ASPHALT MIX DESIGN
FOR
WEARING COURSE/ HEAVY TRAFFIC
(BASALT AGGREGATE & LIMESTONE FINE)

Project: Rehabilitation of AL-KHALDIAH Intersection/ at AL-DHLIAL and the Connected Roads (Part 2-a)

Submitted to

FUAD & OMAR AL DWAIRI CONTRACTING COMPANY

خلاطة شركة فؤاد وعمر الدويري للمقاولات
موقع الخلاطة: المفرق

SEPTEMBER – 2020

Mix Design Report Number:	**AMD20033**

For Scientific Research Purposes Only

المحور الهندسي للدراسات
Engineering Axis for Studies

AXIS OVER 25 YEARS OF PIONEERING

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Messrs.: FUAD & OMAR AL DWAIRI Contracting Co.
Amman - Jordan

Sep. 20, 2020
AMD20033

Subject: Asphalt Mix Design for
Wearing Course/ Heavy Traffic
(Basalt Aggregate & Limestone Fine)

Project: Rehabilitation of AL-KHALDIAH Intersection/ at AL-DHLIAL and the Connected Roads (Part 2-a)

خلاطة شركة فؤاد وعمر الدويري للمقاولات
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Dear Sirs,

Reference to your request regarding the above subject, Engineering Axis for Studies (**AXIS**) has the pleasure to submit herewith this report of asphalt mix design for the requested mix.

This report includes program of testing which has been implemented on the received aggregate samples, asphalt trial mixes, engineering interpretation of tests results and the concluded Job Mix Design.

AXIS would like to express sincere thanks to you for your confidence, looking forward for future cooperation. For further information, discussion or clarification, please do not hesitate to contact our office.

Sincerely Yours,
Engineering Axis for Studies

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(Chartered & Consultant Engineer)
General Manager

مكتب المحور الهندسي للدراسات
Engineering Axis for Studies

1. INTRODUCTION

This report outlines the sequenced process which has been implemented by AXIS to fulfill the requirements of the requested asphalt mix design. In summary, this process involved testing of aggregate samples (cold & hot bins), aggregate proportioning, conducting lab trial mixes, optimizing bitumen content, applying full-scale trial mixes on the asphalt batch plant, evaluation of results, and finalizing and concluding the Job Mix Design.

The following samples, which were delivered to AXIS Labs by the Client during the period from Sep. 02 to 15, 2020, were incorporated in the asphalt mix design;

- Coarse Aggregate 1: Crushed Basalt (Cold & Hot Bins)
- Coarse Aggregate 2: Crushed Basalt (Hot Bins)
- Medium Aggregate: Crushed Basalt (Cold & Hot Bins)
- Medium-Fine Aggregate: Crushed (Basalt & Limestone) (Hot Bins)
- Fine Aggregate: Crushed (Basalt & Limestone) (Cold & Hot Bins)
- Bitumen: Asphalt Cement; Penetration Grade (60/70), as delivered.
- Hot Asphalt Mix; as delivered from a full-scale trial on the asphalt batch plant.

2. JOB MIX REQUIREMENTS

The design aimed at satisfying the job mix requirements for Wearing Course – Heavy Traffic as stated in the Project Special Specifications in addition to "Specifications for Highway and Bridge Construction-1991" of Ministry of Public Works and Housing (MPWH). Accordingly, the following job mix requirements were considered;

- Marshall Stability, kg: 1225 (min.) [12,000 N]
- Marshall Flow, mm: 2.0 – 4.0
- Voids in Mineral Aggregate (VMA), %: 14 (min.)
- Air Voids, %: 3 – 6
- Marshall Stiffness, kg/mm: 500 (min.) [4900 N/mm]
- Loss of Stability, %: 25 (max.)
- Filler/Bitumen Ratio: 0.6 – 1.2
- Air Voids at Refusal, %: 2 (min.)
- Tensile Strength Ratio (TSR): 0.80 (min.)

Specifications of the mix aggregates, the Job Mix Gradation Envelope, and tolerances on the Job Mix Formula were according to the abovementioned Project Special Specifications.

