Investigation of Airfield Runways at Jacksonville Naval Air Station

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In October 1990, the U.S. Army Engineer Waterways Experiment Station (WES) was requested by the Naval Facilities Engineering Command, Southern Division, Charleston, South Carolina, to provide technical assistance in analyzing the airfield pavement distresses at Jacksonville Naval Air Station in Florida. Runways 9/27 and 14/32 had been rehabilitated and resurfaced with asphalt concrete in 1988. Within 1 year, significant amounts of loose fine aggregate appeared on the pavement surface. The asphalt concrete had begun to deteriorate prematurely and exhibit pavement surface distresses. The primary surface distresses were an open-textured surface, raveling, and evidence of roots in the asphalt concrete. The Materials Research and Construction Technology Branch of the Geotechnical Laboratory at WES was requested to inspect the airfield pavements and perform laboratory tests on asphalt concrete samples to determine properties of the asphalt cement, aggregates, and asphalt concrete mixture. The purpose of the analysis was to evaluate the in-place materials for compliance with specifications, determine possible causes for these pavement distresses, and recommend options for the repair of the airfield pavements. The laboratory evaluation of the asphalt concrete material indicated that pavement raveling was due to an improperly produced and constructed asphalt concrete mixture. Factors that contributed to the improper asphalt mixture were as follows: field density and compaction results were low and below minimum compaction requirements, aggregate gradations were consistently out of specification, natural sand contents were extremely high, in-place asphalt contents were extremely low, and void properties did not meet standard criteria for airfield pavements.

The U.S. Army Engineer Waterways Experiment Station (WES) was requested by the Southern Division, Naval Facilities Engineering Command, Charleston, South Carolina, in October 1990, to provide technical assistance in analyzing the airfield pavement distresses at the Jacksonville Naval Air Station (NAS), Florida. Runways 9/27 and 14/32 were rehabilitated and resurfaced during 1988. Runway 14/32 was resurfaced with an asphalt slurry seal followed by a 1½-in. asphalt concrete overlay. The rehabilitation of Runway 9/27 included cold milling 3 in. of the existing asphalt pavement and resurfacing with 2½ to 6 in. of new asphalt concrete. Two different asphalt concrete mix designs were used during the rehabilitation of Runways 9/27 and 14/32. The asphalt concrete mixture placed on Runway 9/27 had a ¾-in. maximum size aggregate gradation, whereas the material on Runway 14/32 had a ½-in. maximum size aggregate gradation. The rehabilitation project was completed in December 1988.

Within 1 year, the airfield manager noticed significant amounts of fine aggregate on the pavement surface. The asphalt concrete surface had begun to deteriorate and showed surface distresses. The primary surface distresses were raveling and evidence of roots in the asphalt concrete. On November 6, 1990, Navy and WES personnel inspected the airfield pavement. The asphalt concrete on Runway 9/27 was raveling and losing fine aggregate. Traffic areas, especially the touchdown zone, were extremely open textured and exhibited severe raveling. Runway 14/32 had similar defects, but the degree of deterioration was not as severe.

On the basis of visual inspection, it was concluded that the pavement deterioration was caused by several factors that dealt with material and mixture properties. The Materials Research and Construction Technology Branch of the Geotechnical Laboratory was requested by Jacksonville NAS to perform laboratory tests on asphalt concrete samples to determine properties of the asphalt cement, aggregate, and asphalt concrete mixture. The purpose of the analysis was to evaluate the in-place materials for compliance with specifications, determine possible causes for these pavement distresses, and recommend options for the repair of the airfield pavement.

On December 15, 1990, eight slab samples approximately 2 ft by 2 ft in size were extracted from Runways 9/27 and 14/32. Six samples were obtained from Runway 9/27, and two samples were obtained from Runway 14/32. These slab samples were selected to evaluate typical asphalt concrete materials throughout the airfield pavement. The individual slab sample location and pavement surface characteristics are given in Table 1.

The slab samples were removed by full-depth saw cutting. This process produced asphalt concrete slabs with approximate dimensions of 2 ft by 2 ft with a depth equivalent to the full depth of the asphalt concrete surfacing. These samples were easily separated from the compacted granular limerock base course and shipped to the WES laboratories. During removal of the slab samples, voids throughout the surface course layer were evident, especially at the bottom of the wearing surface.

ANALYSIS OF PAVEMENT MATERIALS

Because of the nature of the pavement distresses, primarily surface raveling, only the surface course material was tested and analyzed. The laboratory test plan used to evaluate these slab samples follows.

