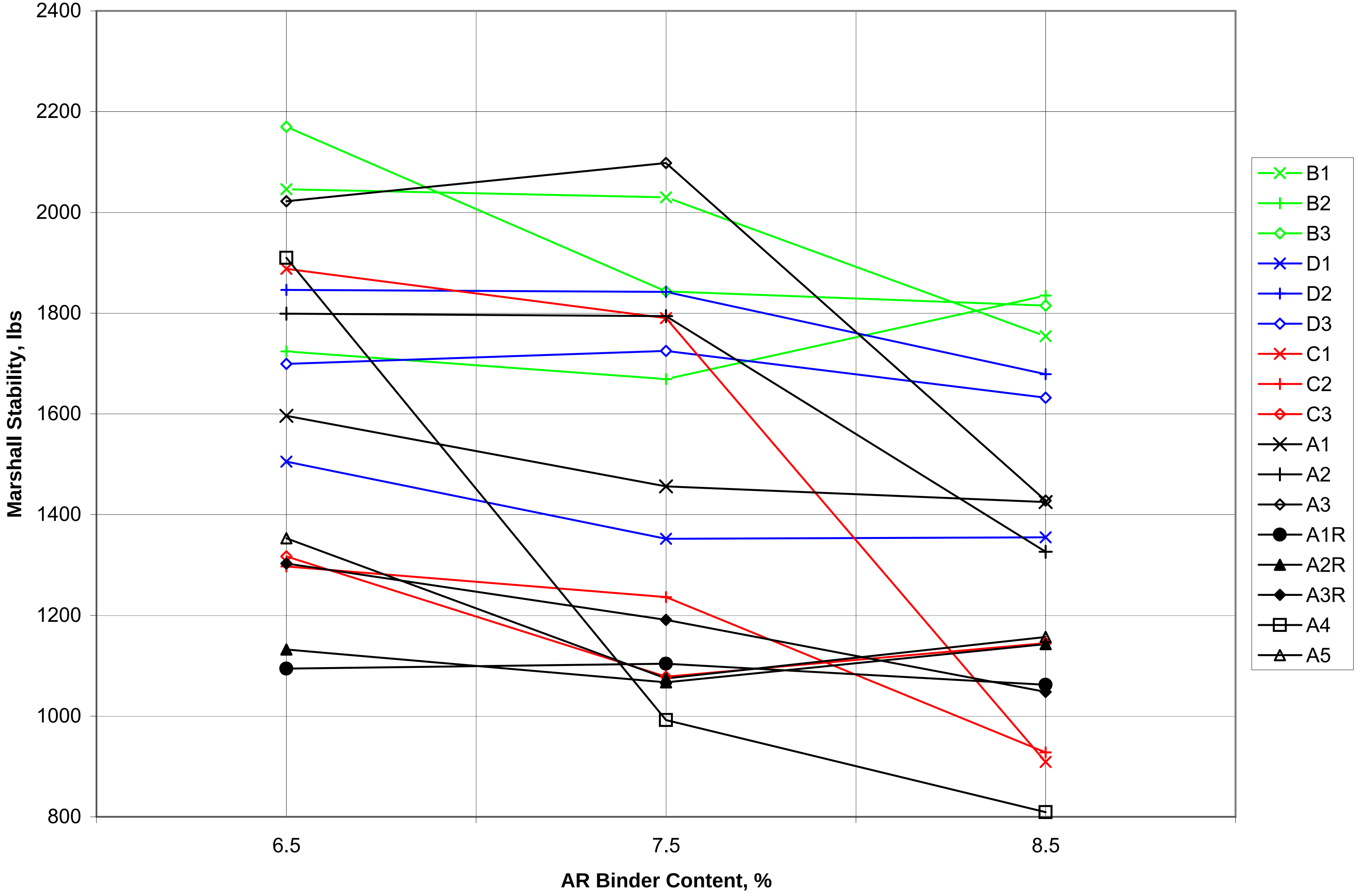
Preliminary Big Bug VMA
Figure 35



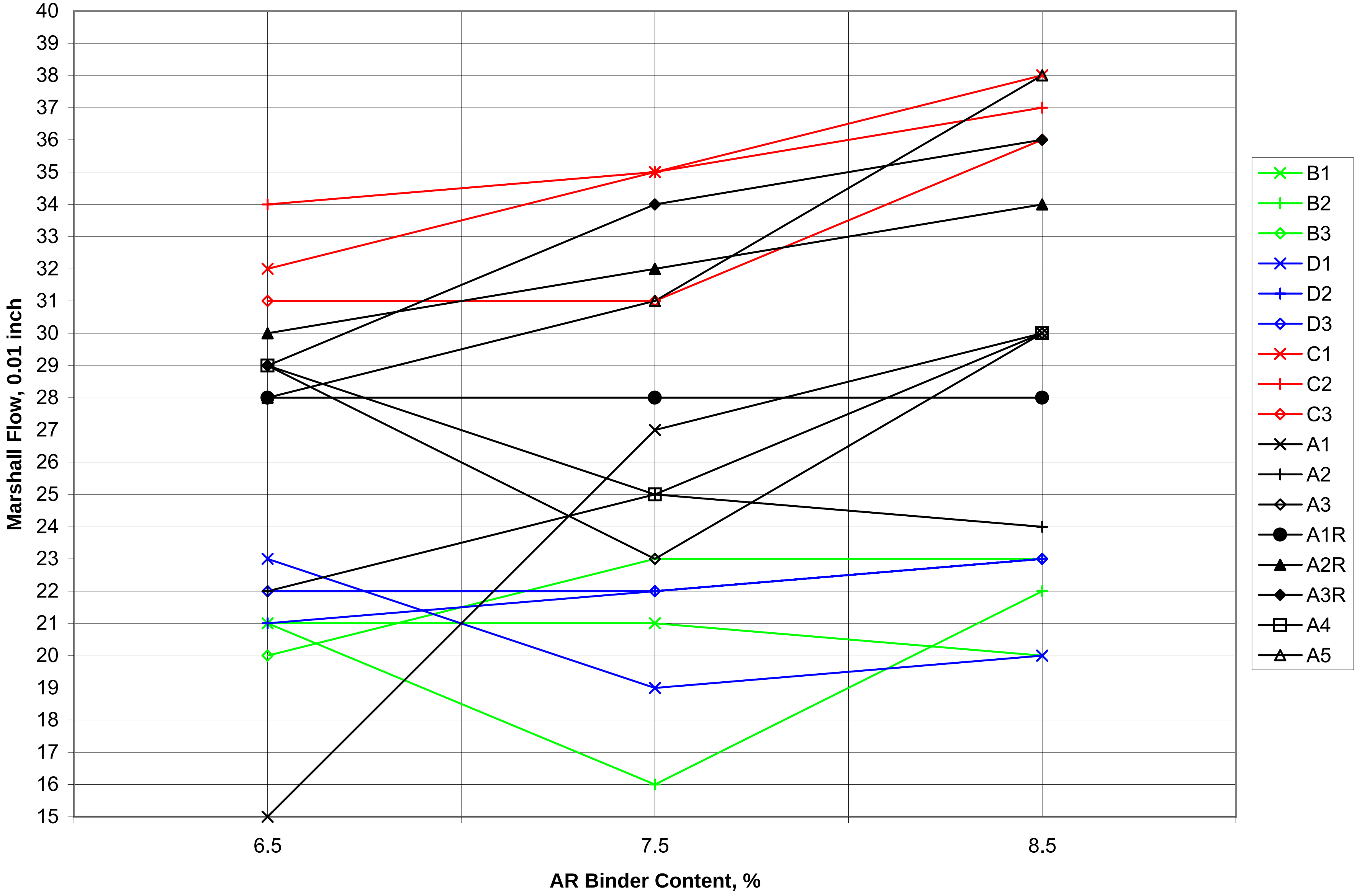
Preliminary Big Bug VFA
Figure 36



Preliminary Big Bug Air Voids
Figure 37



Preliminary Big Bug Stability
Figure 38



Preliminary Big Bug Flow
Figure 39

DUNCAN'S MULTIPLE RANGE TEST
Table 34

Description of Duncan's Multiple Range Test for comparing and ranking means of test results.

Standard error of each average is:

$$\boxed{S_{\overline{y_i.}} = \sqrt{\frac{MS_E}{n_h}}}$$

Use MSE from corresponding ANOVA

For unequal sample sizes, use harmonic mean n_h, where

$$\boxed{n_h = \frac{a}{\sum_{i=1}^{a} 1/n_i}}$$

a = treatment = lab

For the round robin, n_h is calculated as follows and remains constant

$$\boxed{n_h = \frac{4}{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}+\frac{1}{8}} = \frac{4}{1.125} = 3.556}$$

Calculate *a-1* significant ranges for comparing the mean values for each laboratory as follows:

Use Duncan/s Table of Significant Ranges (Montgomery, Design and Analysis of Experiments Appendix Table VII) to obtain the respective Rp values indicated below:

$$\boxed{R_p = r_\alpha(p, f)S_{\overline{y_{i.}}}}$$

for *p = 2,3, ..a*

where *f* = degrees of freedom for error (MSE) = 13 for this analysis
and α = significance level (0.05 for this analysis)

Means are arranged in order of low to high individual value.

$$\boxed{R_4 = 3.30 S_{\overline{y_i}}}$$

Range of means spaced 4 apart (highest vs. lowest value)

$$\boxed{R_3 = 3.21 S_{\overline{y_i}}}$$

Range of means spaced 3 apart

$$\boxed{R_2 = 3.06 S_{\overline{y_i}}}$$

Range of adjacent means

If the difference between individual means exceeds the corresponding range, then the means are considered to differ.

Lines are drawn under the ordered means to group like means together and identify which are different.

Big Bug Round Robin
Preliminary Statistical Analysis at 6.5% AR Binder Content
Table 35

EFFECTIVE AR VOLUME @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
13.861	12.261	12.693	13.056
13.765	12.756	13.222	13.165
14.064	12.529	13.241	13.906
			13.031
			13.253
			13.425
			13.408
			13.355

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	41.69	13.89666667	0.023304333	0.1527
C	3	37.546	12.51533333	0.061396333	0.2478
D	3	39.156	13.052	0.096751	0.3110
A	8	106.599	13.324875	0.077847268	0.2790

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.03225485	3	1.010751617	14.47375622	0.000195	3.410534
Within Groups	0.907834208	13	0.069833401			
Total	3.940089059	16				

Hypothesis 0 rejected: At least two of the mean Effective AR Volume values are not equal

DUNCAN'S MULTIPLE RANGE TEST for EFFECTIVE AR VOLUME @ 6.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.1401

R4 = 0.462
R3 = 0.450
R2 = 0.429

AvgC=12.515 AvgD=13.052 AvgA=13.325 AvgB=13.897

Big Bug Round Robin
Preliminary Statistical Analysis at 6.5% AR Binder Content
Table 35

VMA @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
22.41	22.77	22.13	22.10
22.15	22.53	20.75	22.51
22.34	22.83	21.16	22.47
			23.91
			24.05
			23.67
			22.34
			22.64

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B	3	66.9	22.3	0.0181
C	3	68.13	22.71	0.0252
D	3	64.04	21.34666667	0.502233333
A	8	183.69	22.96125	0.609098214

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.940869363	3	1.980289788	4.807646894	0.01821	3.410534
Within Groups	5.354754167	13	0.411904167			
Total	11.29562353	16				

Hypothesis 0 rejected: At least two of the mean VMA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for VMA @ 6.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}} \qquad 0.3403$$

R4 = 1.123
R3 = 1.093
R2 = 1.041

Avg D=21.35 Avg B=22.3 Avg C=22.71 Avg A=22.96

Big Bug Round Robin
Preliminary Statistical Analysis at 6.5% AR Binder Content
Table 35

VFA @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
61.8	53.86	57.35	59.08
62.1	56.63	63.72	58.49
63.0	54.87	62.57	61.88
			54.50
			55.11
			56.71
			60.03
			58.98

NOTE: Lab B data was reported to only 1 decimal place

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B	3	186.9	62.3	0.39
C	3	165.36	55.12	1.9651
D	3	183.64	61.21333333	11.52463333
A	8	464.78	58.0975	6.247478571

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	98.72917157	3	32.90972386	5.984271069	0.008615	3.410534
Within Groups	71.49181667	13	5.499370513			
Total	170.2209882	16				

Hypothesis 0 rejected: At least two of the mean VFA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for VFA @ 6.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 1.2436

R4 = 4.104
R3 = 3.992
R2 = 3.805

Avg C=55.12 Avg A=58.10 Avg D=61.21 Avg B=62.3

Big Bug Round Robin
Preliminary Statistical Analysis at 6.5% AR Binder Content
Table 35

EFFECTIVE AIR VOIDS @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A	Average	9.3
8.6	10.5	9.4	9.0	1s	1.017
8.4	9.8	7.5	9.3	d2s	2.878
8.3	10.3	7.9	8.6	1s%	10.96
			10.9	d2s%	31.03
			10.8		
			10.2		
			8.9		
			9.3		

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	25.3	8.433333333	0.023333333	0.153
C	3	30.6	10.2	0.13	0.361
D	3	24.8	8.266666667	1.003333333	1.002
A	8	77	9.625	0.787857143	0.888

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.722254902	3	2.907418301	4.828158983	0.01796	3.410534
Within Groups	7.828333333	13	0.602179487			
Total	16.55058824	16				

Hypothesis 0 rejected: At least two of the mean air voids values are not equal

DUNCAN'S MULTIPLE RANGE TEST for EFFECTIVE AIR VOIDS @ 6.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}} \quad 0.4115$$

R4 = 1.358
R3 = 1.321
R2 = 1.259

Avg D= 8.27 Avg B=8.43 Avg A=9.63 Avg C=10.20

NOTE: If average values are rounded to a single decimal, Lab A results do not differ from those of Labs D and B

Big Bug Round Robin
Preliminary Statistical Analysis at 6.5% AR Binder Content
Table 35

STABILITY @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
2046	1888	1505	1596
1724	1297	1846	1799
2170	1317	1699	2022
			1094
			1132
			1303
			1910
			1353

Anova: Single Factor   α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	5940	1980	52996	230
C	3	4502	1500.666667	112620.3333	336
D	3	5050	1683.333333	29254.33333	171
A	8	12209	1526.125	127774.125	357

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	512530.027	3	170843.3423	1.729506518	0.21016	3.410534
Within Groups	1284160.208	13	98781.55449			
Total	1796690.235	16				

Hypothesis 0 supported: The mean Marshall stability values do not differ.