3. LABORATORY WORK

3.1. Aggregate Testing:

3.1.1. Cold Bins:

The following determinations were carried out on the cold bin aggregate samples according to the standard procedures, correspondingly, and the tests results were as presented below: -

Aggregate Identification		Coarse Agg.	Medium Agg.	Fine Agg. 1	Fine Agg. 2	Cold Bins	
		(Basalt)			(L.S)		
		حصمة (بازلت)	عدسية (بازلت)	ناعمة 1 (بازلت)	ناعمة 2 (جيري)		
Test Name		Test Result				Test Standard	JAS
- Sieve Analysis: -		% Passing by Weight				AASHTO T 27-18, AASHTO T 11-05 (2018)	☆
Sieve Number (Size, mm):	1" (25)	100	100	100	100		
	3/4" (19)	100	100	100	100		
	1/2" (12.5)	25	94	100	100		
	3/8" (9.5)	3	66	100	100		
	No. 4 (4.75)	1	4	98	99		
	No. 8 (2.36)	1	1	68	69		
	No. 20 (0.850)	1	1	37	45		
	No. 50 (0.300)	1	1	21	30		
	No. 80 (0.180)	1	1	17	23		
	No. 200 (0.075)	0.4	0.5	11	20		
- Specific Gravity (SG):	Bulk SG. (Oven Dry)	2.743	2.732	2.859	2.517	AASHTO T 84-17, AASHTO T 85-18	☆
	Bulk SG. (SSD)	2.791	2.783	2.917	2.593		
	Apparent SG.	2.882	2.880	3.037	2.724		
- Water Absorption, %		1.8	1.9	2.1	3.0		
- Atterberg Limits	Liquid Limit	----		---	18	AASHTO T 89-17 (Method A), AASHTO T 90-16	☆
	Plastic Limit	----		---	16		
	Plasticity Index	---		N.P	2		
- Flakiness Index		19	22	---	---	BS 812: Part 105.1, 1989	☆
- Elongation Index		21	24	---	---	BS 812: Part 105.2, 1990	☆
- Abrasion Loss (500 cycles), %		23	24	---	---	AASHTO T 96-02 (2019)	☆
- Ratio of wear loss (100/500)		0.21	0.23	---	---		
- Clay Lumps, %		0.10	0.16	0.28	0.64	AASHTO T 112-00 (2017)	☆
- Gypsum Content (SO_3), %		0.021			0.044	EN 1744-1: 2012	☆
- Chloride Content (Cl), %		0.006			0.003	EN 1744-1: 2012	☆
- Soundness Loss (Na_2SO_4), %		1.09	1.53	---	---	AASHTO T 104-99 (2016)	☆
- Fractured Faces (at least two), %		100	100	---	---	AASHTO T 335-09 (2018)	☆
- Chert & Flint Content, %		Nil	Nil	---	---	IHM/EAS 003 - 2019 (*)	☆
- Vesicular Particles, %		4	3	---	---	By Inspection	--
- Polished Stone Value, PSV		65		---	---	BS 812, BS EN 1097-8 (2000)	--

(*): In-house Developed Method by **AXIS**.

☆ Test/s within **AXIS** Accreditation Scope by ISO/IEC 17025:2017 (Certificate No.: JAS Test-039).

3.1.2. Hot Bins:

The following determinations were carried out on the hot bin aggregate samples according to the standard procedures, correspondingly, and the tests results were as presented below: -

Aggregate Identification		Coarse Agg. 1	Coarse Agg. 2	Medium Agg.	Medium -Fine Agg.	Fine Agg.	Hot Bins	
		(Basalt)			(Mixed)			
		حصمة 1	حصمة 2	عدسية	سمسمية	ناعمة		
		(بازلت)			(خليط)			
Test Name		Test Result					Test Standard	JAS
- Sieve Analysis: -		% Passing by Weight						
Sieve Number *(Size, mm)*:	1" *(25)*	100	100	100	100	100	AASHTO T 27-18, AASHTO T 11-05 (2018)	☆
	3/4" *(19)*	99	100	100	100	100		
	1/2" *(12.5)*	1	54	100	100	100		
	3/8" *(9.5)*	1	11	80	98	100		
	No. 4 *(4.75)*	1	1	14	55	98		
	No. 8 *(2.36)*	1	1	2	4	86		
	No. 20 *(0.850)*	1	1	2	3	47		
	No. 50 *(0.300)*	1	1	1	3	27		
	No. 80 *(0.180)*	1	1	1	2	21		
	No. 200 *(0.075)*	0.4	0.6	0.9	1.9	13.5		
- Specific Gravity (SG):	Bulk SG. (Oven Dry)	2.748	2.741	2.736	2.718	2.703	AASHTO T 84-17, AASHTO T 85-18	☆
	Bulk SG. (SSD)	2.797	2.791	2.788	2.782	2.773		
	Apparent SG.	2.890	2.886	2.887	2.903	2.907		
- Water Absorption, %		1.8	1.8	1.9	2.3	2.6		
- Atterberg Limits	Liquid Limit	----				---	AASHTO T 89-17 (Method A), AASHTO T 90-16	☆
	Plastic Limit	----				---		
	Plasticity Index	----				N.P		
- Sand Equivalent		---		71			AASHTO T 176-08 (2017)	☆
- Static Stripping, % Coated		>95				---	AASHTO T 182-84 (2002)	☆
- Dynamic Stripping (with Filler), % Coated		~ 70				---	IHM/EAS 001 - 2019 (*)	☆

(*): In-house Developed Method by **AXIS**.