1. Conduct the following tests on slab samples: thickness, field density (MIL STD 620B, Method 101), asphalt extrac-

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TABLE 1 SLAB LOCATIONS AND PAVEMENT SURFACE CHARACTERISTICS

Slab	Runway	Station	Centerline Offset (ft)	Amount of Traffic	Visual Pavement Surface Condition
1	9/27	109+05	15L	Heavy Touchdown Zone	Raveled, open-textured excessive rubber buildup
2	9/27	109+85	80R	Low	Good
3	9/27	132+72	28L	Medium	Raveled
4	9/27	145+13	4L	Heavy	Raveled, open-textured
5	9/27	165+97	65L	Low	Raveled
6	9/27	146+26	34R	Medium	Raveled, open-textured
7	14/32	-	80L	Low	Slightly raveled
8	14/32	-	2L	Heavy	Good

tion (ASTM D2172), recompaction analysis (ASTM D1559, D3387, MIL STD 620B, Method 100), Abson recovery (ASTM D1856), and aggregate tests.

2. Conduct the following tests on recovered asphalt cement: penetration (ASTM D5), absolute viscosity (ASTM D2171), kinematic viscosity (ASTM D2170), ductility (ASTM D113), and specific gravity (ASTM D70).

3. Conduct the following tests on the recovered aggregate material: specific gravity (ASTM C127, C128), absorption (ASTM C127, C128), percent fractured faces, natural sand content, LA abrasion (ASTM C131), and gradation (ASTM C117, C136).

4. Determine the following properties on the recompacted asphalt concrete mixture: Marshall stability and flow (ASTM D1559, MIL STD 620B, Method 100), voids total mix (MIL STD 620B, Method 101), voids filled with asphalt (MIL STD 620B, Method 101), voids in mineral aggregate (MIL STD 620B, Method 101), recompacted density (ASTM D1559, D3387, MIL STD 620B, Method 100), retained stability (MIL STD 620B, Method 104), theoretical density (ASTM D2041, MIL STD 6208, Method 101), gyratory analysis (ASTM D3387), and effect of moisture (ASTM D4867).

The first step in evaluating the in-place material was to determine the thickness of the entire slab and then the surface course layer. Three 4-in. cores were taken from each slab sample so that the in-place field density could be determined (MIL STD 620B, Method 101). Pavement thickness and in-place field density values are given in Table 2.

TABLE 2 PAVEMENT THICKNESS AND FIELD DENSITY RESULTS

Slab	Core No.	Total Pavement Thickness (in.)	Surface Course Thickness (in.)	Field Density (pcf)
1	1	4 7/8	1 3/4	137.3
	2	4 3/4	1 3/4	135.8
	3	4 3/4	1 3/4	136.3
	AVG	4 3/4	1 3/4	136.5
2	1	5 1/4	1 1/2	131.6
	2	5 3/4	1 1/2	131.1
	3	5 1/2	1 1/2	129.8
	AVG	5 1/2	1 1/2	130.8
3	1	6 1/4	1 5/8	129.1
	2	6 1/4	1 1/2	130.6
	3	6 1/4	1 1/2	131.8
	AVG	6 1/4	1 1/2	130.5
4	1	8	1 1/2	136.8
	2	7 7/8	1 3/8	136.5
	3	8	1 1/2	137.2
	AVG	8	1 1/2	136.8
5	1	6 1/4	1 9/16	135.0
	2	6 3/8	1 11/16	134.9
	3	6 1/2	1 11/16	133.8
	AVG	6 3/8	1 5/8	134.6
6	1	6 3/8	1 1/8	129.7
	2	6 1/4	1 3/16	130.8
	3	6 3/8	1 1/8	129.6
	AVG	6 3/8	1 1/8	130.0
7	1	6 3/8	1 3/8	131.9
	2	6 3/4	1 5/8	133.4
	3	6 1/2	1 1/4	131.7
	AVG	6 1/2	1 3/8	132.3
8	1	5 3/4	1 15/16	131.5
	2	5 3/4	1 7/8	131.8
	3	5 3/4	1 7/8	131.4
	AVG	5 3/4	1 7/8	131.6

Before any material testing, the surface course layer for each individual slab was separated from the remaining pavement layers. All loose material that had broken off the slab samples was discarded and not tested. The next step in preparing the asphalt concrete material was to trim and remove all cut edges from the samples. This was accomplished by heating the cut edges and removing at least ¾ in. of material with a hot spatula. This procedure is performed to ensure that the aggregate gradation is not affected by the sampling technique and that a true representative sample is evaluated. After the sample preparation was completed, the material representing individual slabs was broken down and thoroughly mixed before testing.