Big Bug Round Robin
Preliminary Statistical Analysis at 6.5% AR Binder Content
Table 35

FLOW @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
21	32	23	15
21	34	21	22
20	31	22	29
			28
			30
			29
			29
			28

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	62	20.66666667	0.333333333	0.58
C	3	97	32.33333333	2.333333333	1.53
D	3	66	22	1	1.00
A	8	210	26.25	26.78571429	5.18

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	251.2843137	3	83.76143791	5.588872675	0.010978	3.410534
Within Groups	194.8333333	13	14.98717949			
Total	446.1176471	16				

Hypothesis 0 rejected: At least two of the mean flow values are not equal

DUNCAN'S MULTIPLE RANGE TEST for MARSHALL FLOW @ 6.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 2.0530

R4 = 6.775
R3 = 6.590
R2 = 6.282

Avg B=20.7 Avg D=22.0 Avg A=26.3 Avg C=32.3

Big Bug Round Robin
Preliminary Statistical Analysis at 7.5% AR Binder Content
Table 36

EFFECTIVE AR VOLUME @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
16.158	14.511	14.985	15.195
15.986	14.932	15.430	15.534
16.337	14.829	15.370	16.001
			15.007
			15.317
			15.379
			15.412
			15.138

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	48.481	16.16033333	0.030804333	0.1755
C	3	44.272	14.75733333	0.048162333	0.2195
D	3	45.785	15.26166667	0.058308333	0.2415
A	8	122.983	15.372875	0.092266125	0.3038

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.032097243	3	1.010699081	14.27521106	0.000209	3.410534
Within Groups	0.920412875	13	0.07080099			
Total	3.952510118	16				

Hypothesis 0 rejected: At least two of the mean Effective AR Volume values are not equal

DUNCAN'S MULTIPLE RANGE TEST for EFFECTIVE AR VOLUME @ 7.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.1411

R4 = 0.466
R3 = 0.453
R2 = 0.432

AvgC=14.757 AvgD=15.262 AvgA=15.373 AvgB=16.160

Big Bug Round Robin
Preliminary Statistical Analysis at 7.5% AR Binder Content
Table 36

VMA @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
22.63	23.12	22.28	23.13
22.77	23.29	21.53	22.32
22.67	22.91	22.28	23.61
			25.47
			25.13
			25.33
			23.98
			25.33

Anova: Single Factor α = 0.05

SUMMARY

Groups	Count	Sum	Average	Variance	Std Dev
B	3	68.07	22.69	0.0052	0.072
C	3	69.32	23.10666667	0.036233333	0.190
D	3	66.09	22.03	0.1875	0.433
A	8	194.3	24.2875	1.435164286	1.198

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.7023598	3	4.567453268	5.652779729	0.01055	3.410534
Within Groups	10.50401667	13	0.808001282			
Total	24.20637647	16				

Hypothesis 0 rejected: At least two of the mean VMA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for VMA @ 7.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.4767

R4 = 1.573
R3 = 1.530
R2 = 1.459

Avg D=22.03 Avg B=22.69 Avg C=23.11 Avg A=24.29

Big Bug Round Robin
Preliminary Statistical Analysis at 7.5% AR Binder Content
Table 36

VFA @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
71.3	62.77	67.25	65.69
70.2	64.12	71.67	69.59
72.1	64.72	68.98	67.78
			58.92
			60.95
			60.71
			64.27
			59.75

NOTE: Lab B data was reported to only 1 decimal place

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	213.6	71.2	0.91	0.954
C	3	191.61	63.87	0.9975	0.999
D	3	207.9	69.3	4.9609	2.227
A	8	507.66	63.4575	15.72950714	3.966

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	179.0261559	3	59.67538529	6.264204003	0.007294	3.410534
Within Groups	123.84335	13	9.526411538			
Total	302.8695059	16				

Hypothesis 0 rejected: At least two of the mean VFA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for VFA @ 7.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 1.6368

R4 = 5.401
R3 = 5.254
R2 = 5.008

Avg A=63.46   Avg C=63.87   Avg D=69.3   Avg B=71.2

Big Bug Round Robin
Preliminary Statistical Analysis at 7.5% AR Binder Content
Table 36

EFFECTIVE AIR VOIDS @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A	Average	8.0
6.5	8.6	7.3	7.9	1s	1.430
6.8	8.4	6.1	6.8	d2s	4.046
6.3	8.1	6.9	7.6	1s%	17.82
			10.5	d2s%	50.43
			9.8		
			10.0		
			8.6		
			10.2		

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	19.6	6.533333333	0.063333333	0.252
C	3	25.1	8.366666667	0.063333333	0.252
D	3	20.3	6.766666667	0.373333333	0.611
A	8	71.4	8.925	1.922142857	1.386

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.25558824	3	6.085196078	5.472677206	0.011808	3.410534
Within Groups	14.455	13	1.111923077			
Total	32.71058824	16				

Hypothesis 0 rejected: At least two of the mean air voids values are not equal

DUNCAN'S MULTIPLE RANGE TEST for EFFECTIVE AIR VOIDS @ 7.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.5592

R4 = 1.845
R3 = 1.795
R2 = 1.711

Avg B=6.53 Avg D=6.77 Avg C=8.37 Avg A=8.93

Big Bug Round Robin
Preliminary Statistical Analysis at 7.5% AR Binder Content
Table 36

STABILITY @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
2030	1790	1352	1456
1669	1236	1842	1794
1843	1078	1725	2098
			1104
			1067
			1191
			992
			1075

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	5542	1847.333333	32594.33333	181
C	3	4104	1368	139804	374
D	3	4919	1639.666667	65486.33333	256
A	8	10777	1347.125	162497.8393	403

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	658211.3211	3	219403.7737	1.768009681	0.202755	3.410534
Within Groups	1613254.208	13	124096.4776			
Total	2271465.529	16				

Hypothesis 0 supported: The mean Marshall stability values do not differ.

Big Bug Round Robin
Preliminary Statistical Analysis at 7.5% AR Binder Content
Table 36

FLOW @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
21	35	19	27
16	35	22	25
23	31	22	23
			28
			32
			34
			25
			31

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	60	20	13	3.6
C	3	101	33.66666667	5.333333333	2.3
D	3	63	21	3	1.7
A	8	225	28.125	14.98214286	3.9

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	392.5759804	3	130.8586601	11.53004856	0.000576	3.410534
Within Groups	147.5416667	13	11.34935897			
Total	540.1176471	16				

Hypothesis 0 rejected: At least two of the mean flow values are not equal

DUNCAN'S MULTIPLE RANGE TEST for MARSHALL FLOW @ 7.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$

1.7865

R4 = 5.895
R3 = 5.735
R2 = 5.467

Avg B=20 Avg D=21 Avg A=28.1 Avg C=33.7

Big Bug Round Robin
Preliminary Statistical Analysis at 8.5% AR Binder Content
Table 37

EFFECTIVE AR VOLUME @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
18.366	16.825	17.224	17.270
18.197	17.255	17.466	17.474
18.603	17.058	17.522	18.048
			17.120
			17.421
			17.421
			17.308
			17.222

Anova: Single Factor   α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	55.166	18.38866667	0.041594333	0.2039
C	3	51.138	17.046	0.046333	0.2153
D	3	52.212	17.404	0.025084	0.1584
A	8	139.284	17.4105	0.080118286	0.2831

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.073969216	3	1.024656405	16.92892163	8.92049E-05	3.410534
Within Groups	0.786850667	13	0.060526974			
Total	3.860819882	16				

Hypothesis 0 rejected: At least two of the mean Effective AR Volume values are not equal

DUNCAN'S MULTIPLE RANGE TEST for EFFECTIVE AR VOLUME @ 8.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$

0.1305

R4 = 0.431
R3 = 0.419
R2 = 0.399

AvgC=17.046 AvgD=17.404 AvgA=17.411 AvgB=18.389

Big Bug Round Robin
Preliminary Statistical Analysis at 8.5% AR Binder Content
Table 37

VMA @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
23.36	23.31	22.85	24.40
23.48	23.41	23.09	24.27
23.16	23.51	23.22	24.87
			26.24
			25.97
			26.41
			25.87
			26.24

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	70	23.33333333	0.026133333	0.162
C	3	70.23	23.41	0.01	0.100
D	3	69.16	23.05333333	0.035233333	0.188
A	8	204.27	25.53375	0.770255357	0.878

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.00083211	3	7.333610703	17.2258705	8.16355E-05	3.410534
Within Groups	5.534520833	13	0.425732372			
Total	27.53535294	16				

Hypothesis 0 rejected: At least two of the mean VMA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for VMA @ 8.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}} \quad 0.3460$$

R4 = 1.142
R3 = 1.111
R2 = 1.059

Avg D=23.05 Avg B=23.33 Avg C=23.41 Avg A=25.53

Big Bug Round Robin
Preliminary Statistical Analysis at 8.5% AR Binder Content
Table 37

VFA @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
78.6	72.18	75.38	70.78
77.5	73.71	75.65	72.01
80.3	72.55	75.45	72.57
			65.24
			67.07
			65.97
			66.90
			65.63

NOTE: Lab B data was reported to only 1 decimal place

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	236.4	78.8	1.99	1.411
C	3	218.44	72.81333333	0.637233333	0.798
D	3	226.48	75.49333333	0.019633333	0.140
A	8	546.17	68.27125	9.076441071	3.013

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	287.8268027	3	95.94226757	18.1210351	6.29301E-05	3.410534
Within Groups	68.82882083	13	5.294524679			
Total	356.6556235	16				

Hypothesis 0 rejected: At least two of the mean VFA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for VFA @ 8.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}} \quad 1.2202$$

R4 = 4.027
R3 = 3.917
R2 = 3.734

Avg A=68.27 Avg C=72.81 Avg D=75.49 Avg B=78.8

Big Bug Round Robin
Preliminary Statistical Analysis at 8.5% AR Binder Content
Table 37

EFFECTIVE AIR VOIDS @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A	Average	6.82
5	6.5	5.6	7.1	1s	1.510
5.3	6.2	5.6	6.8	d2s	4.274
4.6	6.5	5.7	6.8	1s%	22.13
			9.1	d2s%	62.63
			8.6		
			9.0		
			8.6		
			9.0		

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	14.9	4.966666667	0.123333333	0.35
C	3	19.2	6.4	0.03	0.17
D	3	16.9	5.633333333	0.003333333	0.06
A	8	65	8.125	1.070714286	1.03

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.6822549	3	9.560751634	15.9175801	0.000121791	3.410534
Within Groups	7.808333333	13	0.600641026			
Total	36.49058824	16				

Hypothesis 0 rejected: At least two of the mean air voids values are not equal

DUNCAN'S MULTIPLE RANGE TEST for EFFECTIVE AIR VOIDS @ 8.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}} \quad 0.4110$$

R4 = 1.356
R3 = 1.319
R2 = 1.258

Avg B=4.97 Avg D=5.63 Avg C=6.40 Avg A=8.13

Big Bug Round Robin
Preliminary Statistical Analysis at 8.5% AR Binder Content
Table 37

STABILITY @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
1754	909	1355	1425
1835	928	1679	1326
1815	1145	1632	1428
			1062
			1143
			1048
			809
			1157

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	5404	1801.333333	1780.333333	42
C	3	2982	994	17191	131
D	3	4666	1555.333333	30652.33333	175
A	8	9398	1174.75	44787.35714	212

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1348793.284	3	449597.7614	14.16025637	0.000217323	3.410534
Within Groups	412758.8333	13	31750.67949			
Total	1761552.118	16				

Hypothesis 0 rejected: The mean Marshall stability values are not equal.