☆ Test/s within **AXIS** Accreditation Scope by ISO/IEC 17025:2017 (Certificate No.: JAS Test-039).

3.2. Aggregate Combined Grading:

Several calculation trials were exercised, by using different proportions of hot bin components, to obtain a combined grading which would satisfy the specification grading limits as well as providing satisfactory mix properties. Fuller Curve and Restricted Zone concepts were taken in consideration for finalization of the adopted combined grading. Fuller Curve is the maximum density curve based on (0.45) power, using 19mm-size as the maximum size for this mix. Restricted Zone is usually utilized as a guide to avoid tender mixes.

Accordingly, the following hot bin proportions were found to be the most appropriate;

Hot Bin Components			Hot Bin Proportions, %
- Coarse Agg. 1	(Hot Bin 1)	حصية 1	7.0
- Coarse Agg. 2	(Hot Bin 2)	حصية 2	18.0
- Medium Agg.	(Hot Bin 3)	عدسية	21.0
- Medium-Fine Agg.	(Hot Bin 4)	سمسمية	21.0
- Fine Agg.	(Hot Bin 5)	ناعمة	33.0
- Total		المجموع	100.0

And the obtained combined grading was as follows: -

Sieve No. *(Size, mm)*		% Passing by Weight			
		Combined Grading	Specification Limits		
1"	*(25)*	100	100		
3/4"	*(19)*	99.9	90	-	100
1/2"	*(12.5)*	84.8	71	-	90
3/8"	*(9.5)*	72.4	56	-	80
No. 4	*(4.75)*	47.1	35	-	56
No. 8	*(2.36)*	29.9	23	-	38
No. 20	*(0.850)*	16.8	13	-	27
No. 50	*(0.300)*	10.0	5	-	17
No. 80	*(0.180)*	7.8	4	-	14
No. 200	*(0.075)*	5.2	2	-	8

The adopted combined grading (Job Mix Gradation) and the specified grading limits in addition to Fuller Curve and the Restricted Zone are shown in Figure 1.

