Characterization of Rubblized Concrete Pavements with HMA Overlays at the National Airport Pavement Test Facility

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Abstract

Three rigid airport pavement test items (MRC, MRG, and MRS) at the Federal Aviation Administration's (FAA) National Airport Pavement Test Facility (NAPTF) with 12-inch thick concrete slabs on different support systems (slab on crushed stone base, slab on grade, and slab on stabilized base) were rubblized with a resonant pavement breaker. All three test items were constructed on CBR 7 clay subgrade. After rubblization, the rubblized concrete was rolled and paved with a 5-inch thick P-401 (hot mix asphalt) overlay. Heavy-weight deflectometer (HWD) tests were performed using the FAA's HWD equipment on a 10-foot (3.05 m) grid to study the uniformity of the pavement structures. The results showed that the pavement structure within a test item (for all rubblized test items) was fairly uniform. After the completion of uniformity tests, the overlaid pavements were subjected to full-scale accelerated traffic tests under the 4-wheel landing gear configuration (with wander) and 55,000-lbs (25-tonnes) wheel load. Straightedge rut depth measurements, and transverse profile measurements were made at regular intervals during the traffic tests. No significant distresses were observed for 5000 passes after which the wheel load was increased to 65,000-lbs (29.5-tonnes) and 6-wheel landing gear was used for testing. The paper summarizes the results from pavement layer characterization tests, pavement structure uniformity from HWD tests, and pavement performance during the traffic tests.

Introduction

Rubblization is a method of in situ recycling of deteriorated concrete pavements. The rubblized layer behaves as a tightly keyed, interlocked, high-density unbound base. FAA published guidelines for rubblized Portland cement concrete base courses are summarized in Engineering Brief (EB) 66 (FAA, 2004) and are based on broad industry experience. It is an interim guidance and full-scale testing is still needed to develop design standards for the use of this technology at airports under heavy aircraft loading. As a start, three rigid airport pavement test items (MRC, MRG, and MRS) at the Federal Aviation Administration's (FAA) National Airport Pavement Test Facility (NAPTF) with 12-inch (30.5 cm) thick concrete slabs on different support systems (slab on crushed stone base, slab on grade, and slab on stabilized base) were rubblized with a resonant pavement breaker and overlaid with five inches of P-401 hot mix asphalt (HMA). The rigid pavements had been trafficked to complete failure prior to rubblization using dual-tandem and triple-dual-tandem landing gear configurations at wheel loads of 55,000 lbs (25 tonnes). All three test items were constructed on clay subgrades of approximately 7 CBR. The overlaid pavements were subjected to full-scale accelerated traffic loading. The paper summarizes the results from pavement layer characterization tests, pavement structure uniformity from HWD tests, and pavement performance during the traffic tests.

National Airport Pavement Test Facility (NAPTF)

The FAA's NAPTF is located at the FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey. The primary purpose of the NAPTF is to generate full-scale pavement response and performance data for development and verification of airport pavement design criteria. It is a joint venture between the FAA and the Boeing Company and became operational on April 12, 1999. The test facility consists of a 900 ft (274.3 m) long by 60 ft (18.3 m) wide test pavement area, embedded pavement instrumentation and a dynamic data acquisition system (20 samples per second), environmental instrumentation and a static data acquisition system (4 samples per hour), and a test vehicle for loading the test pavement with up to twelve aircraft tires at wheel loads of up to 75,000 lbs (34 tonnes). Additional information about the test facility is available elsewhere (http://www.airporttech.tc.faa.gov). A construction cycle at the NAPTF includes test pavement construction including instrumentation, traffic tests to failure, posttraffic testing (includes trenching activities and other tests), and pavement removal. A typical construction cycle (CC) at the NAPTF is shown in figure 1.
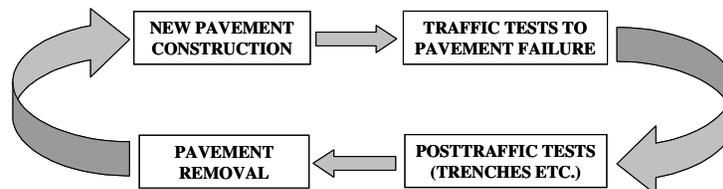
Figure 1. Construction cycle at the NAPTF