DUNCAN'S MULTIPLE RANGE TEST for MARSHALL STABILITY @ 8.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 94.4921

R4 = 311.824
R3 = 303.320
R2 = 289.146

Avg C=994 Avg A=1175 Avg D=1555 Avg B=1801

Big Bug Round Robin
Preliminary Statistical Analysis at 8.5% AR Binder Content
Table 37

FLOW @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
20	38	20	30
22	37	23	24
23	36	23	30
			28
			34
			36
			30
			38

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std Dev*
B	3	65	21.66666667	2.333333333	1.5
C	3	111	37	1	1.0
D	3	66	22	3	1.7
A	8	250	31.25	20.5	4.5

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	540.7745098	3	180.2581699	15.00548266	0.000163441	3.410534
Within Groups	156.1666667	13	12.01282051			
Total	696.9411765	16				

Hypothesis 0 rejected: At least two of the mean flow values are not equal

DUNCAN'S MULTIPLE RANGE TEST for MARSHALL FLOW @ 8.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 1.8380

R4 = 6.065
R3 = 5.900
R2 = 5.624

Avg B=21.7 Avg D=22 Avg A=31.3 Avg C=37

Big Bug Round Robin

Preliminary Statistical Analysis Summary of Duncan's Multiple Range Comparisons of Mean Results

Table 38

AR Content (%)	MIXTURE PROPERTY											
	Effective AR Binder Volume				**VMA**				**VFA**			
6.5	C	D	A	B	D	B	C	A	C	A	D	B
	12.515	13.052	13.325	13.897	21.35	22.3	22.71	22.96	55.12	58.1	61.21	62.3
7.5	C	D	A	B	D	B	C	A	A	C	D	B
	14.757	15.262	15.373	16.16	22.03	22.69	23.11	24.29	63.5	63.9	69.3	71.2
8.5	C	D	A	B	D	B	C	A	A	C	D	B
	17.046	17.404	17.411	18.389	23.05	23.33	23.41	25.53	68.3	72.8	75.5	78.8
	Effective Air Voids				**Marshall Stability**				**Marshall Flow**			
6.5	D	B	A	C	C	A	D	B	B	D	A	C
	8.3	8.4	9.6	10.2	1501	1526	1683	1980	20.7	22	26.3	32.3
	*		*		No Statistical Difference							
	*D and A differ when results not rounded											
7.5	B	D	C	A	A	C	D	B	B	D	A	C
	6.5	6.8	8.4	8.9	1347	1368	1640	1847	20	21	28.1	33.7
					No Statistical Difference							
8.5	B	D	C	A	C	A	D	B	B	D	A	C
	5	5.6	6.4	8.1	994	1175	1555	1801	21.7	22	31.3	37

Big Bug Round Robin
Statistical Analysis of Bulk Specific Gravity of Marshall Specimens
Table 39

BULK SPECIFIC GRAVITY OF MARSHALL SPECIMENS @ 6.5% AR Binder
(Not affected by normalizing data)

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
2.262	2.245	2.240	2.269
2.274	2.250	2.255	2.289
2.284	2.256	2.268	2.274
2.283	2.253	2.293	2.270
2.274	2.254	2.296	2.281
2.287	2.263	2.292	2.244
2.274	2.251	2.270	2.276
2.273	2.241	2.297	2.261
2.281	2.253	2.278	2.261
			2.221
			2.236
			2.215
			2.206
			2.249
			2.204
			2.226
			2.228
			2.238
			2.280
			2.251
			2.278
			2.270
			2.270
			2.244

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std. Dev
B	9	20.49207079	2.276896755	5.94498E-05	0.0077
C	9	20.266	2.251777778	3.96944E-05	0.0063
D	9	20.489	2.276555556	0.000403028	0.0201
A	24	54.041	2.251708333	0.000640998	0.0253

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.007279316	3	0.002426439	6.0789227	0.001390186	2.802352
Within Groups	0.018760334	47	0.000399156			
Total	0.026039651	50				

Hypothesis 0 rejected: At least two of the mean bulk specific gravity values are not equal

Big Bug Round Robin
Statistical Analysis of Bulk Specific Gravity of Marshall Specimens
Table 39

DUNCAN'S MULTIPLE RANGE TEST for BULK SPECIFIC GRAVITY @ 6.5% AR Binder

$$\boxed{n_h = \frac{4}{\frac{1}{9}+\frac{1}{9}+\frac{1}{9}+\frac{1}{24}} = \frac{4}{0.375} = 10.667}$$

$$\boxed{S_{\overline{y_i}\cdot} = \sqrt{\frac{MS_E}{n_h}}}$$

0.006117165

R4 = 0.0189
R3 = 0.0184
R2 = 0.0174

AvgA=2.2517 AvgC=2.2518 AvgD=2.2766 AvgB=2.2769

PRECISION CALCULATIONS

Average	2.261
1s	0.023
d2s	0.065
1s%	1.01
d2s%	2.86

Big Bug Round Robin
Statistical Analysis of Bulk Specific Gravity of Marshall Specimens
Table 39

BULK SPECIFIC GRAVITY OF MARSHALL SPECIMENS @ 7.5% AR Binder
(Not affected by normalizing data)

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
2.289	2.270	2.276	2.253
2.297	2.268	2.282	2.279
2.288	2.253	2.264	2.280
2.279	2.268	2.300	2.291
2.286	2.259	2.285	2.293
2.298	2.251	2.304	2.300
2.281	2.275	2.260	2.269
2.294	2.270	2.281	2.251
2.297	2.264	2.280	2.250
			2.200
			2.209
			2.197
			2.212
			2.212
			2.211
			2.196
			2.209
			2.213
			2.228
			2.257
			2.253
			2.197
			2.211
			2.209

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std. Dev
B	9	20.61030522	2.290033913	4.97914E-05	0.0071
C	9	20.378	2.264222222	6.74444E-05	0.0082
D	9	20.532	2.281333333	0.00020775	0.0144
A	24	53.68	2.236666667	0.001208406	0.0348

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.025371562	3	0.008457187	13.07817367	2.45397E-06	2.802352
Within Groups	0.03039322	47	0.000646664			
Total	0.055764783	50				

Hypothesis 0 rejected: At least two of the mean bulk specific gravity values are not equal

Big Bug Round Robin
Statistical Analysis of Bulk Specific Gravity of Marshall Specimens
Table 39

DUNCAN'S MULTIPLE RANGE TEST for BULK SPECIFIC GRAVITY @ 7.5% AR Binder

$$\boxed{S_{\overline{y_i}\cdot} = \sqrt{\frac{MS_E}{n_h}}}$$ 0.00778607

R4 = 0.0241
R3 = 0.0234
R2 = 0.0222

AvgA=2.2367 AvgC=2.2642 AvgD=2.2813 AvgB=2.2900

PRECISION CALCULATIONS

Average	2.259
1s	0.033
d2s	0.095
1s%	1.48
d2s%	4.18

Big Bug Round Robin
Statistical Analysis of Bulk Specific Gravity of Marshall Specimens
Table 39

BULK SPECIFIC GRAVITY OF MARSHALL SPECIMENS @ 8.5% AR Binder
(Not affected by normalizing data)

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
2.304	2.289	2.288	2.258
2.299	2.277	2.272	2.230
2.281	2.283	2.285	2.285
2.284	2.288	2.282	2.241
2.286	2.284	2.282	2.263
2.305	2.267	2.261	2.282
2.310	2.279	2.264	2.245
2.303	2.277	2.278	2.236
2.290	2.275	2.272	2.250
			2.191
			2.216
			2.201
			2.210
			2.210
			2.213
			2.195
			2.197
			2.201
			2.206
			2.220
			2.216
			2.196
			2.206
			2.207

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std. Dev
B	9	20.66119757	2.295688619	0.000117302	0.0108
C	9	20.519	2.279888889	4.78611E-05	0.0069
D	9	20.484	2.276	8.775E-05	0.0094
A	24	53.375	2.223958333	0.000758389	0.0275

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.047547296	3	0.015849099	38.26658908	1.1408E-12	2.802352
Within Groups	0.019466267	47	0.000414176			
Total	0.067013562	50				

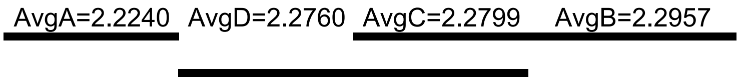
Hypothesis 0 rejected: At least two of the mean bulk specific gravity values are not equal

Big Bug Round Robin
Statistical Analysis of Bulk Specific Gravity of Marshall Specimens
Table 39

DUNCAN'S MULTIPLE RANGE TEST for BULK SPECIFIC GRAVITY @ 8.5% AR Binder

$$\boxed{S_{\overline{y_i}.} = \sqrt{\frac{MS_E}{n_h}}} \qquad 0.006231194$$

R4 = 0.0193
R3 = 0.0187
R2 = 0.0178



AvgA=2.2240 AvgD=2.2760 AvgC=2.2799 AvgB=2.2957

PRECISION CALCULATIONS

Average	2.256
1s	0.037
d2s	0.104
1s%	1.62
d2s%	4.59

APPENDIX G
BIG BUG ROUND ROBIN
NORMALIZED DATA AND ANALYSES

Big Bug Round Robin
Normalized AR-AC Round Robin Data
Table 40

Replicate	AR	Effect. Binder Volume,%			VMA, %			VFA, %			Effect. Air Voids,%		
Number	Content	B	C	D	B	C	D	B	C	D	B	C	D
1	6.5	13.336	13.009	13.225	21.98	22.78	22.62	59.76	57.12	57.54	8.8	9.8	9.6
1	7.5	15.632	15.256	15.516	22.20	23.13	22.77	69.50	65.97	67.23	6.8	7.9	7.5
1	8.5	17.853	17.568	17.751	22.91	23.32	23.34	77.06	75.34	75.18	5.3	5.8	5.8
2	6.5	13.383	13.050	13.459	21.70	22.54	21.25	60.73	57.91	62.35	8.5	9.5	8.0
2	7.5	15.611	15.222	15.666	22.30	23.30	22.03	69.09	65.34	70.18	6.9	8.1	6.6
2	8.5	17.829	17.545	17.697	23.01	23.42	23.57	76.62	74.92	74.20	5.4	5.9	6.1
3	6.5	13.354	12.998	13.389	21.87	22.84	21.66	60.12	56.90	60.84	8.7	9.8	8.5
3	7.5	15.632	15.297	15.516	22.20	22.92	22.77	69.50	66.73	67.23	6.8	7.6	7.5
3	8.5	17.899	17.522	17.666	22.71	23.52	23.71	77.95	74.50	73.65	5.0	6.0	6.2

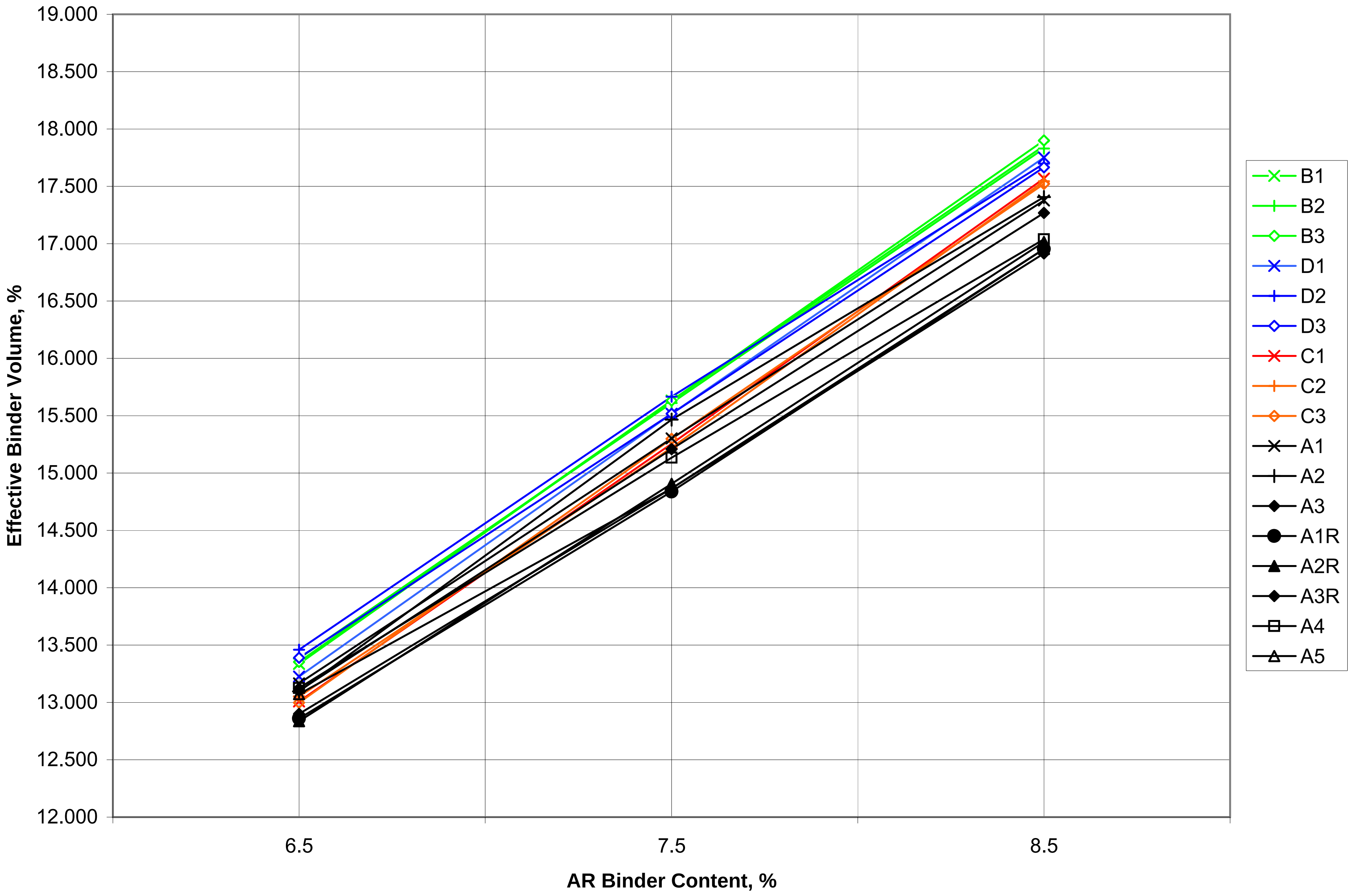
		Stability, lbs			Flow		
		B	C	D	B	C	D
1	6.5	2046	1888	1505	21	32	23
1	7.5	2030	1790	1352	21	35	19
1	8.5	1754	909	1355	20	38	20
2	6.5	1724	1297	1846	21	34	21
2	7.5	1669	1236	1842	16	35	22
2	8.5	1835	928	1679	22	37	23
3	6.5	2170	1317	1699	20	31	22
3	7.5	1843	1078	1725	23	31	22
3	8.5	1815	1145	1632	23	36	23