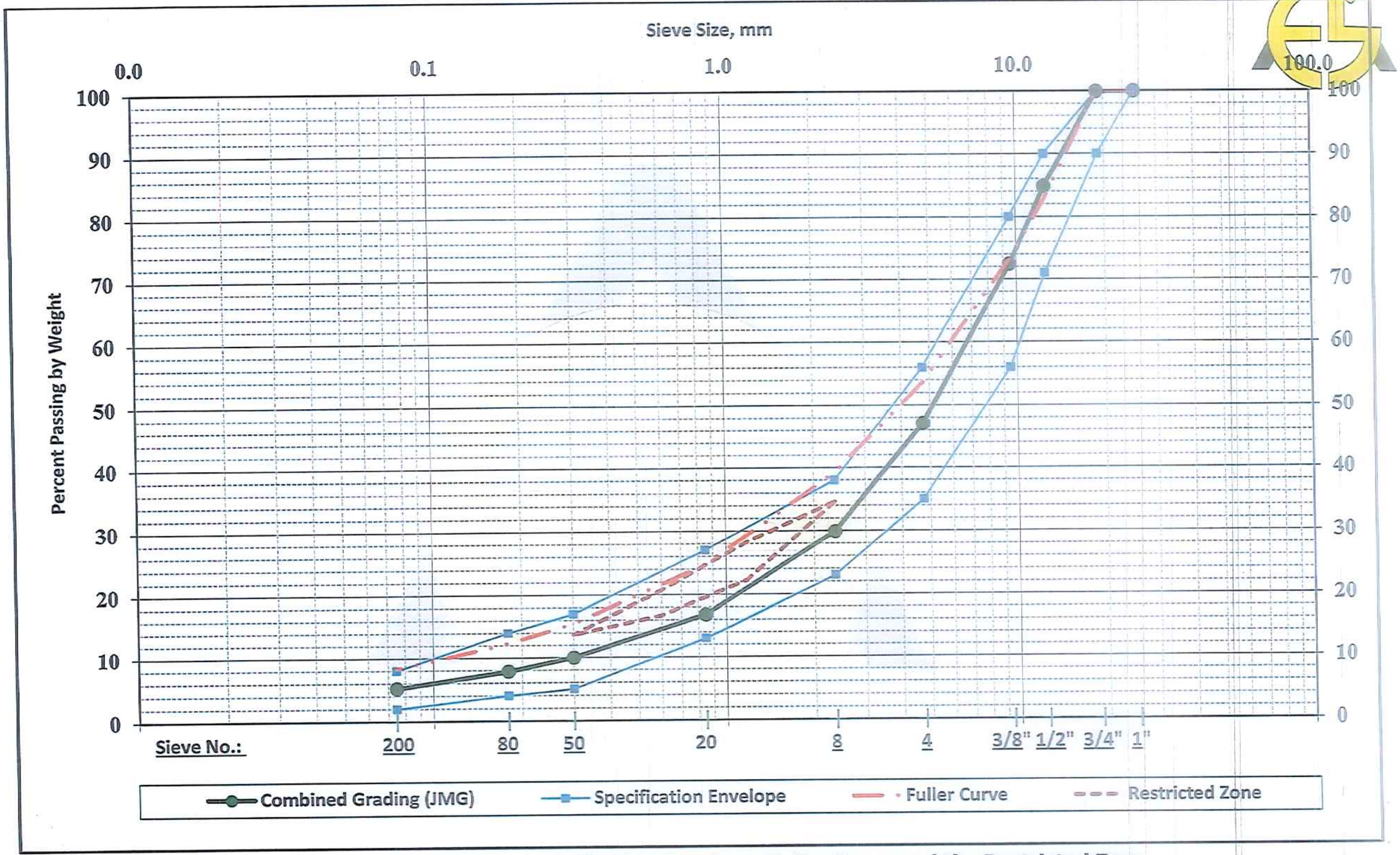

Figure 1: Job Mix Grading, Specification Envelope, Fuller Curve and the Restricted Zone

3.3. Mix Design Procedure:

The procedure followed in the mix design was Marshall Method as outlined in Asphalt Institute Manual Series No. 02 (MS-2, Seventh Edition, 2014); "Asphalt Mix Design Methods". Using the adopted aggregate combined grading, five sets of trial test specimens (i.e. three specimens for each set) were prepared to cover a range of asphalt contents, aiming at bracketing the anticipated Optimum Bitumen Content (OBC) in a manner having at least two points above and two points below such OBC. The estimated un-extractable bitumen was added to these asphalt contents (*See Clause 6; Remarks*). Mixing temperature in the said trial mixes was (159±2.5) °C. The test specimens were conditioned for two hours after mixing as stated in the Standard Practice of AASHTO R30-02 (2015); "Mixture Conditioning of Hot Mix Asphalt (HMA)". The following tests were carried out on the conditioned test specimens: -

- AASHTO R 68-15 (2019) (✫); "Preparation of Asphalt Mixtures by Means of the Marshall Apparatus".
- AASHTO T 166-16 (✫); "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens".
- AASHTO T 245-19 (✫); "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus". *75 blows were applied on each specimen face at (149±2) °C temperature. Marshall Stability was tested after soaking for 1/2 hour at 60 °C.*
- AASHTO T 209-19 (✫); "Theoretical Maximum Specific Gravity (G_{mm}) and Density of Asphalt Mixtures". *This test was performed on two trial mixes of 4.50% & 5.00% bitumen contents by weight of total mix.*

The following determinations were performed on a full-scale trial mix from the asphalt plant: -

- "Loss of Stability Test". *Additional three specimens were prepared, soaked for 24 hours at 60 °C, tested for stability and related to the conventional Marshall Stability.*
- "Air Voids at Refusal". *Marshall Specimens were prepared and compacted by increasing number of blows reaching 500 blows, and the reached density was considered as the reasonable maximum density, where further blows would cause dramatic unrealistic degradation (beyond the intended densification level).*
- AASHTO T 283-14; "Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage".

✫ Test/s within **AXIS** Accreditation Scope by ISO/IEC 17025:2017 (Certificate No.: JAS Test-039).

Tests results of the trial asphalt mixes, after refinement, are presented in Table 1.

4. INTERPRETATION OF TESTS RESULTS

The refined average results of the mix property tests were plotted versus the corresponding bitumen contents on the following set of curves as shown in Figure 2;

- Bulk Specific Gravity VS. Bitumen Content
- Marshall Stability VS. Bitumen Content
- Voids in Mineral Aggregate VS. Bitumen Content
- Percent Air Voids VS. Bitumen Content
- Marshall Flow VS. Bitumen Content
- Marshall Stiffness VS. Bitumen Content

Remark: It is to be recognized that the sixth curve (Marshall Stiffness VS. Bitumen Content) had been firstly added and used in 1994 by AXIS.

Inspection of the plotted curves reveals that the mix property curves follow a reasonably consistent pattern for dense-graded asphalt paving mixes. Therefore, these curves were considered in determination of the OBC.