A complete laboratory analysis was conducted on each of the eight slab samples. Because of the condition of Slab 1, two separate sets of tests were conducted for the raveled and nonraveled portions of the slab. A total of nine individual samples were evaluated. The laboratory evaluation for each sample included extractions, asphalt recoveries, recompaction analyses, and material tests.

Four asphalt extractions (ASTM D2172), two aggregate washed gradations (ASTM C136 and C117), and one Abson recovery (ASTM D1586) were conducted on each individual slab sample. Extractions and recoveries were conducted on split-out representative samples. Technical grade trichloroethylene and a two-stage extraction procedure using a high-speed continuous flow centrifuge were used to optimize the results of this procedure. The aggregates from this procedure were used to conduct aggregate gradation, specific gravity, fractured face, natural sand content, and LA abrasion tests. The results are summarized in Tables 3 and 4. The asphalt cements recovered from the Abson recovery procedure were used to conduct penetration, viscosity, specific gravity, and ductility tests. The results of these tests are given in Table 5.

The remaining material from each slab sample was then used for a recompaction analysis. Three procedures were used to recompact the asphalt concrete material. The first used was in accordance with ASTM D1559, which required a compaction temperature of 290°F and a compactive effort of 75 blows on each side with a hand hammer. The second followed the guidelines in MIL STD 620B, Method 100, which required a compaction temperature of 250°F and a compactive effort of 75 blows on each side with the hand hammer. The third was conducted according to ASTM D3387, which uses the Corps of Engineers gyratory testing machine (GTM). The GTM was used to compact asphalt specimens at 250°F using 200 psi, 30 revolutions, and 1-degree gyration angle, which is equivalent to a 75-blow hand hammer compactive effort.

The specimens produced by the three compaction procedures were used to determine standard Marshall mix design properties, which include density, stability, flow, and void requirements. The results of these recompaction analyses are given in Tables 6 through 11. Recompacted specimens were also evaluated using ASTM D4867 and MIL STD 620B, Method 104.

DISCUSSION OF LABORATORY RESULTS

Asphalt Concrete Thickness and Field Density

The asphalt concrete thickness and field density results are listed in Tables 3, 12, and 13. The total asphalt concrete pavement thicknesses for Runway 9/27 varied between 4¾ and 8 in. with the average thickness being approximately 6¼ in. The total asphalt concrete thicknesses of the two slab samples from Runway 14/32 were 6½ in. and 5¾ in. The surface course layer thickness for Runway 9/27 varied between 1⅛ in. and 1¾ in. The surface course thicknesses for Runway 14/32 were 1⅜ in. and 1⅞ in. On the basis of the absence of pavement structural failures, the thicknesses of the asphalt

TABLE 3 SURFACE COURSE AGGREGATE ANALYSIS, RUNWAY 9/27

Sieve Size	JMF	JMF Tolerances	Slab 1A	Slab 1B	Slab 2	Slab 3	Slab 4	Slab 5	Slab 6
3/4 in.	100	100	100	100	100	100	100	100	100
1/2 in.	91	83-96	82.6	89.3	87.3	83.9	77.2	85.3	92.3
3/8 in.	81	75-88	67.9	79.0	77.0	70.4	64.7	72.9	84.4
No. 4	64	59-71	43.4	55.3	62.0	46.2	43.2	47.6	61.5
No. 8	53	46-59	35.0	44.8	53.7	36.5	35.4	38.8	48.3
No. 16	40	34-46	29.7	37.4	44.0	31.2	30.6	32.6	39.5
No. 30	29	24-34	26.4	32.7	37.3	27.9	27.3	28.3	34.3
No. 50	20	15-25	22.9	28.9	31.2	24.4	24.0	24.3	30.0
No. 100	9	8-13	10.5	11.9	9.9	10.9	11.1	11.1	14.3
No. 200	4	3-6	4.1	4.6	4.7	4.3	4.2	4.5	5.1
Specific Gravity		(+No. 4)	2.48	2.48	2.49	2.48	2.52	2.47	2.49
		(-No. 4)	2.62	2.61	2.63	2.63	2.62	2.62	2.61
		(Total)	2.54	2.55	2.56	2.55	2.56	2.54	2.56
Absorption		(+No. 4)	1.9	2.0	2.4	2.0	2.6	2.3	2.0
		(-No. 4)	0.9	0.5	1.6	1.8	2.2	1.3	1.5
Fractured Faces		(+No. 4)	100	100	96.2	99.3	99.6	99.4	100
		(-No. 4)	100	100	100	100	100	99.5	99.5
Natural Sand Content			18.5	23.2	35.4	20.2	19.0	19.6	24.4
LA Abrasion									
Grading B			37.0	37.0	37.0	37.0	--	--	--
Grading C			34.9	34.9	34.9	34.9	34.9	34.9	34.9

NOTE: Underlined data are outside of JMF tolerances.