NOTES

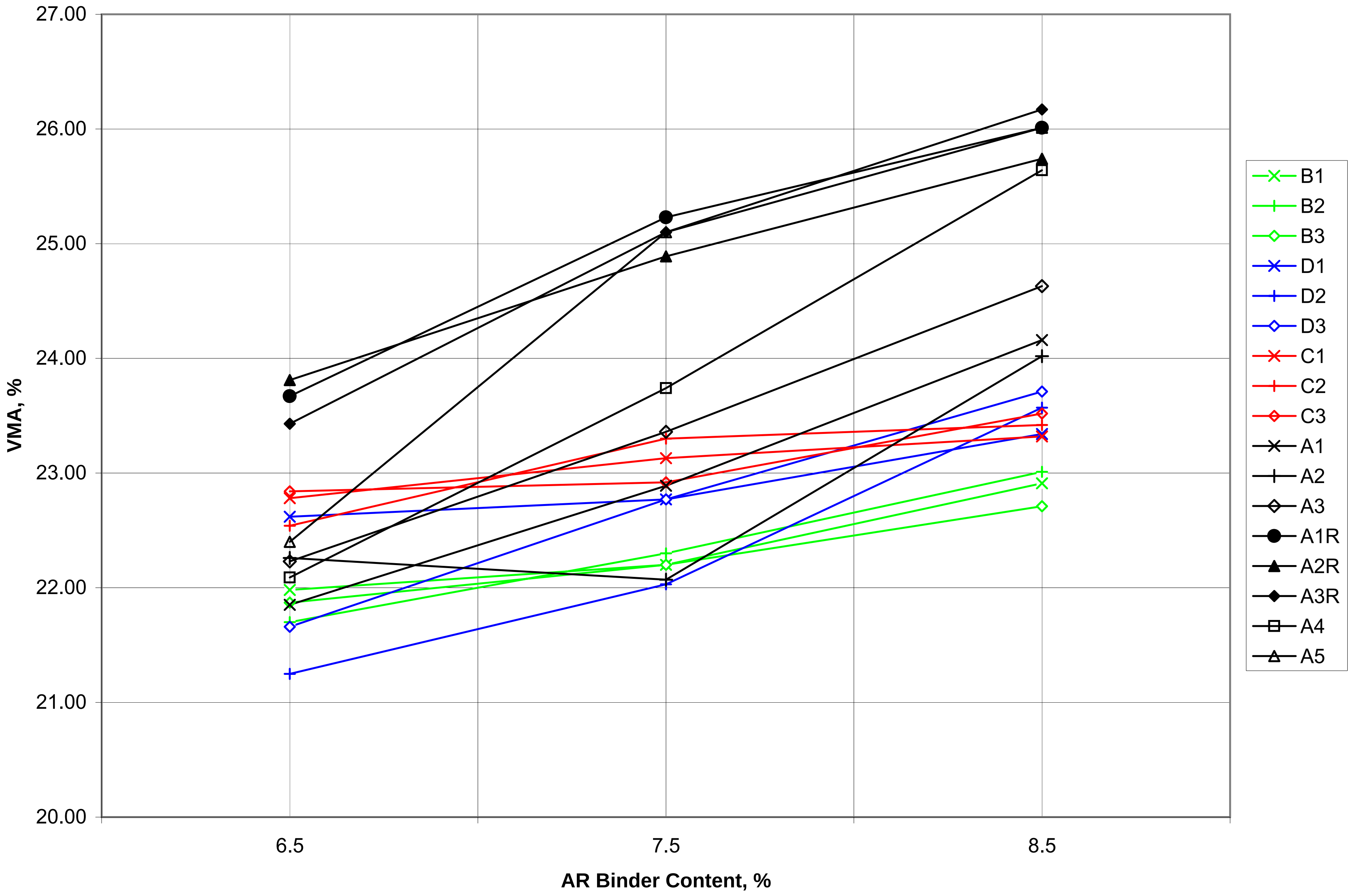
Data normalized by applying overall average Rice value to each mix specimen, and overall averages of agg spec gravity & absorption

Big Bug Round Robin
Normalized AR-AC Round Robin Data
Table 40

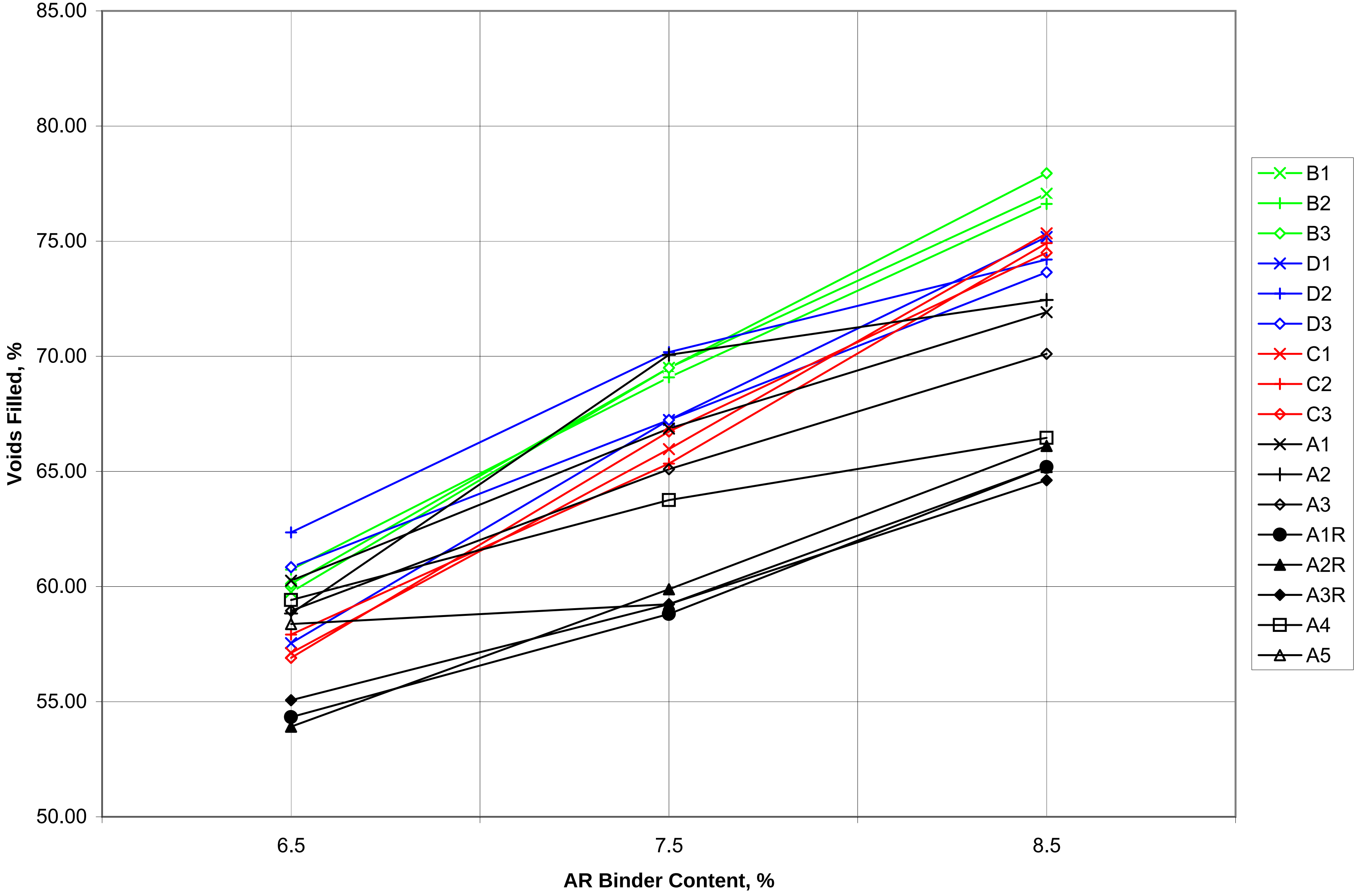
Replicate	AR	Effect. Binder Volume,%	VMA, %	VFA, %	Effect. Air Voids, %	Stability, lbs	Flow
Number	Content	A	A	A	A	A	A
1	6.5	13.165	21.85	60.26	8.7	1596	15
1	7.5	15.303	22.89	66.86	7.6	1456	27
1	8.5	17.376	24.16	71.92	6.8	1425	30
2	6.5	13.096	22.26	58.83	9.2	1799	22
2	7.5	15.465	22.07	70.06	6.6	1794	25
2	8.5	17.407	24.02	72.45	6.6	1326	24
3	6.5	13.102	22.23	58.95	9.1	2022	29
3	7.5	15.209	23.36	65.10	8.2	2098	23
3	8.5	17.268	24.63	70.11	7.4	1428	30
1R	6.5	12.859	23.67	54.33	10.8	1094	28
1R	7.5	14.838	25.23	58.81	10.4	1104	28
1R	8.5	16.953	26.01	65.19	9.1	1062	28
2R	6.5	12.836	23.81	53.92	11.0	1132	30
2R	7.5	14.906	24.89	59.88	10.0	1067	32
2R	8.5	17.014	25.74	66.11	8.7	1143	34
3R	6.5	12.899	23.43	55.06	10.5	1303	29
3R	7.5	14.865	25.10	59.23	10.2	1191	34
3R	8.5	16.914	26.17	64.62	9.3	1048	36
4	6.5	13.125	22.09	59.42	9.0	1910	29
4	7.5	15.135	23.74	63.76	8.6	992	25
4	8.5	17.038	25.64	66.46	8.6	809	30
5	6.5	13.073	22.40	58.37	9.3	1353	28
5	7.5	14.865	25.10	59.23	10.2	1075	31
5	8.5	16.953	26.01	65.19	9.1	1157	38



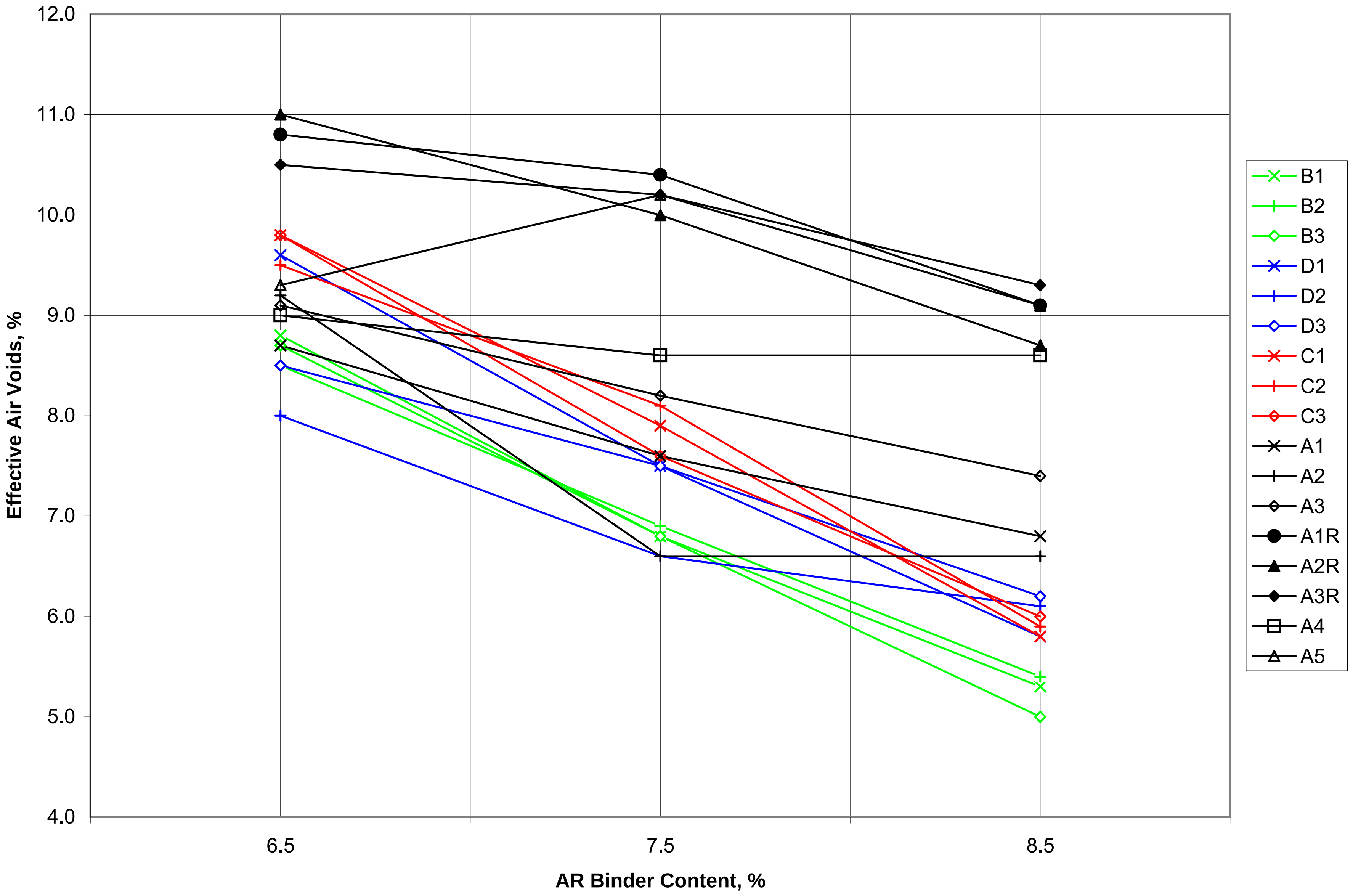
Normalized Big Bug Effective Binder Volume
Figure 40



Normalized Big Bug VMA
Figure 41



Normalized Big Bug VFA
Figure 42



Normalized Big Bug Air Voids
Figure 43

Big Bug Round Robin
Statistical Analysis of Normalized Data at 6.5% AR Binder Content
Table 41

NORMALIZED EFFECTIVE AR VOLUME @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
13.336	13.009	13.225	13.165
13.383	13.05	13.459	13.096
13.354	12.998	13.389	13.102
			12.859
			12.836
			12.899
			13.125
			13.073