Table 1: Tests Results of Marshall Lab Trial Mixes

Bulk Specific Gravity of Combined Aggregate	*(Gsb) =*	2.723
Effective Specific Gravity of Combined Aggregate	*(Gse) =*	2.779
Absorbed Asphalt by Weight of Aggregate	*(Pba) =*	0.75%
Specific Gravity of Bitumen	*(Gb) =*	1.019

Bitumen Content by Weight of Total Mix, %	Specimen Number	Marshall Bulk Sp. Gr. (Gmb)	Theoretical Maximum Sp. Gr. (Gmm)	Marshall Air Voids (AV), %	Voids in Mineral Aggregate (VMA), %	Marshall Stability, kg	Marshall Flow, mm	Marshall Stiffness, kg/mm
3.5	1	2.396				1335	1.35	
	2	2.385				1186	1.75	
	3	2.404				1383	1.40	
	Average	**2.395**	**2.620**	**8.6**	**15.1**	**1301**	**1.50**	**868**
4.0	1	2.433				1576	1.70	
	2	2.413				1492	2.25	
	3	2.410				1386	2.15	
	Average	**2.419**	**2.599**	**6.9**	**14.7**	**1485**	**2.03**	**730**
4.5	1	2.446				1762	2.10	
	2	2.427				1643	2.65	
	3	2.430				1486	2.60	
	Average	**2.434**	**2.578**	**5.6**	**14.6**	**1630**	**2.45**	**665**
5.0	1	2.457				1730	2.80	
	2	2.437				1642	3.20	
	3	2.453				1810	3.05	
	Average	**2.449**	**2.558**	**4.3**	**14.6**	**1727**	**3.02**	**573**
5.5	1	2.466				1652	3.25	
	2	2.447				1518	3.95	
	3	2.459				1676	3.65	
	Average	**2.457**	**2.538**	**3.2**	**14.7**	**1615**	**3.62**	**447**