TABLE 4 SURFACE COURSE AGGREGATE ANALYSIS, RUNWAY 14/32

Sieve Size	JMF	JMF Tolerances	Slab 7	Slab 8
3/4 in.	--	--	100	100
1/2 in.	100	100	99.0	99.0
3/8 in.	87	82-94	81.9	90.1
No. 4	65	59-72	51.8	65.7
No. 8	54	48-60	40.3	49.0
No. 16	41	35-47	31.9	38.3
No. 30	30	25-35	25.9	31.2
No. 50	20	15-25	20.2	25.1
No. 100	10	8-14	10.9	13.3
No. 200	4.0	3-6	5.2	5.3
Specific Gravity	(+No. 4)		2.52	2.54
	(-No. 4)		2.63	2.64
	(Total)		2.57	2.61
Absorption	(+No. 4)		2.9	2.7
	(-No. 4)		2.8	2.8
Fractured	(+No. 4)		100	99.7
	(-No. 4)		99.7	100
Natural Sand Content			15.0	20.4

NOTE: Underlined data are outside of JMF tolerances.

TABLE 5 RECOVERED ASPHALT CEMENT ANALYSIS

Slab	Penetration (0.1 mm)	Absolute Viscosity (poises)	Kinematic Viscosity (cSt)	Specific Gravity	Ductility (cm)
1A	24	45,085	1540	1.064	10
1B	22	36,698	1355	1.057	8
2	30	17,063	1101	1.050	42
3	25	27,526	1194	1.060	9
4	26	27,744	1134	1.059	10
5	26	28,657	1451	1.056	22
6	19	57,796	1614	1.060	7
7	24	21,109	1530	1.048	40
8	27	26,164	1531	1.054	32

TABLE 6 SURFACE COURSE MIXTURE RECOMPACTION ANALYSIS, RUNWAY 9/27—COMPACTION TEMPERATURE OF 290°F AND COMPACTIVE EFFORT OF 75 BLOWS ON EACH SIDE WITH HAND HAMMER

Property	Specs (JMF)	Slab 2	Slab 3	Slab 4	Slab 5	Slab 6
Asphalt Content (%)	6.5	5.5	4.3	5.3	4.6	5.2
Recompacted Density (pcf)	135.9	138.6	140.6	140.6	140.1	141.1
Theoretical Density (pcf)	141.3					
MIL STD 620B		148.8	149.9	148.7	148.8	148.9
ASTM D2041		148.4	150.1	149.8	149.9	148.5
Stability (lbs)	1800 min	3846	5246	5119	5392	6119
Flow (0.01 in.)	8-16	8	9	9	7	7
Voids Total Mix (%)	3-5					
Mil STD 620B	(3.8)	6.9	6.2	5.5	5.9	5.3
ASTM D2041		6.6	6.4	6.2	6.5	5.0
Voids Filled (%)	--					
Mil STD 620B		62.7	59.5	67.3	62.4	67.7
ASTM D2041		63.7	58.7	64.6	60.1	68.9
Voids in Mineral Aggregate (%)	15 min					
Mil STD 620B	(16.2)	18.5	15.3	16.8	15.7	16.4
ASTM D2041		18.2	15.5	17.5	16.3	16.1

TABLE 7 SURFACE COURSE MIXTURE RECOMPACTION ANALYSIS, RUNWAY 14/32—COMPACTION TEMPERATURE OF 290°F AND COMPACTIVE EFFORT OF 75 BLOWS ON EACH SIDE WITH HAND HAMMER

Property	Specs (JMF)	Slab 7	Slab 8
Asphalt Content (%)	6.5	5.4	6.9
Recompacted Density (pcf)	135.0	141.0	141.3
Theoretical Density (pcf)	140.7		
MIL STD 620B		149.0	147.6
ASTM D2041		146.3	144.6
Stability (lbs)	1800 min	6000+	5275
Flow (0.01 in.)	8-16	8	8
Voids Total Mix (%)	3-5		
MIL STD 620B	(4.0)	5.3	4.2
ASTM D2041		5.0	2.3
Voids Filled (%)	--		
MIL STD 620B		68.6	77.9
ASTM D2041		76.3	86.6
Voids in Mineral Aggregate (%)	16 min		
MIL STD 620B	(15.6)	16.9	19.0
ASTM D2041		15.2	17.1