Pavement Structures

Three rigid pavement test items were constructed and tested during construction cycle two (CC2) at the NAPTF. Each test item was 75 feet long by 60 feet wide (22.9 m by 18.3 m) with thirty 15 by 15 foot by 12-inch thick concrete slabs (4.57 m by 4.57 m by 30.5 cm). One of the test items (MRG) was built directly on the subgrade, the second (MRC) was built on a crushed aggregate subbase on top of the subgrade, and the third (MRS) was built on an econocrete subbase over a crushed aggregate lower subbase. Each test item was separated into two 30-foot (9-m) wide traffic lanes, north and south. Construction was completed in April, 2004, and traffic testing was completed in December, 2004. Posttraffic testing included the excavation of four test pits, approximately five feet wide by five feet long, and extending down into the subgrade. One test pit was opened in the south traffic lane of each test item and one opened in the north traffic lane of MRC. Detailed information on the design and construction characteristics of the pavement structures can be found in (Ricalde). The structural condition index (SCI) of all the rigid pavement test items, in both traffic lanes, was less than 20 at the end of trafficking. However, most of the cracks were tight, with none rated worse than low severity. Also, both the transverse and the longitudinal joints were formed and doweled.

In January, 2005, all of the concrete slabs in the north traffic lane, including those in the transition sections, were rubblized with an RMI RB-500 resonant breaker operating at 44 Hz. Then, in June, 2005, the rubblized pavement was lightly wetted, rolled with a vibratory steel drum roller, and overlaid with five inches of P-401 hot mix asphalt. Figures 2 through 5 show, respectively, the vibrating foot of the resonant breaker, the rubblized surface being rolled, the test pavement surface after rubblization, and the test pavement surface after overlaying (with the HWD equipment in position for uniformity testing).

Figure 2. Rubblizing the north traffic lane with the resonant breaker.

Figure 3. Rolling the rubblized pavement.

Figure 4. Rubblized on the left (north) as-trafficked on the right (south).

Figure 5. After asphalt overlay, with HWD equipment in foreground.

Test Pits in Rubblized Test Items

After the three test items were rubblized, a 4-foot (1.22 m) long by 4-foot (1.22 m) wide test pit was saw cut in each test item for visual examination of the rubblized concrete (extent of fractures from rubblization process, particle sizes, etc.). Figure 6 shows fracture patterns and particle sizes in test items MRC, MRG, and MRS respectively. In general, the top 2 to 3 inches (5 to 7.6 cm) in all the test items was rubblized into dust and stones with a top particle size of 1 inch (2.54 cm) (figure 6). The particle size in the bottom 9 inches (22.9 cm) ranged from 4 inches (10.16 cm) to 15 inches (38.1 cm) with larger particle sizes in MRS. The test pits showed that the rubblization process induced cracks/fractures for the entire depth of the slabs and that the cracks were tightly held.
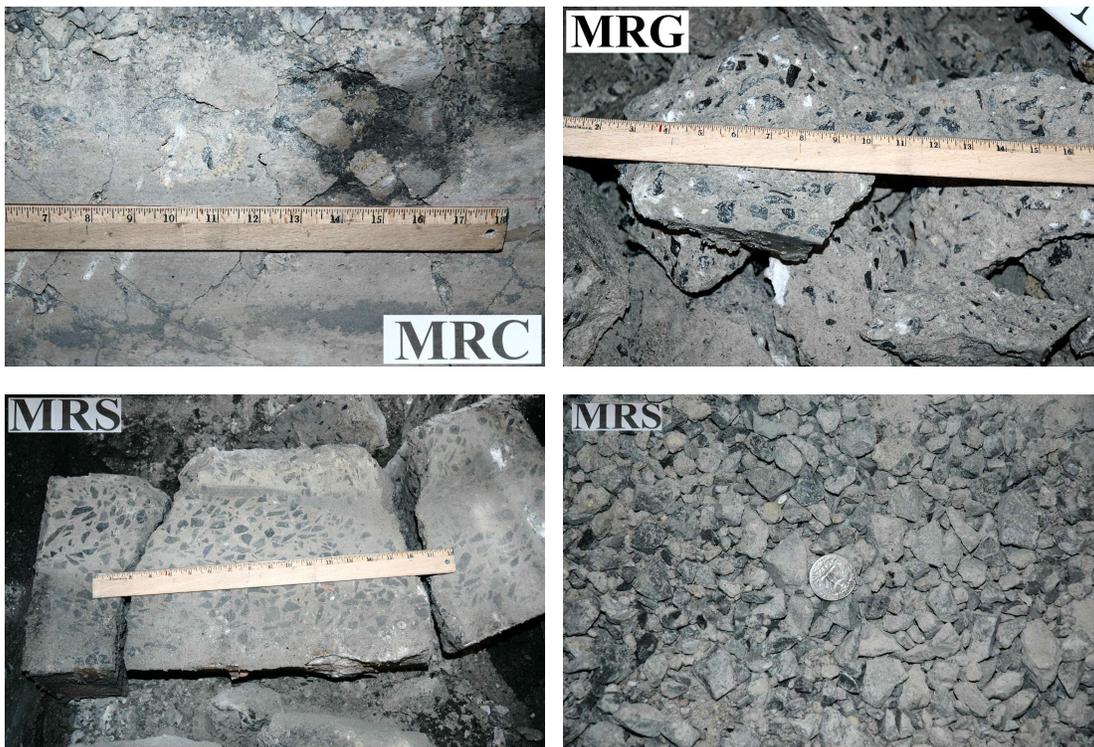
Figure 6. Visual Observations from the Test Pits in Rubblized Test Items