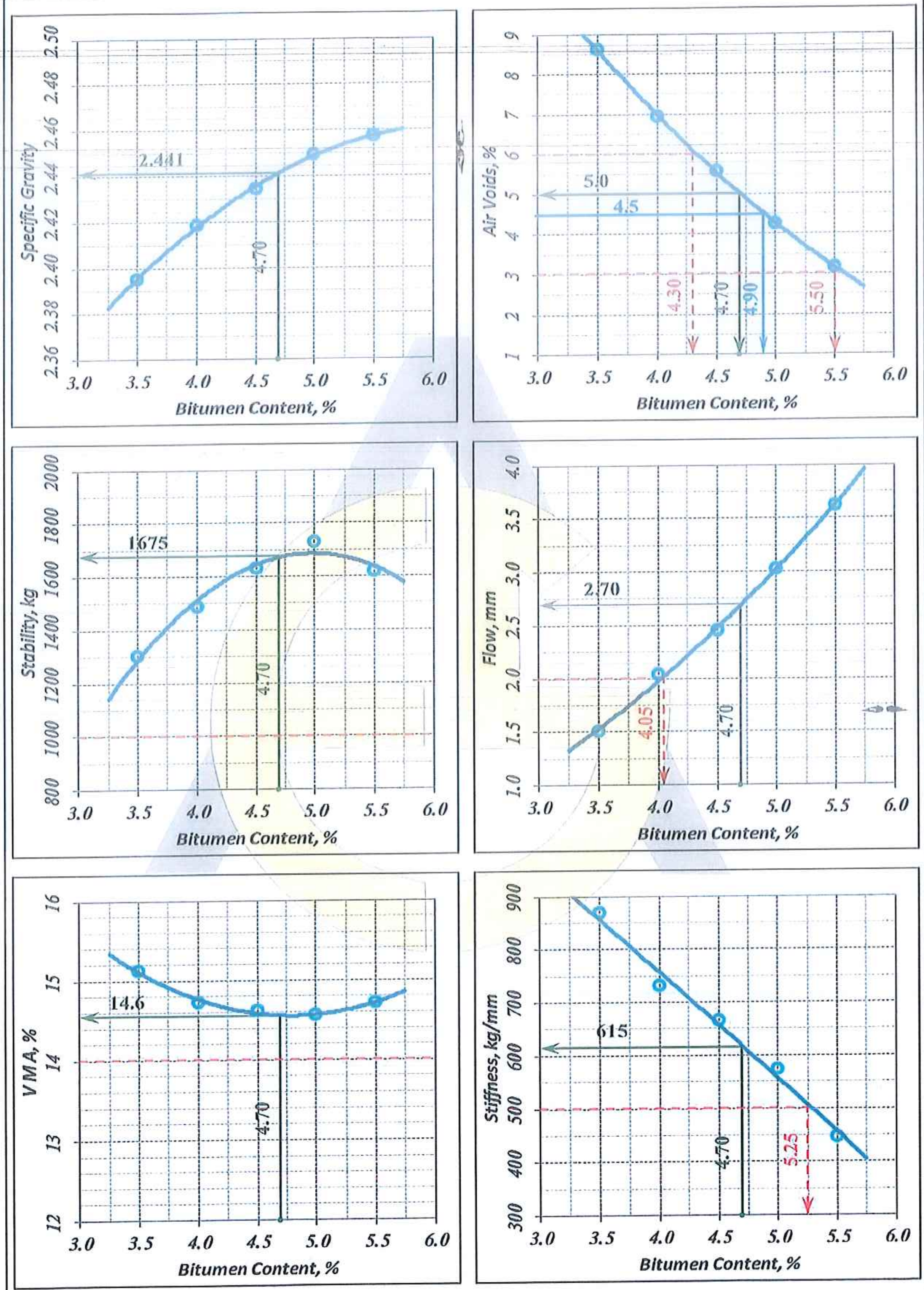

Figure 2: Marshall Mix-Property Set of Curves

3.4. Optimum Bitumen Content (OBC):

3.4.1. Asphalt Institute Approach (MS-2, 7th Edition; 2014):

Recently (*), the Asphalt Institute (MS-2, 7th Edition) recommends considering all of the mix properties for the selection of the Optimum Bitumen Content (OBC). In general, the Asphalt Institute recommends choosing the bitumen content at the median of the percent air voids limits, to be termed as the "Preliminary Design Bitumen Content". If all of the calculated and measured mix properties at this bitumen content meet the mix design criteria, then this bitumen content is considered as the "Optimum Bitumen Content" for the mix design. However, if not all of the design criteria are met, then some adjustment or compromise is necessary or the mix may need to be redesigned. It's worthmentioning that this recent MS-2 approach is similar to the "Range Approach" as presented in Clause 4.1.2 below. For this mix, the bitumen content which corresponds to the mid-range of the specified air voids (AV = 4.5%) is 4.90%. However, AXIS is convinced that adopting such air voids range for determination of the (OBC) is unadvisable; mainly due to the unjustifiable low limit of this range (i.e. 3%), which would lead in turn to a high bitumen content (e.g. 4.90%) to be considered as an optimum for such type of mix. Accordingly and in light of Clause 5 of 4.05.3 of the Special Specifications, the bitumen content which corresponds to 5.0% air voids, as being the mid of the *preferred* air voids range (4% – 6%), was adopted and found to be 4.70%, see Figure 2.

(*) *The "Averaging Approach", which had been used earlier by Asphalt Institute, has been superseded in the latest editions. By Averaging Approach, the OBC was being determined by numerically averaging the values of the bitumen content which corresponds to the maximum stability, maximum density and median of the specified air voids range. Generally speaking, it was a normal local practice in Jordan to use this average value minus a certain percentage (almost being 0.3%) as the OBC. The "Range Approach" had been implemented by AXIS since establishment in 1994 and it was being used earlier by "Arab Center for Engineering Studies". Furthermore, the sixth curve of Figure 2 "Marshall Stiffness VS. Bitumen Content" had been firstly added and used in 1994 by AXIS, as found essential in adoption of the "Range Approach".*

3.4.2. Range Approach (University of Birmingham, England):

Based upon an original concept in Japanese Standard Specifications, the Range Approach was developed and adopted at the University of Birmingham. In addition to the mix property curves; an additional graph is constructed, on which are drawn the ranges of bitumen content over which the specified values of each of these *mix* properties are satisfied. The mid-point of the common overlap of all ranges is taken as the Target Bitumen Content for the Job Mix, provided that when the permitted tolerances are applied, the mix properties remain within their individual specified limits.

Application of the Range Approach on this mix is illustrated in Figure 3, which suggests that the mix satisfies all specifications requirements over a bitumen content range from 4.30% to 5.25% by weight of total mix. If the allowable tolerances in bitumen content (±0.30%) were applied, a narrower range from 4.60% to 4.95% would be deduced. Within the latter range, the bitumen content which corresponds to the median of the *preferred* air voids range **(4.70%)**, as determined in Clause 4.1.1 above, is recommended as the Optimum Bitumen Content (OBC). This OBC is slightly to the left side from the minimum point of the VMA curve, as recommended by MS-2. Moreover, the effective bitumen content by volume of total mix obtained at the OBC is 9.6%. Although not mentioned in the specifications, this value can essentially affect mix behavior and performance. According to AXIS records, the most satisfactory mixes for Wearing Course/ heavy traffic were found to be having an effective bitumen content in the range of 9% by volume.