TABLE 8 SURFACE COURSE MIXTURE RECOMPACTION ANALYSIS, RUNWAY 9/27—COMPACTION TEMPERATURE OF 250°F AND COMPACTIVE EFFORT OF 75 BLOWS ON EACH SIDE WITH HAND HAMMER

Property	Specs (JMF)	Slab 1A	Slab 1B	Slab 2	Slab 3	Slab 4	Slab 5	Slab 6
Asphalt Content (%)	6.5	4.3	5.6	5.5	4.3	5.3	4.6	5.2
Recompacted Density (pcf)	35.9	140.0	139.6	137.4	139.2	139.5	138.5	138.6
Theoretical Density (pcf)	41.3							
MIL STD 620B		149.5	147.5	148.8	149.9	148.7	148.8	148.9
ASTM D2041		152.2	149.4	148.4	150.1	149.8	149.9	148.5
Stability (lbs)	1800 min	5731	5029	3578	4992	4520	4725	5046
Flow (0.01 in.)	8-16	9	9	9	7	8	14	8
Voids Total Mix (%)	3-5							
MIL STD 620B	(3.8)	6.3	5.3	7.7	7.2	6.2	7.0	7.0
ASTM D2041		8.0	6.6	7.4	7.3	6.9	7.6	6.7
Voids Filled (%)	--							
MIL STD 620B		59.1	69.2	59.9	55.6	64.4	58.1	60.9
ASTM D2041		53.2	64.3	60.9	55.2	61.9	56.1	61.9
Voids in Mineral Aggregate (%)	15 min							
MIL STD 620B	(16.2)	5.4	17.2	19.2	16.2	17.4	16.7	17.9
ASTM D2041		7.1	18.5	18.9	16.3	18.1	17.3	17.6
Retained Stability (%)	75 min	--	--	100.0	97.0	100.0	97.1	97.1

TABLE 9 SURFACE COURSE MIXTURE RECOMPACTION ANALYSIS, RUNWAY 14/32—COMPACTION TEMPERATURE OF 250°F AND COMPACTIVE EFFORT OF 75 BLOWS ON EACH SIDE WITH HAND HAMMER

Property	Specs (JMF)	Slab 7	Slab 8
Asphalt Content (%)	6.5	5.4	6.9
Recompacted Density (pcf)	135.0	139.4	140.9
Theoretical Density (pcf)	140.7		
MIL STD 620B		149.0	147.6
ASTM D2041		146.3	144.6
Stability (lbs)	1800 min	5354	4875
Flow (0.01 in.)	8-16	9	9
Voids Total Mix (%)	3-5		
MIL STD 620B	(4.0)	6.4	4.5
ASTM D2041		4.7	2.6
Voids Filled (%)	--		
MIL STD 620B		64.3	76.7
ASTM D2041		71.0	85.1
Voids in Mineral Aggregate (%)	16 min		
MIL STD 620B	(15.6)	17.9	19.3
ASTM D2041		16.2	17.4
Retained Stability (%)	75 min	91.4	100.0

TABLE 10 GYRATORY ANALYSIS OF SURFACE COURSE MIXTURE, RUNWAY 9/27

Property	Slab 1A	Slab 1B	Slab 2	Slab 3	Slab 4	Slab 5	Slab 6
Asphalt Content (%)	4.3	5.6	5.5	4.3	5.3	4.6	5.2
Recompacted Density (pcf)	139.1	139.2	138.6	139.4	140.2	138.9	139.3
Theoretical Density (pcf)							
MIL STD 620B	149.5	147.5	148.8	149.9	148.7	148.8	148.9
ASTM D2041	152.2	149.4	148.4	150.1	149.8	149.9	148.5
Stability (lbs)	5252	4753	4059	4888	4706	5047	5228
Flow (0.01 in.)	10	11	11	10	9	12	7
Voids Total Mix (%)							
MIL STD 620B	7.0	5.6	6.9	7.0	5.7	6.7	6.5
ASTM D2041	8.6	6.8	6.6	7.1	6.4	7.3	6.2
Voids Filled (%)							
MIL STD 620B	56.3	67.8	62.7	56.5	66.3	59.2	62.9
ASTM D2041	51.1	63.4	63.7	56.2	63.6	57.1	64.0
Voids in Mineral Aggregate (%)							
MIL STD 620B	16.0	17.4	18.5	16.1	16.9	16.4	17.5
ASTM D2041	17.6	18.6	18.2	16.2	17.6	17.0	17.2
Gyratory Stability Index (GSI)	0.92	0.94	0.93	0.96	0.99	0.93	0.95