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Uniformity of Pavement Structures

Heavy-weight deflectometer (HWD) tests were performed using the FAA's HWD equipment on a 10-foot (3.05 m) grid to study the uniformity of the pavement structures, see figure 5. Tests were performed with a 12-inch diameter plate at three different load levels – 12,000, 24,000, and 36,000 lbs (53.4, 106.8, and 160.2 kN). The results showed that the pavement structure within each test item was fairly uniform. For peak center deflection (D0), the coefficient of variation (COV) ranged between 20 to 25 percent. For deflection D7 (at 72-inch (182.9-cm) offset from the center of load plate, and an indicator of subgrade condition), the COVs were around 10 percent. Figure 7 shows that the mean peak center deflections (D0s) for the rubblized test items were larger than the D0 deflections for the unrubblized test items. Also, among the rubblized test items, MRC showed the highest deflections, followed by MRG and then by MRS. This order was counter to expectations because MRC had a crushed aggregate subbase course and would normally be expected to be of higher stiffness than the MRG pavement built directly on the subgrade. Pretraffic measurements of subgrade strength in the test pits showed that water had migrated from the crushed aggregate subbase into the subgrade of MRC and softened the top three or so inches of the subgrade. The surface of the subgrade in the MRC test pits had a strength of approximately 4 CBR whereas the strength one foot (30 cm) below the surface was approximately 8 CBR. The surface of the subgrade in the MRG and MRS test pits was in the range 7 to 8 CBR, as constructed. The order of failure, discussed below, also followed the order of the HWD deflection magnitudes.
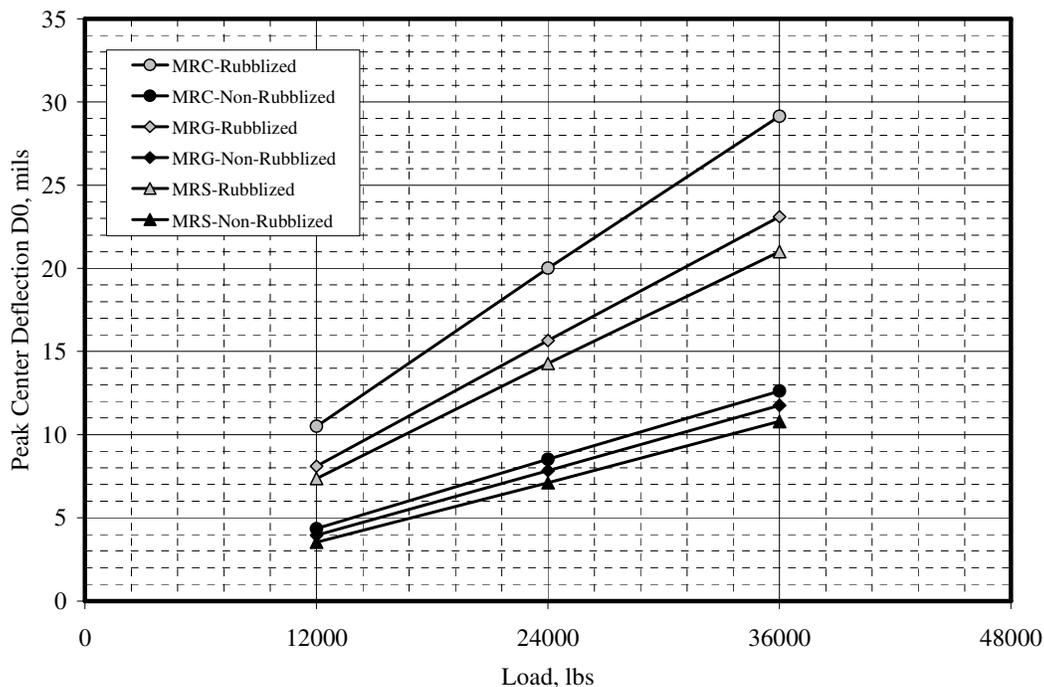
Figure 7. Mean Peak Center Deflections D0 from Uniformity Tests
(1 mil = 25.4 microns)