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	40.073	13.35766667	0.000562333	0.0237
C	3	39.057	13.019	0.000751	0.0274
D	3	40.073	13.35766667	0.014425333	0.1201
A	8	104.155	13.019375	0.017396268	0.1319

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.444570321	3	0.148190107	12.57067668	0.000385	3.410534
Within Groups	0.153251208	13	0.011788554			
Total	0.597821529	16				

Hypothesis 0 rejected: At least two of the mean normalized Effective AR Volume values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED EFFECTIVE AR VOLUME @ 6.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.057577049

R4 = 0.190
R3 = 0.185
R2 = 0.176

$\underline{\text{AvgC=13.019 AvgA=13.019}}$ AvgB=13.358 AvgD=13.358

Big Bug Round Robin
Statistical Analysis of Normalized Data at 6.5% AR Binder Content
Table 41

NORMALIZED VMA @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
21.98	22.78	22.62	21.85
21.7	22.54	21.25	22.26
21.87	22.84	21.66	22.23
			23.67
			23.81
			23.43
			22.09
			22.4

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	65.55	21.85	0.0199	0.141
C	3	68.16	22.72	0.0252	0.159
D	3	65.53	21.84333333	0.494433333	0.703
A	8	181.74	22.7175	0.61465	0.784

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.948877451	3	0.98295915	2.374466586	0.117394	3.410534
Within Groups	5.381616667	13	0.413970513			
Total	8.330494118	16				

Hypothesis 0 supported: The mean normalized VMA values do not differ

Big Bug Round Robin
Statistical Analysis of Normalized Data at 6.5% AR Binder Content
Table 41

NORMALIZED VFA @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
59.76	57.12	57.54	60.26
60.73	57.91	62.35	58.83
60.12	56.90	60.84	58.95
			54.33
			53.92
			55.06
			59.42
			58.37

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	180.61	60.20333333	0.240433333	0.490
C	3	171.93	57.31	0.2821	0.531
D	3	180.73	60.24333333	6.051033333	2.460
A	8	459.14	57.3925	6.379821429	2.526

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31.62546961	3	10.5418232	2.370756984	0.117775	3.410534
Within Groups	57.80588333	13	4.44660641			
Total	89.43135294	16				

Hypothesis 0 supported: The mean normalized VFA values do not differ

Big Bug Round Robin
Statistical Analysis of Normalized Data at 6.5% AR Binder Content
Table 41

NORMALIZED EFFECTIVE AIR VOIDS @ 6.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
8.8	9.8	9.6	8.7
8.5	9.5	8.0	9.2
8.7	9.8	8.5	9.1
			10.8
			11.0
			10.5
			9.0
			9.3

Anova: Single Factor   α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	26	8.666666667	0.023333333	0.15
C	3	29.1	9.7	0.03	0.17
D	3	26.1	8.7	0.67	0.82
A	8	77.6	9.7	0.828571429	0.91

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.014509804	3	1.338169935	2.40058084	0.114755	3.410534
Within Groups	7.246666667	13	0.557435897			
Total	11.26117647	16				

Hypothesis 0 supported: The mean normalized effective air voids values do not differ.

Big Bug Round Robin
Statistical Analysis of Normalized Data at 6.5% AR Binder Content
Table 41

STABILITY @ 6.5% - Unaffected by normalizing data

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
2046	1888	1505	1596
1724	1297	1846	1799
2170	1317	1699	2022
			1094
			1132
			1303
			1910
			1353

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	5940	1980	52996	230.2
C	3	4502	1500.666667	112620.3333	335.6
D	3	5050	1683.333333	29254.33333	171.0
A	8	12209	1526.125	127774.125	357.5

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	512530.027	3	170843.3423	1.729506518	0.21016	3.410534
Within Groups	1284160.208	13	98781.55449			
Total	1796690.235	16				

Hypothesis 0 supported: The mean Marshall stability values do not differ.

Big Bug Round Robin
Statistical Analysis of Normalized Data at 6.5% AR Binder Content
Table 41

FLOW @ 6.5%- Unaffected by normalizing data

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
21	32	23	15
21	34	21	22
20	31	22	29
			28
			30
			29
			29
			28

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	62	20.66666667	0.333333333	0.6
C	3	97	32.33333333	2.333333333	1.5
D	3	66	22	1	1.0
A	8	210	26.25	26.78571429	5.2

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	251.2843137	3	83.76143791	5.588872675	0.010978	3.410534
Within Groups	194.8333333	13	14.98717949			
Total	446.1176471	16				

Hypothesis 0 rejected: At least two of the mean flow values are not equal

DUNCAN'S MULTIPLE RANGE TEST for MARSHALL FLOW @ 6.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 2.0530

R4 = 6.775
R3 = 6.590
R2 = 6.282

Avg B=20.7 Avg D=22.0 Avg A=26.3 Avg C=32.3

Big Bug Round Robin
Statistical Analysis of Normalized Data at 7.5% AR Binder Content
Table 42

NORMALIZED EFFECTIVE AR VOLUME @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
15.632	15.256	15.516	15.303
15.611	15.222	15.666	15.465
15.632	15.297	15.516	15.209
			14.838
			14.906
			14.865
			15.135
			14.865

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	46.875	15.625	0.000147	0.0121
C	3	45.775	15.25833333	0.001410333	0.0376
D	3	46.698	15.566	0.0075	0.0866
A	8	120.586	15.07325	0.056935071	0.2386

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.944054892	3	0.314684964	9.818324044	0.001188	3.410534
Within Groups	0.416660167	13	0.032050782			
Total	1.360715059	16				

Hypothesis 0 rejected: At least two of the mean normalized Effective AR Volume values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED EFFECTIVE AR VOLUME @ 7.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$

0.094937642

R4 = 0.313
R3 = 0.305
R2 = 0.291

AvgA=15.073 AvgC=15.258 AvgD=15.566 AvgB=15.625

Big Bug Round Robin
Statistical Analysis of Normalized Data at 7.5% AR Binder Content
Table 42

NORMALIZED VMA @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
22.20	23.13	22.77	22.89
22.30	23.30	22.03	22.07
23.01	22.92	22.77	23.36
			25.23
			24.89
			25.10
			23.74
			25.10

Anova: Single Factor α = 0.05

SUMMARY

Groups	Count	Sum	Average	Variance	Std Dev
B	3	67.51	22.50333333	0.195033333	0.442
C	3	69.35	23.11666667	0.036233333	0.190
D	3	67.57	22.52333333	0.182533333	0.427
A	8	192.38	24.0475	1.448735714	1.204

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.254897059	3	2.751632353	3.2611939	0.056211	3.410534
Within Groups	10.96875	13	0.84375			
Total	19.22364706	16				

Hypothesis 0 supported: The mean normalized VMA values do not differ

Big Bug Round Robin
Statistical Analysis of Normalized Data at 7.5% AR Binder Content
Table 42

NORMALIZED VFA @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
69.50	65.97	67.23	66.86
69.09	65.34	70.18	70.06
69.50	66.73	67.23	65.10
			58.81
			59.88
			59.23
			63.76
			59.23

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	208.09	69.36333333	0.056033333	0.237
C	3	198.04	66.01333333	0.484433333	0.696
D	3	204.64	68.21333333	2.900833333	1.703
A	8	502.93	62.86625	17.90056964	4.231

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	123.1438596	3	41.04795319	4.036895131	0.031217	3.410534
Within Groups	132.1865875	13	10.16819904			
Total	255.3304471	16				

Hypothesis 0 rejected: At least two of the mean normalized VFA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED VFA @ 7.5%

$$\boxed{S_{\bar{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 1.690990405

R4 = 5.580
R3 = 5.428
R2 = 5.174

Avg A=62.87 Avg C=66.01 Avg D=68.21 Avg B=69.36

Big Bug Round Robin
Statistical Analysis of Normalized Data at 7.5% AR Binder Content
Table 42

NORMALIZED EFFECTIVE AIR VOIDS @ 7.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
6.8	7.9	7.5	7.6
6.9	8.1	6.6	6.6
6.8	7.6	7.5	8.2
			10.4
			10.0
			10.2
			8.6
			10.2

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Std Dev
B	3	20.5	6.833333333	0.003333333	0.06
C	3	23.6	7.866666667	0.063333333	0.25
D	3	21.6	7.2	0.27	0.52
A	8	71.8	8.975	2.050714286	1.43

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.52931373	3	4.509771242	3.901099666	0.034482	3.410534
Within Groups	15.02833333	13	1.156025641			
Total	28.55764706	16				

Hypothesis 0 rejected: At least two of the mean normalized effective air voids values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED EFFECTIVE AIR VOIDS @ 7.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.570168024

R4 = 1.882
R3 = 1.830
R2 = 1.745

Avg B=6.83 Avg D=7.20 Avg C=7.87 Avg A=8.98

Big Bug Round Robin
Statistical Analysis of Normalized Data
Table 43

NORMALIZED EFFECTIVE AR VOLUME @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
17.853	17.568	17.751	17.376
17.829	17.545	17.697	17.407
17.899	17.522	17.666	17.268
			16.953
			17.014
			16.914
			17.038
			16.953

Anova: Single Factor α = 0.05

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B	3	53.581	17.86033333	0.001265333
C	3	52.635	17.545	0.000529
D	3	53.114	17.70466667	0.001850333
A	8	136.923	17.115375	0.040830268

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.613280674	3	0.537760225	23.85142989	1.4653E-05	3.410534
Within Groups	0.293101208	13	0.022546247			
Total	1.906381882	16				

Hypothesis 0 rejected: At least two of the mean normalized Effective AR Volume values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED EFFECTIVE AR VOLUME @ 8.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}} \qquad 0.079626248$$

R4 = 0.263
R3 = 0.256
R2 = 0.244

AvgA=17.115 AvgC=17.545 AvgD=17.705 AvgB=17.860

Big Bug Round Robin
Statistical Analysis of Normalized Data
Table 43

NORMALIZED VMA @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
22.91	23.32	23.34	24.16
23.01	23.42	23.57	24.02
22.71	23.52	23.71	24.63
			26.01
			25.74
			26.17
			25.64
			26.01

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B	3	68.63	22.87666667	0.023333333
C	3	70.26	23.42	0.01
D	3	70.62	23.54	0.0349
A	8	202.38	25.2975	0.780164286

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.007559804	3	6.002519935	13.94035423	0.000234533	3.410534
Within Groups	5.597616667	13	0.430585897			
Total	23.60517647	16				

Hypothesis 0 rejected: At least two of the mean normalized VMA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED VMA @ 8.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.347975786

R4 = 1.148
R3 = 1.117
R2 = 1.065

Avg B=22.88 Avg C=23.42 Avg D=23.54 Avg A=25.30

Big Bug Round Robin
Statistical Analysis of Normalized Data
Table 43

NORMALIZED VFA @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
77.06	75.34	75.18	71.92
76.62	74.92	74.20	72.45
77.95	74.50	73.65	70.11
			65.19
			66.11
			64.62
			66.46
			65.19

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B	3	231.63	77.21	0.4591
C	3	224.76	74.92	0.1764
D	3	223.03	74.34333333	0.600633333
A	8	542.05	67.75625	10.32942679

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	267.1839223	3	89.06130743	15.48307071	0.000139879	3.410534
Within Groups	74.77825417	13	5.752173397			
Total	341.9621765	16				

Hypothesis 0 rejected: At least two of the mean normalized VFA values are not equal

DUNCAN'S MULTIPLE RANGE TEST for NORMALIZED VFA @ 8.5%

$$\boxed{S_{\overline{y}_{i.}} = \sqrt{\frac{MSE}{3.556}}}$$ 1.271847699

R4 = 4.197
R3 = 4.083
R2 = 3.892

Avg A=67.76 Avg D=74.34 Avg C=74.92 Avg B=77.21

Big Bug Round Robin
Statistical Analysis of Normalized Data
Table 43

NORMALIZED EFFECTIVE AIR VOIDS @ 8.5%

H0: Means of respective laboratories are equal
H1: At least two of the means are not equal

B	C	D	A
5.3	5.8	5.8	6.8
5.4	5.9	6.1	6.6
5.0	6.0	6.2	7.4
			9.1
			8.7
			9.3
			8.6
			9.1

Anova: Single Factor $\alpha = 0.05$

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B	3	15.7	5.233333333	0.043333333
C	3	17.7	5.9	0.01
D	3	18.1	6.033333333	0.043333333
A	8	65.6	8.2	1.2

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27.10431373	3	9.034771242	13.66780754	0.000258089	3.410534
Within Groups	8.593333333	13	0.661025641			
Total	35.697647059	16				

Hypothesis 0 rejected: At least two of the mean normalized effective air voids values are not equal

DUNCAN'S MULTIPLE RANGE TEST
for NORMALIZED EFFECTIVE AIR VOIDS @ 8.5%

$$\boxed{S_{\overline{y_{i.}}} = \sqrt{\frac{MSE}{3.556}}}$$ 0.431149887

R4 = 1.423
R3 = 1.384
R2 = 1.319

Avg B=5.2 Avg C=5.9 Avg D=6.0 Avg A=8.2

Big Bug Round Robin
Statistical Analysis of Normalized Data
Summary of Duncan's Multiple Range Comparisons of Mean Normalized Results
Table 44