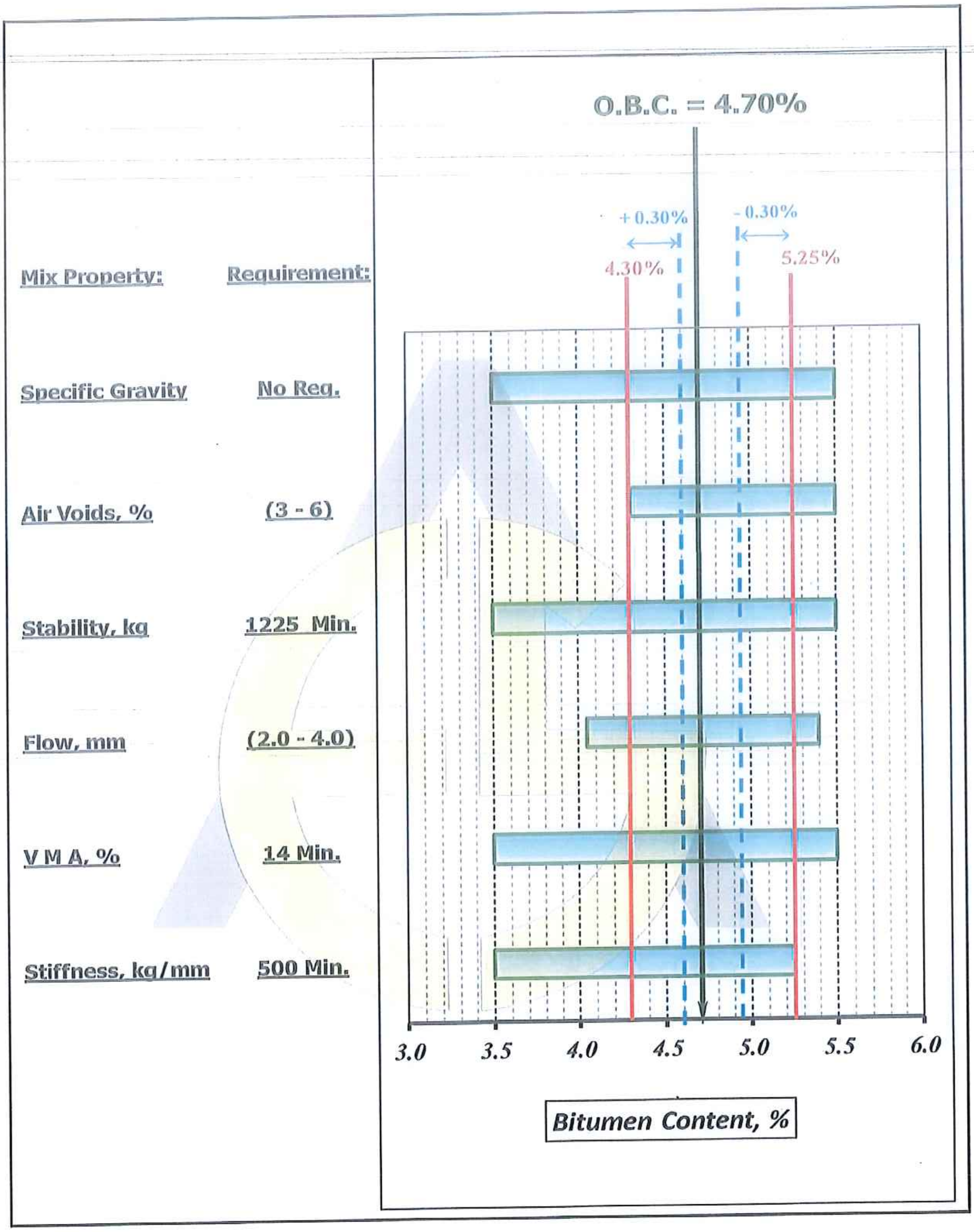

Figure 3: Design Bitumen Content by Range Approach

3.5. Job Mix Formula and Production Envelope:

The table below indicates the Job Mix Formula (i.e. Job Mix Grading and Optimum Bitumen Content), the specified tolerances, and the "Production Envelope" which can be applied during production.

Sieve No. *(Size, mm)*		% Passing by Weight				
		Job Mix Grading	Specified Tolerances	Production Envelope		
1"	*(25)*	100	---	100		
3/4"	*(19)*	100	± 5	95	-	100
1/2"	*(12.5)*	85	± 5	80	-	90
3/8"	*(9.5)*	72	± 5	67	-	77
No. 4	*(4.75)*	47	± 4	43	-	51
No. 8	*(2.36)*	30	± 4	26	-	34
No. 20	*(0.850)*	17	± 4	13	-	21
No. 50	*(0.300)*	10	± 4	6	-	14
No. 80	*(0.180)*	8	± 4	4	-	12
No. 200	*(0.075)*	5.2	± 1.5	3.7	-	6.7
Optimum Bitumen Content (OPC)		4.70%	± 0.30%	4.40%	-	5.00%

Notes:

- *The Job Mix grading values are given as whole numbers except that for sieve no. 200, to be comparable with the grading of the extracted mix aggregates (refer to AASHTO T 30-19; "Mechanical Analysis of Extracted Aggregate"). It is to be recognized that reporting of the tested mix grading shall comply with this relevant standard.*
- *It is to be realized that the above tolerances on gradation are given for production purposes. These tolerances should be fully applied even if the resulted Production Envelope falls outside the specification limits indicated in Clause 3.2 of this report. To uncover any vagueness regarding this issue, it's advisable to refer to Subsections 4.01.3 and 4.03.3, and the relevant Tables 4.1 and 4.10 of the MPWH Specifications, 1991. Reference can be made also to ASTM D 3515-01; Standard Specification for "Hot-Mixed, Hot-Laid Bituminous Paving Mixtures".*

5. MIX PROPERTIES AT THE OPTIMUM BITUMEN CONTENT

The deduced mix properties at the recommended Optimum Bitumen Content of **(4.70%)** by weight of total mix, were as tabulated below;

Mix Property	Job Mix Result
- Marshall Specific Gravity	2.441
- Air Voids in Mix, %	5.0
- Marshall Stability, kg	1675
- Marshall Flow, mm	2.70
- Marshall Stiffness, kg/mm	615
- Voids in Mineral Aggregate, %	14.6
- Loss of Stability, %	13
- Air Voids at Refusal, %	3.2
- TSR	0.85
- Filler/Bitumen Ratio	1.10

6. REMARKS

➢ The following mix components should be applied on the asphalt plant for the production of each Metric Ton (1000 kg) of mix. Extra asphalt weight was added to compensate for un-extractable bitumen in the lab extraction test, and has been taken in consideration in preparation of the lab trial mixes (see Clause 3.3 - Mix Design Procedure). However, such extra asphalt weight can be tuned to suit absorption of the incorporated aggregate during production, as part of the quality control scheme, to keep the asphalt content within the specified range (OBC ± 0.3%), satisfying the remaining mix properties as well.

Components of Hot Mix				Weight, kg
- Asphalt Cement (60/70)		أسفلت		49.0
- Coarse Agg. 1	(Hot Bin 1)	حصية 1	خشن ↓ ناعم	66
- Coarse Agg. 2	(Hot Bin 2)	حصية 2		171
- Medium Agg.	(Hot Bin 3)	عدسية		200
- Medium-Fine Agg.	(Hot Bin 4)	سمسمية		200
- Fine Agg.	(Hot Bin 5)	ناعمة		314
- Total		المجموع		≈ 1000

- The given hot bin proportions are based on gradation analysis results of the incorporated aggregate samples. Should these gradations reasonably vary; the given hot bin proportions can be adjusted to achieve the Job Mix Grading with the allowable tolerances (see Clause 8 of Subsection 4.03.3 of MPWH Specifications).
- It is to be recognized that the obtained Job Mix Design and the mix properties are based on the aggregate samples supplied and incorporated in the mix design. Therefore, it is essential to take aggregate samples and check their properties, periodically, during work. In case of significant variation in aggregate properties, the given mix design and mix properties wouldn't necessarily be valid. In such a case, it is recommended to contact our office.
- To ensure consistent production with minimal waste in aggregate materials, the cold bin feeding should be kept close to the following proportions;

Cold Bin Components		Cold Bin Proportions (by Weight), %
- Coarse Agg.	حصبية (بازلت)	17
- Medium Agg.	عدسية (بازلت)	35
- Fine Agg. 1	ناعمة 1 (بازلت)	31
- Fine Agg. 2	ناعمة 2 (جيري)	17
- Total	المجموع	100

- Gradations of the hot bin aggregates and in turn gradation of the produced mix are strictly related to the cold bin feeding. Therefore, it is advisable to keep the cold bin gradations and proportions close to those given in this report as much as practically possible.
- Workability, cohesion, uniformity, and compactability (e.g. stability under compaction) of this mix, in addition to adequateness of utilized compaction machinery and procedures, are to be monitored and checked continuously during application of this mix. Furthermore, it's advisable to update AXIS with the mix tests results during the first few days of application to ensure that the given Job Mix Formula is achievable and the remaining mix properties are satisfactory. In the event that any unsatisfactory mix behavior/results was encountered, appropriate adjustments would be made by AXIS.
- Accuracy of aggregate, bitumen, and temperature scales; and adequacy of cold feeders, dryer, filler system, hot screens, hot bins, pugmill, and all other facilities of the batch plant should be checked and maintained continuously during operation.
- It is to be recognized that this mix design is intended to be used for Wearing Course in Heavy Traffic roads' category. AXIS strictly recommends limiting the use of this mix for the said purpose.
- <u>As mentioned earlier, the sixth curve of Figure 2 "Marshall Stiffness VS. Bitumen Content" had been firstly added and used in 1994 by "Engineering Axis for Studies". Therefore, AXIS preserves his all rights against any unwarranted use of this curve without formal permission. Also, AXIS preserves his rights against any reprint, change, or use of all or any part of this report beyond its intended purpose.</u>