Figure 8 shows deflections D7 (at 72-inch offset from center of plate) that are indicative of subgrade stiffness. Figure 8 is further indication that the subgrade of MRC was of lower stiffness than the subgrade of MRG and MRS.
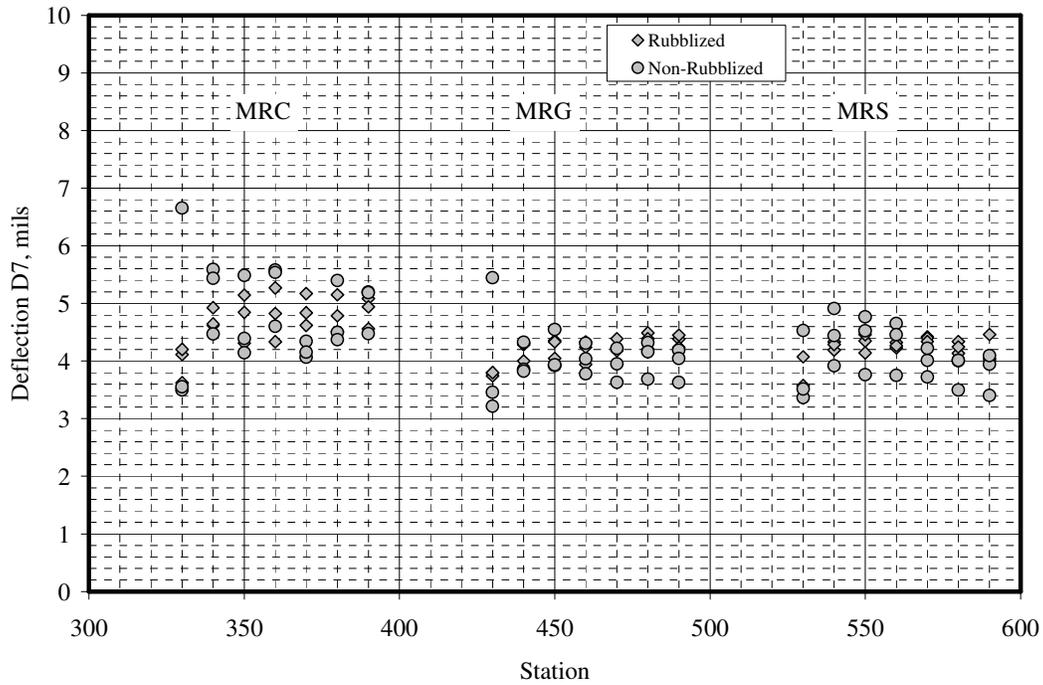
Figure 8. Deflections D7 from Uniformity Tests (1 mil = 25.4 microns)