TABLE 11 GYRATORY ANALYSIS OF SURFACE COURSE MIXTURE, RUNWAY 14/32

Property	Slab 7	Slab 8
Asphalt Content (%)	5.4	9
Recompacted Density (pcf)	140.1	141.3
Theoretical Density (pcf)		
MIL STD 620B	149.0	147.6
ASTM D2041	146.3	144.6
Stability (lbs)	5334	4992
Flow (0.01 in.)	12	9
Voids Total Mix (%)		
MIL STD 620B	5.9	4.2
ASTM D2041	4.2	2.3
Voids Filled (%)		
MIL STD 620B	66.3	77.9
ASTM D2041	73.4	86.6
Voids in Mineral Aggregate (%)		
MIL STD 620B	17.5	19.0
ASTM D2041	15.8	17.1
Gyratory Stability Index (GSI)	0.96	1.1

TABLE 12 FIELD COMPACTION RESULTS

Slab	Field Density (pcf)	Recompacted Laboratory Density (250°F)*	Percent Compaction	Recompacted Laboratory Density (290°F)**	Percent Compaction
1	136.5	139.8	97.6	--	--
2	130.8	137.4	95.2	138.6	94.4
3	130.5	139.2	93.8	140.6	92.8
4	136.8	139.5	98.1	140.6	97.3
5	134.6	138.5	97.2	140.1	96.1
6	130.0	138.6	93.8	141.1	92.1
7	132.3	139.4	94.9	141.0	93.8
8	131.6	140.9	93.4	141.3	93.1

* 75 blow hand hammer, MIL STD 620B, Method 100
** 75 blow hand hammer, ASTM D1559

TABLE 13 IN-PLACE VOID RESULTS

Slab	Field Density (pcf)	MIL STD 620B Theoretical Density (pcf)	In place Voids (%)	ASTM D2041 Theoretical Density (pcf)	In place Voids (%)
1A	136.5	149.5	8.7	152.2	10.3
1B	136.5	147.5	7.5	149.4	8.6
2	130.8	148.8	12.1	148.4	11.6
3	130.5	149.9	12.9	150.1	13.1
4	136.8	148.7	8.0	149.8	8.7
5	134.6	148.8	9.5	149.9	10.2
6	130.0	148.9	12.7	148.5	12.5
7	132.3	149.0	11.2	146.3	9.6
8	131.6	147.6	10.8	144.6	9.0

concrete represented by these samples are adequate for the amount and type of air traffic for these runways.

The field density results were determined from 4-in. cored specimens taken from each slab sample. The field density values were determined only for the surface course layer. The field density values for Runways 9/27 and 14/32 varied from 130.0 to 136.8 pcf. The average field compaction results given in Table 12 for these slab samples indicated that a majority of the in-place asphalt concrete did not meet the minimum compaction requirement of 97 percent. The field compaction results for the laboratory densities recompacted at 250°F varied from 93.4 to 98.1 percent. The field compaction results for the laboratory densities recompacted at 290°F were lower and varied from 92.8 to 97.3 percent.

The field compaction results and the visual voids on the cut faces of the slabs indicated that the in-place voids in the asphalt concrete mixtures were high. The in-place voids were calculated using field density values and two theoretical density values determined by MIL STD 620B and ASTM D2041. The in-place void results are given in Table 13. The in-place void results calculated using MIL STD 620B varied between 7.5 and 12.9 percent for Runway 9/27 and between 10.8 and 11.2 percent for Runway 14/32. The in-place void results calculated using ASTM D2041 varied between 8.6 and 13.1 percent for Runway 9/27 and between 9.0 and 9.6 for Runway 14/32. Asphalt concrete mixtures with in-place voids above 8 percent are considered permeable. Asphalt concrete mixtures that are permeable and allow water and air intrusion are subjected to oxidation, which leads to weathering of the pavement surface. Excessive weathering of an asphalt concrete mixture decreases the durability and service life of a pavement.