AR Content (%)	MIXTURE PROPERTY											
	Effective AR Binder Volume				**VMA**				**VFA**			
6.5	A	C	D	B	D	B	A	C	C	A	B	D
	13.019	13.019	13.358	13.358	21.84	21.85	22.72	22.72	57.31	57.39	60.2	60.24
					No Statistical Difference				No Statistical Difference			
7.5	A	C	D	B	B	D	C	A	A	C	D	B
	15.073	15.258	15.566	15.625	22.5	22.52	23.12	24.05	62.87	66.01	68.21	69.36
					No Statistical Difference							
8.5	A	C	D	B	B	C	D	A	A	D	C	B
	17.115	17.545	17.705	17.86	22.83	23.42	23.54	25.3	67.76	74.34	74.92	77.21
	Effective Air Voids				**Marshall Stability**				**Marshall Flow**			
6.5	B	D	C	A	C	A	D	B	B	D	A	C
	8.67	8.7	9.7	9.7	1501	1526	1683	1980	20.7	22	26.3	32.3
	No Statistical Difference				No Statistical Difference							
7.5	B	D	C	A	A	C	D	B	B	D	A	C
	6.83	7.2	7.87	8.98	1347	1368	1640	1847	20	21	28.1	33.7
					No Statistical Difference							
8.5	B	C	D	A	C	A	D	B	B	D	A	C
	5.23	5.9	6.03	8.2	994	1175	1555	1801	21.7	22	31.3	37

Precision Calculations for Results of Big Bug Round Robin
Table 45

NORMALIZED EFFECTIVE AIR VOIDS @ 6.5%

B	C	D	A
8.8	9.8	9.6	8.7
8.5	9.5	8.0	9.2
8.7	9.8	8.5	9.1
			10.8
			11.0
			10.5
			9.0
			9.3

Average	9.3
1s	0.839
d2s	2.37
1s%	8.98
d2s%	25.42

STABILITY @ 6.5% - Unaffected by normalizing data

B	C	D	A
2046	1888	1505	1596
1724	1297	1846	1799
2170	1317	1699	2022
			1094
			1132
			1303
			1910
			1353

Average	1629
1s	335
d2s	948
1s%	21
d2s%	58

FLOW @ 6.5%- Unaffected by normalizing data

B	C	D	A
21	32	23	15
21	34	21	22
20	31	22	29
			28
			30
			29
			29
			28

Average	25.6
1s	5.3
d2s	14.9
1s%	20.6
d2s%	58.4

(AMRL uses values of flow /100)

B	C	D	A
0.21	0.32	0.23	0.15
0.21	0.34	0.21	0.22
0.2	0.31	0.22	0.29
			0.28
			0.30
			0.29
			0.29
			0.28

Average	0.256
1s	0.053
d2s	0.149
1s%	20.6
d2s%	58.4

Precision Calculations for Results of Big Bug Round Robin

Table 45

NORMALIZED EFFECTIVE AIR VOIDS @ 7.5%

B	C	D	A
6.8	7.9	7.5	7.6
6.9	8.1	6.6	6.6
6.8	7.6	7.5	8.2
			10.4
			10.0
			10.2
			8.6
			10.2

Average	8.1
1s	1.336
d2s	3.78
1s%	16.52
d2s%	46.74

STABILITY @ 7.5% - Unaffected by normalizing data

B	C	D	A
2030	1790	1352	1456
1669	1236	1842	1794
1843	1078	1725	2098
			1104
			1067
			1191
			992
			1075

Average	1491
1s	377
d2s	1066
1s%	25
d2s%	72

FLOW @ 7.5%- Unaffected by normalizing data

B	C	D	A
21	35	19	27
16	35	22	25
23	31	22	23
			28
			32
			34
			25
			31

Average	26.4
1s	5.8
d2s	16.4
1s%	22.0
d2s%	62.3

(AMRL uses values of flow /100)

B	C	D	A
0.21	0.35	0.19	0.27
0.16	0.35	0.22	0.25
0.23	0.31	0.22	0.23
			0.28
			0.32
			0.34
			0.25
			0.31

Average	0.264
1s	0.058
d2s	0.164
1s%	22.
d2s%	62.3

Precision Calculations for Results of Big Bug Round Robin

Table 45

NORMALIZED EFFECTIVE AIR VOIDS @ 8.5%

B	C	D	A
5.3	5.8	5.8	6.8
5.4	5.9	6.1	6.6
5.0	6.0	6.2	7.4
			9.1
			8.7
			9.3
			8.6
			9.1

Average	6.888
1s	1.494
d2s	4.227
1s%	21.685
d2s%	61.367

STABILITY @ 8.5%- Unaffected by normalizing data

B	C	D	A
1754	909	1355	1425
1835	928	1679	1326
1815	1145	1632	1428
			1062
			1143
			1048
			809
			1157

Average	1321
1s	332
d2s	939
1s%	25
d2s%	71

FLOW @ 8.5%- Unaffected by normalizing data

B	C	D	A
20	38	20	30
22	37	23	24
23	36	23	30
			28
			34
			36
			30
			38

Average	28.9
1s	6.6
d2s	18.7
1s%	22.8
d2s%	64.5

(AMRL uses values of flow /100)

B	C	D	A
0.20	0.38	0.20	0.30
0.22	0.37	0.23	0.24
0.23	0.36	0.23	0.30
			0.28
			0.34
			0.36
			0.30
			0.38

Average	0.289
1s	0.066
d2s	0.187
1s%	22.8
d2s%	64.5

Comparison of Multilaboratory Precision of Test Results
Big Bug Round Robin Compared to AMRL and ADOT Conventional Marshall PSP Data
Table 46

NORMALIZED EFFECTIVE AIR VOIDS

	Big Bug Round Robin				ADOT Range
	6.5% AR	7.5% AR	8.5% AR	AMRL Range	(1 data set)
Average	9.3	8.1	6.9	3.38-5.56	5.76-5.83
1s	0.839	1.336	1.494	0.8-1.1	1.41-1.65
d2s	2.37	3.78	4.23	2.3-3.2	3.99-4.67
1s%	8.98	16.52	21.68	19-30	24.5-28.3
d2s%	25.42	46.74	61.37	54-91	69.4-80.1

NOTE: ADOT has just added to PSP and only 1 data set is available now

EFFECTIVE AIR VOIDS

	Big Bug Round Robin				ADOT Range
	6.5% AR	7.5% AR	8.5% AR	AMRL Range	(1 data set)
Average	9.3	8.0	6.8	3.38-5.56	5.76-5.83
1s	1.017	1.43	1.51	0.8-1.1	1.41-1.65
d2s	2.88	4.05	4.27	2.3-3.2	3.99-4.67
1s%	10.96	17.82	22.1	19-30	24.5-28.3
d2s%	31.03	50.43	62.6	54-91	69.4-80.1

BULK SPECIFIC GRAVITY - 75 BLOWS

	Big Bug Round Robin							
	6.5% AR	7.5% AR	8.5% AR	AMRL Range	ADOT Range (3 sets)	ADOT Bulk Density (10 sets)	ASTM D 2726-00 Precision	ASTM D2726-04 Precision
Average	2.261	2.259	2.256	2.365-2.490	2.260-2.319			
1s	0.023	0.033	0.037	0.017-0.027	0.020-0.042		0.0269	0.015**
d2s	0.065	0.095	0.104	0.048-0.076	0.057-0.119		0.076	0.042**
1s%	1.01	1.48	1.62	0.68-1.14	0.88-1.81	0.4-1.97		
d2s%	2.86	4.18	4.59	1.94-3.23	2.49-5.13	1.13-5.58		

**For aggregates with absorption < 1.5%, which does not apply to Big Bug round robin aggregate

MARSHALL STABILITY

	Big Bug Round Robin				
	6.5% AR	7.5% AR	8.5% AR	AMRL Range	ADOT Range
Average	1629	1491	1321	1826-2860	2976-4316
1s	335	377	332	351-469	419.4-753.5
d2s	948	1066	939	991-1326	1186.9-2132.4
1s%	21	25	25	14-23	12.2-23.2
d2s%	58	72	71	39-66	34.5-65.6

MARSHALL FLOW

	Big Bug Round Robin				
	6.5% AR	7.5% AR	8.5% AR	AMRL Range*	ADOT Range
Average	25.6	26.4	28.9	0.082-0.126	9.8-15
1s	5.3	5.8	6.6	0.015-0.031	1.51-3.2
d2s	14.9	16.4	18.7	0.042-0.086	4.273-9.056
1s%	20.6	22.1	22.8	16-24	13.9-22.8
d2s%	58.4	62.3	64.5	47-69	39.37-64.52

*AMRL uses decimals for flow values; 20 is reported as 0.20

APPENDIX H
ARIZ 832 DRAFT SEPTEMBER 6, 2007 MARSHALL MIX DESIGN METHOD FOR AR-AC

ARIZ 832
DRAFT September 6, 2007
(18 Pages)

MARSHALL MIX DESIGN METHOD FOR ASPHALTIC CONCRETE (ASPHALT-RUBBER) [AR-AC]

(An Arizona Method)

SCOPE

1. (a) This method is used to design Asphaltic Concrete (Asphalt-Rubber) [AR-AC] mixes using 4-inch diameter Marshall apparatus.

(b) This test method involves hazardous material, operations, and equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

(c) See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

APPARATUS

2. This test method is used in conjunction with the test methods listed below. Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual. The required apparatus is shown in the individual test methods, as appropriate.

ARIZ 201	Sieving of Coarse and Fine Graded Soils and Aggregates
ARIZ 205	Composite Grading
ARIZ 210	Specific Gravity and Absorption of Coarse Aggregate
ARIZ 211	Specific Gravity and Absorption of Fine Aggregate
ARIZ 212	Percentage of Fractured Coarse Aggregate Particles
ARIZ 238	Percent Carbonates in Aggregate
ARIZ 247	Particle Shape and Texture of Fine Aggregate Using Uncompacted Void Content
ARIZ 410	Compaction and Testing of Bituminous Mixtures Utilizing 101.6 mm (Four-Inch) Marshall Apparatus
ARIZ 415	Bulk Specific Gravity and Bulk Density of Compacted Bituminous Mixtures

ARIZ 416	Preparing and Splitting Field Samples of Bituminous Mixtures for Testing
ARIZ 806	Maximum Theoretical Specific Gravity of Laboratory Prepared Bituminous Mixtures (Rice Test)
AASHTO T 96	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
AASHTO T 176	Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
AASHTO T 228	Specific Gravity of Semi-Solid Bituminous Materials

MATERIALS

3. (a) Mineral Aggregate - The mineral aggregate used in the design shall be produced material from the source(s) for the project. Use of natural sand is not permitted in AR-AC mixtures.

1) Mineral aggregate from each source shall be tested for compliance to the project requirements for Abrasion (AASHTO T 96).

2) The composited gradation of the aggregate and the composited gradation of the aggregate-mineral admixture blend shall comply with the grading limits of the specifications.

3) The composited mineral aggregate shall conform to the requirements of the specifications for Sand Equivalent (AASHTO T 176), Fractured Coarse Aggregate Particles (ARIZ 212), Uncompacted Void Content (ARIZ 247), and Percent Carbonates (ARIZ 238) when applicable.

(b) Bituminous Material - The bituminous material used in the design shall be asphalt-rubber material [hereinafter Crumb Rubber Asphalt (CRA)], conforming to the requirements of Section 1009 of the specifications, which is to be used in the production of the AR-AC. The specific gravity of the CRA and of the asphalt cement used in the CRA shall be determined in accordance with AASHTO T 228.

(c) Mineral Admixture - Mineral admixture is required. The mineral admixture used in the design shall be the same type of material to be used in production of the AR-AC. The mineral admixture shall conform to the requirements of the specifications.

DETERMINATION OF COMPOSITE GRADATION

4. (a) The gradation of the aggregate from each individual component stockpile or bin shall be determined in accordance with ARIZ 248 using washed sieve analysis Alternate #4 or Alternate #5. For alternate #5, washing of the coarse aggregate may be performed on the composite Plus No. 4 material and applied to the composite percent pass the minus No. 200 determined from the unwashed coarse sieving and washed fine sieving of the individual stockpiles.

(b) The composite gradation of the mineral aggregate is determined using desired percentages of each component based on washed sieve analysis. Mix designs may be developed based on bin or stockpile material, as appropriate for the respective mix production facility to be used.

(c) The mineral aggregate composite shall be determined in accordance with ARIZ 205.

(d) The aggregate-mineral admixture blend composite is determined by adjusting the mineral aggregate composite (percent passing) for mineral admixture by performing the calculation in Equation 1 for each sieve:

Equation 1:

$$\left(\begin{array}{c}\text{\% passing}\\ \text{each sieve}\\ \text{[Adjusted for}\\ \text{Mineral}\\ \text{Admixture]}\end{array}\right) = \frac{\left(\begin{array}{c}\text{\% passing}\\ \text{each sieve in}\\ \text{the aggregate}\\ \text{composite}\end{array}\right) + \left(\begin{array}{c}\text{\% Mineral}\\ \text{Admixture}\end{array}\right)}{(100) + (\text{\% Mineral Admixture})} \times 100$$

(e) The composited gradation of the aggregate and the composited gradation of the aggregate-mineral admixture blend shall be shown on the design report, along with the percentage of each material.

PREPARING AGGREGATE SAMPLES FOR MIX DESIGN TESTING

5. Based on the stockpile or bin composite aggregate gradation, the aggregate samples needed for mix design tests are prepared as follows.

(a) Representative samples of material which are retained on the individual No. 8 and larger sieve sizes and the minus No. 8 material from each stockpile or bin are used to prepare the aggregate samples for mix design testing.

(b) Table 1 shows the aggregate sample sizes, the number of samples required for each test listed, and which samples include mineral admixture. The aggregate weight shown for Maximum Theoretical Specific Gravity will provide 3 Rice test specimens and the amount shown for Density-Stability/Flow will produce 3 Marshall specimens.