Aggregate Analysis

The results of the analyses performed on the aggregates recovered from the extraction process are given in Tables 3 and 4. The aggregate gradations determined for the slab samples from Runway 9/27 indicated that all samples have aggregate gradations that do not meet the contract specifications. The predominant problem with the aggregate gradations for the surface course mixtures is that the gradations were too coarse and not well graded. Slab Samples 1A, 3, 4, and 5 are much coarser than the specified limits. These slab samples also had an extremely open-textured surface. Slab Samples 1B, 2, and 6 have aggregate gradations that exceed the upper limit on the No. 50 sieve and vary from the lower to upper limits of the specified limits. As a whole, the aggregate gradations determined from the slab samples taken from Runway 9/27 do not meet the required limits for heavy-duty airfield pavements.

The aggregate gradations determined from slab samples taken from Runway 14/32 are inconsistent. Slab Sample 7 had a gradation that did not meet the specifications and was similar to the coarse aggregate gradations found on Runway 9/27. Slab Sample 8 had the only aggregate gradation that was close to meeting the required contract specifications.

The natural sand content of the slab samples was determined by observing the aggregate particles smaller than the No. 4 sieve under a microscope. The percentage of natural sand is calculated by determining the number of sand particles in the aggregate gradation. The natural sand contents in the aggregate gradations from Runway 9/27 were all above the maximum limit of 15 percent. The natural sand content varied from 18.5 to 35.4 percent for Slab Samples 1 through 6. Slab Samples 1B, 2, and 6 had high natural sand contents of 23.2, 35.4, and 24.4 percent, respectively. The natural sand content for Slab Samples 7 and 8 from Runway 14/32 were 15.0 and 20.4 percent, respectively.

The LA abrasion test (ASTM C131) was conducted on combined samples of extracted aggregate. A combined sample from Slab Samples 1 through 3 was evaluated using Grading B. The percent wear of these aggregates was 37.0. A combined sample of Slab Samples 1 through 6 was used to evaluate Grading C. The percent wear of these aggregates was 34.9. The Florida limerock aggregate meets the requirements of the specification.

Asphalt Cement Analysis

The test results for the asphalt cement recovered from the Abson recovery process are listed in Table 5. They indicated that this material had aged and hardened during plant production and a 2-year service life. The initial penetration for the Chevron AC-20 asphalt cement was 87. Typical values for the recovered penetration ranged between 19 and 30. These values indicated a reduction in penetration of 66 to 78 percent. Asphalt cements recovered from mixtures after plant production typically have reduced penetration values of 40 to 50 percent. The ductility and viscosity values also indicated that the asphalt cement had hardened significantly.

In the previous visual inspection on November 6, it was observed that an obvious color difference existed between the outside paving lanes and the inside lanes. Slab Samples 2 and 5 were taken from the outside lanes. The ductility values indicated that there was a difference in the asphalt cements. The ductility values for Slab Samples 2 and 5 were two to four times greater than for the other slab samples, indicating that this binder was not as brittle or hard as the asphalt cements of the inside lanes.

Recompaction Analysis

The test results from the three recompaction studies are given in Tables 6 through 11. All three recompaction procedures, ASTM D1559, MIL STD 620B (Method 100), and ASTM D3387, indicated that the asphalt concrete mixtures do not meet the contract specifications.

The asphalt contents determined from the extraction process were very low. The asphalt contents determined for slab samples from Runway 9/27 ranged from 4.3 to 5.6 percent. The asphalt content for slab samples from Runway 14/32 were 5.4 and 6.9 percent. The asphalt content recommended by the contractor as optimum was 6.5 percent. The asphalt contents of the in-place material were between 0.9 and 2.2 percent below the optimum asphalt content. Low asphalt contents cause improper film coating of aggregate particles, which leads to insufficient bonding and raveling.

The voids total mix (VTM) requirement of 3 to 5 percent was not met by these asphalt concrete mixtures from Runway

9/27. The VTM values were extremely high for all three recompaction procedures and each theoretical density determination, ASTM D2041 and MIL STD 620B (Method 101). The VTM values computed from the recompaction analysis using ASTM D1559 procedure ranged from 5.0 to 6.6 percent (ASTM D2041) and from 5.3 to 6.9 percent (MIL STD 620B).

The VTM values computed from the recompaction analysis using MIL STD 620B (Method 100) procedure ranged from 6.7 to 8.0 percent (ASTM D2041) and from 5.3 to 7.7 percent (MIL STD 620B). The VTM values computed from the gyratory analysis ranged from 6.2 to 8.6 percent (ASTM D2041) and from 5.6 to 7.0 percent (MIL STD 620B).