<table>
<tr><th colspan="3">Table 1</th></tr>
<tr><th>Test</th><th>Sample Size</th><th>Number of Samples</th></tr>
<tr><td>Fine Aggregate Specific Gravity/ Absorption (ARIZ 211)</td><td>1200 grams of Mineral Aggregate [No mineral admixture]</td><td>1</td></tr>
<tr><td>Coarse Aggregate Specific Gravity/Absorption (ARIZ 210)</td><td>2000 grams of Mineral Aggregate [No mineral admixture]</td><td>1</td></tr>
<tr><td>Maximum Theoretical Specific Gravity (Rice Test) (ARIZ 806, as modified in Section 10)</td><td>3000 grams of Mineral Aggregate [Plus 30 grams of mineral admixture]</td><td>1 [Yields 3 test specimens]</td></tr>
<tr><td>Density-Stability/Flow (ARIZ 415 and ARIZ 410, as modified in Sections 8 and 9 respectively)</td><td>3000 grams of Mineral Aggregate (See Note 1) [Plus 30 grams of mineral admixture]</td><td>3 (See Note 2) [Each sample yields 1 set of 3 Marshall Specimens]</td></tr>
<tr><td colspan="3">Note 1: Generally the weight shown will provide specimens of acceptable heights, but adjustments may be necessary in some cases. Use Equation 2 to adjust aggregate weights as necessary to conform to specimen height requirements of 2.50 ± 0.20 inches.
Equation 2: $\text{Adjusted Wt. of Aggregate} = \dfrac{\left(\begin{array}{c}\text{Combined Bulk O.D.}\\ \text{Agg. Specific Gravity}\end{array}\right)}{2.650} \text{ x Sample Size}$</td></tr>
<tr><td colspan="3">Note 2: Requires one (1) sample for each CRA binder content to be tested (minimum of 3 contents, with 3 Marshall specimens at each content).</td></tr>
</table>

(c) After the aggregate samples for the Rice and Marshall specimens have been composited, add 1% mineral admixture by weight of the aggregate, and mix thoroughly. Add 3% water by dry weight to each sample and mix thoroughly to wet the mineral admixture and aggregate surfaces. After mixing, dry to constant weight in accordance with paragraph 7(a).

AGGREGATE SPECIFIC GRAVITIES AND ABSORPTION

6. Determine the Bulk Oven Dry, S.S.D., Apparent Specific Gravities and Absorption for the fine aggregate (Minus No. 4) and the coarse aggregate (Plus No. 4) in accordance with ARIZ 211 and ARIZ 210 respectively.

(a) Using Equation 3, calculate the Combined Bulk Oven Dry (Gsb), S.S.D., and Apparent Specific Gravities of the aggregate-mineral admixture blend.

Equation 3:

$$\left(\begin{array}{l}\text{Combined Specific Gravity}\\ \text{of Aggregate and Mineral}\\ \text{Admixture Blend}\end{array}\right) = \frac{P_c + P_f + P_{admix}}{\frac{P_c}{G_c} + \frac{P_f}{G_f} + \frac{P_{admix}}{G_{admix}}}$$

Where: P_c, P_f = Weight percent of coarse aggregate and fine aggregate respectively. Determined from the aggregate composite without mineral admixture.

P_{admix} = Percent mineral admixture by weight of the aggregate.

$P_c + P_f$ = 100

$P_c + P_f + P_{admix}$ = 100 + % Mineral Admixture

G_c, G_f = Specific gravity of the coarse and the fine aggregate respectively.

G_{admix} = Specific gravity of the mineral admixture.

Type II Cement = 3.14
Type IP Cement = 3.00
Hydrated Lime = 2.20

(b) Using Equation 4, calculate the Combined Absorption of the aggregate-mineral admixture blend.

Equation 4:

$$\left(\begin{array}{l}\text{Combined Absorption}\\ \text{of Aggregate and Mineral}\\ \text{Admixture Blend}\end{array}\right) = \frac{(P_c \text{ x } A_c) + (P_f \text{ x } A_f) + (P_{admix} \text{ x } A_{admix})}{P_c + P_f + P_{admix}}$$

Where: P_c, P_f = Weight percent of coarse aggregate and fine aggregate respectively. Determined from the aggregate composite without mineral admixture.

P_{admix} = Percent mineral admixture by weight of the aggregate.

$P_c + P_f$ = 100

$P_c + P_f + P_{admix}$ = 100 + % Mineral Admixture

A_c, A_f = Percent water absorption of the coarse aggregate and the fine aggregate respectively.

A_{admix} = Percent water absorption of mineral admixture (assumed to be 0.0%).

PREPARATION OF SPECIMENS FOR DENSITY AND MARSHALL STABILITY/FLOW DETERMINATION

7. Marshall specimens shall be prepared as follows.

NOTE: Normally a range of 3 different CRA binder contents at 1.0% increments will provide sufficient information, although in some cases it may be necessary to prepare additional sets of samples at other CRA binder contents. Two series of CRA binder contents are customarily used: either 6.0, 7.0, and 8.0% CRA by total mix weight; or 6.5, 7.5, and 8.5% CRA by total mix weight.

NOTE: Although a wide range of mixers may provide the desired well-coated homogeneous mixture, commercial potato mashers or dough mixers with whips are often used. Minimum recommended capacity of the mixing bowl is 10 quarts.

(a) The aggregate-mineral admixture blend shall be dried to constant weight at 325 ± 3 ºF and shall be at this temperature at the time of mixing with the CRA. If necessary, a small amount of proportioned Pass No. 8 make up material may be added to bring samples to the desired weight of approximately 3000 grams plus mineral admixture needed to make a batch of three Marshall specimens. The aggregate weight may be adjusted as necessary to conform to specimen height requirements using Equation 2.

(b) Before each batch of AR-AC is mixed, the CRA shall be heated in a loosely covered container in a forced draft oven for approximately 2 hours or as necessary to reach a temperature of 330 ± 5 ºF. Upon removal from the oven, the CRA shall be thoroughly stirred using a stiff-bladed flat spatula with blade approximately 1-inch wide, 1/8-inch thick, and long enough to reach the bottom of the container. (As an alternate to a stiff-bladed spatula, flat bar stock meeting the dimensional requirements may be used.) Use combined circular, vertical, and radial stirring motions to uniformly distribute the rubber particles throughout the CRA before adding the designated proportion to the aggregate-mineral admixture blend. If there is any delay before beginning of mixing the CRA with the aggregate-mineral admixture blend, thoroughly stir the CRA again immediately before pouring.

CAUTION: To avoid damage to the CRA, do not use a hot plate or open flame to bring it to temperature. Once the CRA temperature has reached 330 ± 5 ºF, the container may briefly be moved to a hot plate for no more than 5 minutes to maintain temperature. If a hot plate is utilized, the CRA shall be constantly stirred to avoid sticking or scorching. Do not heat the CRA longer than necessary to complete batching and mixing operations (approximately three hours total heating time), or damage may occur.

NOTE: Before each batch is mixed, the mixing bowl and whip shall be heated to 325 ± 3 ºF, and the weight of CRA required to provide the desired content shall be calculated.

(c) The aggregate-mineral admixture blend and the appropriate amount of CRA shall be mixed together as quickly as possible in order to maintain the required mixing temperature of 325 ± 3 ºF while producing a well-coated homogeneous AR-AC mixture. **Mechanical mixing is required.**

NOTE: After mechanical mixing, hand mixing may be used as needed to obtain more thorough coating of the aggregate.

(d) Immediately after mixing, each batch of AR-AC shall be placed on a tarp or sheet of heavy paper and in a rolling motion thoroughly mixed and spread according to the procedures described in ARIZ 416. The circular mass shall be cut into 6 equal pie-shaped segments. Take opposite segments for each individual specimen and use up the entire batch.

(e) Each AR-AC specimen shall be spread in a large pan at nominal single-stone thickness. Avoid stacking particles as feasible. Allow specimen to cure for 2 hours ± 10 minutes at 300 ± 5 ºF.

(f) A mold assembly (base plate, mold, and collar) shall be heated to approximately 325 ± 3 ºF. The face of the compaction hammer shall be thoroughly cleaned and heated on a hot plate set at 325 ± 3 ºF.

(g) Place a 4-inch diameter paper disc in the bottom of the mold before the mixture is introduced. Place the entire specimen in the mold with a heated spoon. Spade the mixture vigorously with a heated flat metal spatula, with a blade approximately 1-inch wide and 6-inches long and stiff enough to penetrate the entire layer of material, 15 times around the perimeter and 10 times at random into the mixture, penetrating the mixture to the bottom of the mold. Smooth the surface of mix to a slightly rounded shape.

> NOTE: To ease removal of the end papers after compaction, they may be sprayed with a light application of aerosol based vegetable oil. PAM brand cooking spray has been found to work well for this application.

(h) Before compaction, put the mold containing the AR-AC specimen in an oven for approximately one hour or as needed to heat the mixture specimen to the proper compaction temperature of 325 ± 3 ºF.

(i) Immediately upon removing the mold assembly loaded with mix from the oven, place a paper disc on top of mixture, place the mold assembly on the compaction pedestal in the mold holder, and apply 75 blows with the compaction hammer. Remove the base plate and collar, and reverse and reassemble the mold. Apply 75 compaction blows to the face of the reversed specimen.

> NOTE: The compaction hammer shall apply only one blow after each fall, that is, there shall not be a rebound impact. The compaction hammer shall meet the requirements specified in Section 2(c) of ARIZ 410.

(j) Remove the collar and top paper disc. Remove the base plate and remove the bottom paper disc while the specimen is still hot. Replace the base plate immediately, making sure to keep the mold and specimen oriented so that the bottom face of the compacted specimen remains directly in contact with, and is fully supported by, the base plate.

> NOTE: Paper discs need to be removed while the AR-AC specimen is hot. The discs are very difficult to remove after the specimens have cooled.

(k) If any part of the top surface of a compacted specimen is visually observed to increase in height (rise or swell in the mold) after compaction, stop testing and discard the prepared specimens. Adjust the gradation of the aggregate-mineral admixture blend to provide additional void space to accommodate the CRA, then batch and compact new trial AR-AC specimens. If no visible increase in height occurs, proceed with paragraphs 7(l) through 7(o).

(l) Allow each compacted specimen to cool in a vertical position in the mold (with the base plate on the bottom and the top surface exposed to air) until they are cool enough to be extruded without damaging the specimen. Rotate the base plate occasionally to prevent sticking.

> NOTE: Generally specimens can be extruded without damage when they are at a temperature of approximately 77 to 90 ºF.

> NOTE: Cooling may be accomplished at room temperature, or in a 77 ºF air bath. If more rapid cooling is desired, the mold and specimen may be placed in front of a fan until cool, ***but do not turn the mold on its side***.

(m) Orienting the mold and specimen so that the ram pushes on the bottom face (base plate face) of the specimen, extrude the specimen.

> NOTE: Care shall be taken in extruding the specimen from the mold, so as not to deform or damage the specimen. If any specimen is deformed or damaged during extrusion, the entire set of specimens at that CRA binder content shall be discarded and a new set prepared.

(n) Immediately upon extrusion, measure and record the height of the specimen to the nearest 0.001 inch and determine and record its weight in air to the nearest 0.1 gram.

> NOTE: Compacted AR-AC specimens shall be 2.50 ± 0.20 inches in height. If this criteria is not met for the specimens at each CRA binder content, the entire set of specimens at that CRA binder content shall be discarded and a new set prepared after necessary adjustments in the aggregate weight have been made using Equation 2.

(o) Repeat the procedures in paragraphs 7(e) through 7(n) for the required specimens.

BULK SPECIFIC GRAVITY/BULK DENSITY OF SPECIMENS

8. (a) Determine the bulk specific gravity of the three compacted AR-AC specimens at each CRA binder content in accordance with ARIZ 415, Method A, except that the paraffin method shall not be used. The determination of the “Weight in Water” and “S.S.D. Weight" of each specimen will be completed before the next specimen is submerged for its "Weight in Water" determination.

NOTE: Specimens fabricated in the laboratory that have not been exposed to moisture do not require drying after extrusion from the molds. The specimen weight in air obtained in paragraph 8(a) is its dry weight.

(b) Determine the density in pounds per cubic foot (pcf) by multiplying the specific gravity of each specimen by 62.3 pcf.

NOTE: For each CRA binder content, the densities of individual compacted specimens shall not differ by more than 2.0 pcf. If this density requirement is not met, the entire set of specimens at that CRA binder content shall be discarded and a new set of specimens prepared.

(c) Determine the average bulk specific gravity (G_{mb}) and/or average bulk density values for each CRA binder content and plot on a separate graph versus CRA binder content. Connect the plotted points with a smooth curve that provides the "best fit" for all values as shown in Figure 1.

STABILITY AND FLOW DETERMINATION

9. The stability, stability corrected for height, and flow of each specimen shall be determined according to ARIZ 410. (Stability and stability corrected for height are recorded to the nearest 10 pounds, and flow is recorded to the nearest 0.01 inch.)

(a) Determine and record the average values for stability corrected for height (to the nearest 10 pounds) and flow (to the nearest 0.01 inch) for each CRA binder content, and plot each on a separate graph using the same scale for CRA binder content as used in 8(c). Connect the plotted points with a smooth curve that provides the "best fit" for all values as shown in Figure 1.

NOTE: Flow values may be high compared to conventional asphaltic concrete mixtures.

MAXIMUM THEORETICAL SPECIFIC GRAVITY (RICE TEST)

10. The maximum theoretical specific gravity of the mixture shall be determined in accordance with ARIZ 806 at 6.0% CRA binder content with the following modifications.

(a) Prepare the AR-AC specimens including mineral admixture according to the procedures described in Sections 5 and 7 herein using 6.0% CRA by total mix weight. A liquid anti-stripping agent is not used.

(b) Spread the entire Rice sample in a large pan at nominal single-stone thickness. Avoid stacking particles as feasible.

(c) Oven cure the entire Rice sample for 2 hours ± 10 minutes at 300 ± 5 ºF.

(d) Immediately upon removal from the oven, break up fine particle agglomerations and split out individual test samples according to paragraph 7(d).

(e) Using Equation 5, calculate the effective specific gravity of the aggregate-mineral admixture blend (G_{se}).

Equation 5:

$$G_{se} = \frac{100 - P_{br}}{\frac{100}{G_{mm}} - \frac{P_{br}}{G_b}}$$

Where: G_{se} = Effective specific gravity of the aggregate-mineral admixture blend.
G_{mm} = Maximum theoretical specifc gravity of the AR-AC at CRA binder content P_{br}.
P_{br} = CRA binder content at which the Rice test was performed.
G_b = Specific gravity of the CRA.

(f) Using Equation 6, calculate the maximum theoretical specific gravity (G_{mm}) for different CRA binder contents.

NOTE: G_{se} is considered constant regardless of binder content.

Equation 6:

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

Where: G_{mm} = Maximum theoretical specific gravity of the AR-AC at CRA binder content P_b.
P_s = Aggregate and mineral admixture content, percent by total weight of mix (100-P_b).
P_b = CRA binder content, percent by total weight of mix.
G_{se} = Effective specific gravity of the aggregate-mineral admixture blend.
G_b = Specific gravity of the CRA.

DETERMINATION OF DESIGN CRA BINDER CONTENT

11. The design CRA binder content is determined as follows in paragraphs 11(a) through 11(e).

(a) For each CRA binder content used, calculate effective voids (V_a), percent absorbed CRA (P_{ba}), voids in mineral aggregate (VMA), and voids filled with CRA (VFA) using the following equations.

1) Using Equation 7, calculate the effective voids (V_a). The calculated G_{mm} values for the respective CRA binder contents are used to determine the corresponding effective voids content of the compacted Marshall specimens at each CRA binder content level.

Equation 7:
$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}} \right) \text{ x } 100$$

Where: V_a = Effective voids in the compacted mixture, percent of total volume.

G_{mm} = Maximum theoretical specifc gravity of the AC-AR at CRA binder content P_b.

G_{mb} = Bulk specific gravity of compacted mixture specimens.

2) Using Equation 8, calculate the percent absorbed CRA (P_{ba}).

Equation 8:
$$P_{ba} = \left(\frac{G_{se} - G_{sb}}{G_{sb} \text{ x } G_{se}} \right) \text{ x } G_b \text{ x } 100$$

Where: P_{ba} = Absorbed CRA, percent by total weight of mix.

G_{se} = Effective specific gravity of the aggregate-mineral admixture blend.

G_b = Specific gravity of the CRA.

G_{sb} = Bulk oven dry specific gravity of the aggregate-mineral admixture blend.

3) Using Equation 9, calculate voids in mineral aggregate (VMA).

Equation 9:
$$\text{VMA} = 100 - \left(\frac{G_{mb} \text{ x } P_s}{G_{sb}} \right)$$

Where: VMA = Voids in the mineral aggregate, percent of bulk volume.
G_{sb} = Bulk oven dry specific gravity of the aggregate-mineral admixture blend.
G_{mb} = Bulk specific gravity of compacted mixture specimens.
P_s = Aggregate and mineral admixture content, percent by total weight of mix (100-P_b).

4) Using Equation 10, calculate voids filled with CRA (VFA).

Equation 10:

$$VFA = \left(\frac{VMA - V_a}{VMA} \right) x\ 100$$

Where: VFA = Voids filled with CRA.
VMA = Voids in the mineral aggregate, percent of bulk volume.
V_a = Effective voids in the compacted mixture, percent of total volume.

(b) Using a separate graph for each of the volumetric properties calculated in paragraph 11(a), plot the average value for each set of three specimens versus CRA binder content. Connect the plotted points with a smooth curve that provides the “best fit” for all values as shown in Figure 1.

NOTE: The percentage of absorbed CRA (P_{ba}) and the effective specific gravity of the aggregate-mineral admixture blend (G_{se}) do not vary with CRA binder content.

(c) The design CRA binder content shall be the CRA binder content which meets the Mix Design Criteria requirements of the specifications, and provides effective voids as close as possible to the middle of the specified range.

(d) Use the effective voids (V_a) plot or interpolation to select the CRA binder content that yields the target effective voids content in the specifications. Use interpolation or the other plots to determine the values of bulk specific gravity (G_{mb}) and/or bulk density, VMA, VFA, stability and flow that correspond to the selected CRA binder content, and compare these with the limits in the specifications. Properties for which limits are not specified are evaluated by the Engineer for information only.

(e) If it is not possible to obtain specification compliance within the range of CRA binder contents used, a determination must be made to either redesign the mix (different aggregate gradation or source) or prepare additional specimens at other CRA binder contents for bulk specific gravity (G_{mb}) and/or bulk density, stability/flow testing, and volumetric analyses.

(f) Using Equation 6, calculate the maximum theoretical specific gravity (G_{mm}) for the design CRA design content. The maximum theoretical density is determined by multiplying the calculated G_{mm} by 62.3 pounds per cubic foot.

(g) For information, calculate the following volumetric properties at the design CRA binder content.

1) Using Equation 11, calculate the percent effective CRA binder content (P_{be}) of the AR-AC mixture.

Equation 11:

$$P_{be} = P_b - \left(\frac{P_{ba} \text{ x } P_s}{100} \right)$$

Where:
P_{be} = Percent effective CRA binder content of the mixture (free binder not absorbed).
P_b = CRA binder content, percent by total weight of mix.
P_{ba} = Absorbed CRA, percent by total weight of mix.
P_s = Aggregate and mineral admixture content, percent by total weight of mix ($100-P_b$).

2) Using Equation 12, calculate the effective CRA volume (V_{be}).

Equation 12:

$$V_{be} = \frac{P_{be} \times G_{mb}}{G_b}$$

Where:
V_{be} = Effective CRA volume, percent of bulk volume.
P_{be} = Percent effective CRA binder content of the mixture (free binder not absorbed).
G_{mb} = Bulk specific gravity of compacted mixture specimens.
G_b = Specific gravity of the CRA.

MIX DESIGN GRADATION TARGET VALUES

12. The desired target values for the aggregate composite and the aggregate-mineral admixture blend composite in the AR-AC mixture shall be from the composited gradation and shall be expressed as percent passing particular sieve sizes as required by the specifications for the project.

REPORT

13. Report the test results and data obtained on the appropriate form. Liberal use of the remarks area to clarify and/or emphasize any element of the design is strongly recommended. Information required in the mix design report includes:

- (a) Aggregate and Mineral Admixture:
  - 1) Aggregate source and identification
  - 2) Individual aggregate stockpile or bin gradations
  - 3) Mineral admixture type, source, and specific gravity
  - 4) Aggregate blend proportions and composite gradation for the mix design, with and without mineral admixture
  - 5) Fine and coarse aggregate specific gravities (Bulk Oven Dry, SSD, Apparent) and absorption
  - 6) Combined specific gravities [Bulk Oven Dry (G_{sb}), SSD, Apparent] and absorption of the aggregate-mineral admixture blend
  - 7) Aggregate quality
    - a) LA Abrasion
    - b) Sand Equivalent
    - c) Fractured Coarse Aggregate Particles (Percentage with one fractured face and percentage with two fractured faces)
    - d) Uncompacted Void Content
    - e) Carbonates (When applicable)
- (b) CRA Binder Design (from supplier), including:
  - 1) Source and grade of base asphalt cement
  - 2) Source and type of crumb rubber
  - 3) Crumb rubber gradation
  - 4) Proportions of asphalt cement and crumb rubber
  - 5) CRA binder properties, in compliance with Section 1009 of the ADOT Specifications
  - 6) CRA specific gravity (G_b)
  - 7) Asphalt cement specific gravity
- (c) Maximum theoretical specific gravity (G_{mm}) and density (pcf) at the CRA binder content at which the Rice test was performed (P_{br})
- (d) Mixture Compaction Trials:
  - 1) CRA binder content (P_b)
  - 2) Aggregate and mineral admixture content (P_s)
  - 3) Calculated maximum theoretical specific gravity (G_{mm}) and density (pcf)
  - 4) Bulk specific gravity (G_{mb}) and bulk density (pcf) of Marshall specimens
  - 5) Percent effective voids (V_a)
  - 6) Percent voids in mineral aggregate (VMA)
  - 7) Percent air voids filled (VFA)
  - 8) Percent absorbed CRA (P_{ba})

- 9) Effective specific gravity of the aggregate-mineral admixture blend (G_{se})
- 10) Effective CRA binder contents (P_{be}) and volumes (V_{be})
- 11) Marshall stability (nearest 10 pounds)
- 12) Marshall flow (0.01 inch)

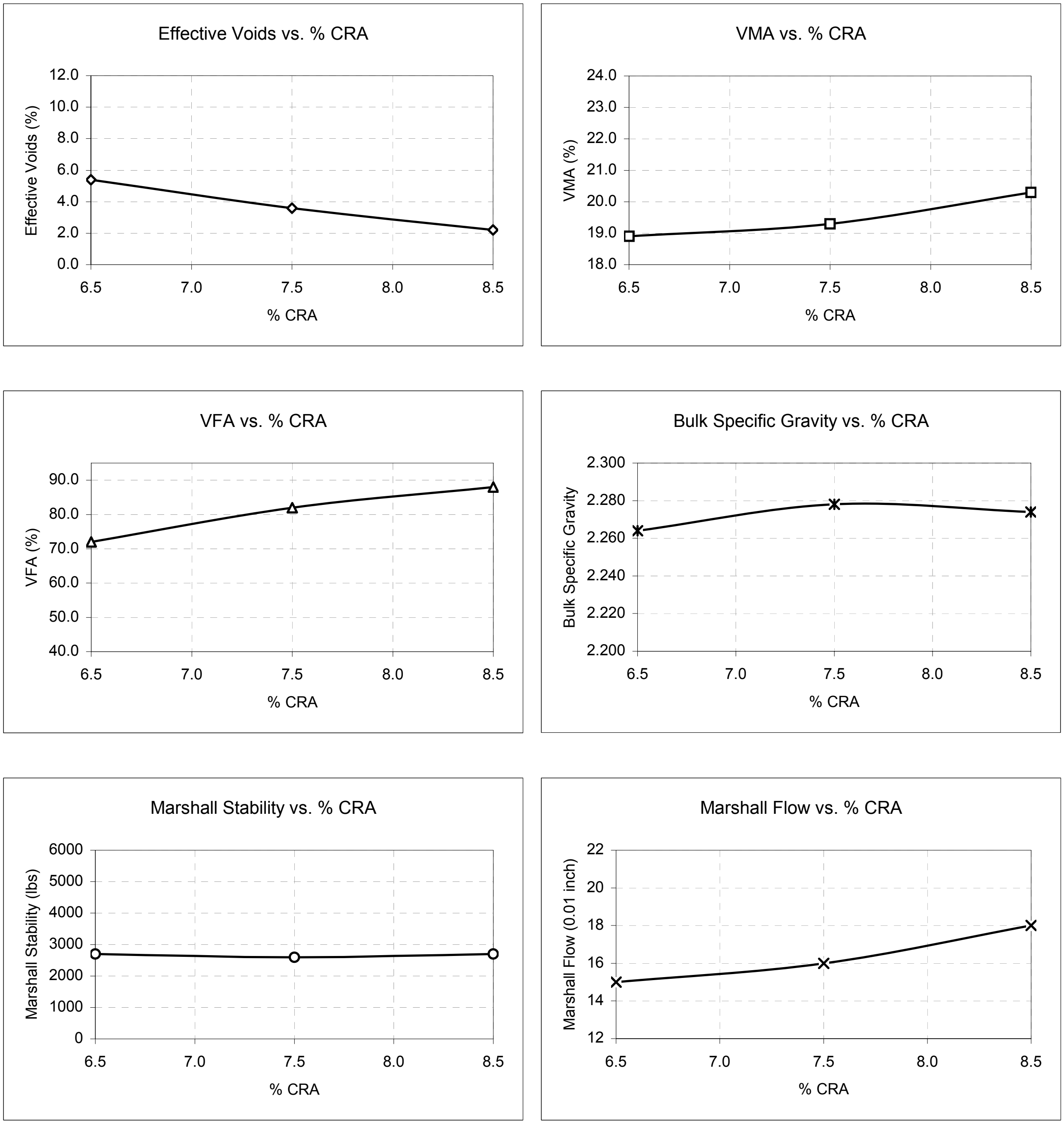
(e) Plots of the following properties versus CRA binder content:

- 1) Percent effective voids (V_a)
- 2) Percent voids in mineral aggregate (VMA)
- 3) Percent air voids filled (VFA)
- 4) Bulk specific gravity (G_{mb}) and/or bulk density
- 5) Marshall stability
- 6) Marshall flow

(f) Final Design:

- 1) CRA binder content (P_b)
- 2) Calculated maximum theoretical specific gravity (G_{mm}) and density (pcf)
- 3) Bulk specific gravity (G_{mb}) and bulk density (pcf) of Marshall specimens
- 4) Percent effective voids (V_a)

5) Percent voids in mineral aggregate (VMA)
6) Percent air voids filled (VFA)
7) Percent absorbed CRA (P_{ba})
8) Effective specific gravity of the aggregate-mineral admixture blend (G_{se})
9) Effective CRA binder contents (P_{be}) and volumes (V_{be})
10) Marshall stability (nearest 10 pounds)
11) Marshall flow (0.01 inch)



Effective Voids vs. % CRA

VMA vs. % CRA

VFA vs. % CRA

Bulk Specific Gravity vs. % CRA

Marshall Stability vs. % CRA

Marshall Flow vs. % CRA

Example Plots of Effective Voids, VMA, VFA, Bulk Specific Gravity, Marshall Stability, and Marshall Flow versus CRA Binder Content

FIGURE 1

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