The other Marshall void property, voids filled with asphalt (VF), was also determined for these asphalt concrete mixtures from Runway 9/27. The VF values were extremely low for an asphalt concrete mixture that is used on a heavy-duty airfield pavement. The typical voids filled with asphalt requirement is 70 to 80 percent for airfield pavements. The VF values computed from the ASTM D1559 procedure ranged from 58.7 to 68.9 percent (ASTM D2041) and from 59.5 to 67.7 percent (MIL STD 620B). The VF values computed for the MIL STD 620B (Method 100) procedure ranged from 53.2 to 64.3 percent (ASTM D2041) and from 55.6 to 69.2 percent (MIL STD 620B). The VF values computed from the gyratory analysis ranged from 51.1 to 64.0 percent (ASTM D2041) and from 56.3 to 67.8 percent (MIL STD 620B).

The recompaction analysis of slab samples from Runway 14/32 indicated that these asphalt concrete mixtures did not fully meet the specification requirements but were much closer than the previously discussed slab samples. The asphalt content for Slab Sample 7 was 5.4 percent, whereas the asphalt content for Slab 8 was 6.9 percent. The VTM values for Slab 7 varied from 4.2 to 6.4 percent for the three recompaction procedures. The VTM values for Slab 8 were much lower and varied from 2.3 to 4.5 percent for the recompaction procedures. The VF values for Slab Sample 7 were slightly lower than recommended values and varied from 64.3 to 76.3 percent. The VF values for Slab Sample 8 indicated that too much asphalt was in the mixture. The VF values ranged from 76.7 to 86.6 percent. The gyratory analysis also indicated that Slab Sample 8 had an excessive amount of asphalt cement in the mixture. A gyratory stability index (GSI) value of 1.1 indicated that the asphalt concrete mixture had an excessive asphalt content.

SUMMARY

The performance of the asphalt concrete overlays, especially Runway 9/27, has been unacceptable due to the raveling of the pavement surface. On the basis of visual inspection of the runways and test results from the laboratory analysis, the poor performance of the asphalt concrete overlay was due to an improperly produced and constructed asphalt concrete mixture. Several factors contributed to this improper asphalt mixture:

- The field density and compaction results are low and did not meet the minimum compaction requirements. The high in-place voids total mix indicated that the asphalt concrete mixtures were susceptible to weathering and decreased service life.
- The aggregate gradations were consistently out of specification and were predominantly coarse. Coarse gradations promote an open-textured pavement surface, which allows increased raveling when combined with a low asphalt content.
- The natural sand content was above the maximum 15 percent limit. The use of high percentages of local natural sand increased the incidence of roots, sticks, and organics in the asphalt concrete mixtures.
- The test results for the recovered asphalt cements indicated that these materials have aged and hardened significantly during the 2 years these pavements have been in service. Hardened asphalt cements produce brittle asphalt concrete mixtures that increase the potential for weathering and raveling.
- The asphalt contents determined from the extraction process indicated that the asphalt concrete mixtures had less asphalt cement than recommended by the JMF. The asphalt contents were extremely low, 1 to 2 percent by weight lower than the optimum asphalt content. These low asphalt contents are a major contributor to the raveling problem.
- The recompaction analyses for these slab samples indicated that the asphalt concrete mixtures did not meet the contract specifications. The Marshall mix design void properties were not acceptable for heavy-duty airfield pavements. The voids total mix values were extremely high, and the voids filled with asphalt values were consistently low. These Marshall properties indicate that the in-place asphalt concrete does not have enough asphalt cement to properly coat the aggregate particles and to prevent further deterioration and raveling.

The combination of these factors has contributed to pavement surface raveling that has occurred on Runways 9/27 and 14/32. The test results for the laboratory evaluation indicate that the in-place material is not the quality pavement required by the specification. On the basis of the test results of this investigation, the pavement surface raveling will continue and eventually cause a foreign object damage problem.

RECOMMENDATIONS

On the basis of the visual inspection and laboratory analysis of the in-place materials at Jacksonville NAS, the following recommendations are given:

1. The in-place asphalt concrete surface course material on Runway 9/27 is unacceptable for airfield pavements and should be removed to eliminate surface raveling and potential foreign object damage.
2. The existing asphalt concrete surface course should be removed by cold milling to a minimum depth of 2 in.
3. An asphalt concrete layer 2 in. thick should be placed and constructed for the new runway surface. Proper materials and construction procedures should be required to ensure an acceptable pavement surface.
4. The existing asphalt concrete material on Runway 14/32 is not exhibiting severe pavement raveling as is Runway 9/27. However, the potential for future deterioration exists. Periodic

inspections should be conducted by Jacksonville NAS personnel to monitor the pavement surface on Runway 14/32.

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