Figure 9 shows the AREA for rubblized and non-rubblized test items. AREA is the area of deflection basin normalized with D0 and is a deflection basin shape factor (Hoffman, 1981). The magnitude of the AREA term is a fairly good indicator of layer behavior (bound or unbound). Higher AREA values indicate bound material and lower AREA values indicate unbound material.
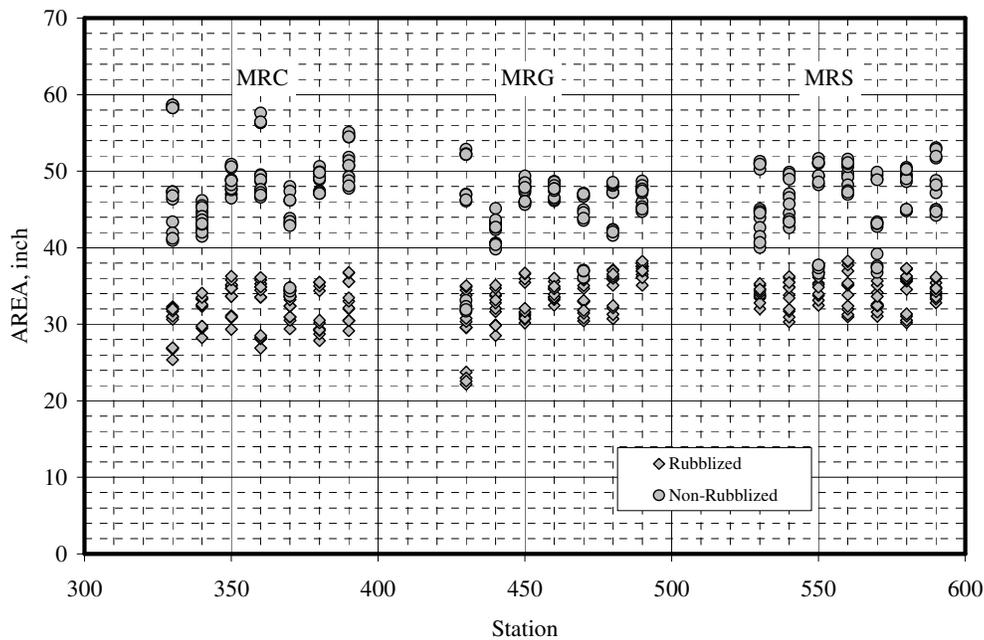
Figure 9. AREA from Uniformity Tests (1 inch = 2.54 cm)

The rubblized test items show lower AREA values (mean AREA = 33.2 inches, (84.3 cm)) compared to non-rubblized test items (mean AREA = 46.6 inches (118.4 cm)).

Traffic Testing of CC2 Overlay Test Items

Rubblizing of concrete pavements is a relatively new technique and full-scale trafficking of rubblized airport pavements under heavy airplane loading had not been conducted previously. Design procedures for determining the required thickness of asphalt overlays on rubblized pavements have therefore not been developed in the traditional sense. The most usual assumption (see, for example, FAA EB66) is that the rubblized and overlaid pavement behaves like a flexible pavement and that the overlay thickness can be determined by assigning an equivalent thickness or modulus value to the rubblized layer and applying this in a standard flexible pavement design procedure. In view of the unsubstantiated nature of thickness design for rubblized pavements it was decided to start testing at an arbitrary loading condition and to adjust the loading according to the observed behavior under traffic.

Only four wheels were available for loading on the unrubblized traffic lane, so traffic was begun with a four-wheel dual-tandem configuration on both traffic lanes. The geometry was the same on both traffic lanes, with dual spacing of 54 inches (137.2 cm) and tandem spacing of 57 inches (144.8 cm). Wheel load was set at 55,000 lbs (25 tonnes) because this was the load applied to the new construction CC2 test items and, although badly cracked at the end of trafficking, all of the test items were capable of structurally supporting the loads applied up to the end of trafficking. Adding five inches of asphalt implied that the unrubblized pavement would be capable of structurally supporting considerably more traffic at the same load.

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Calculations of the predicted life of the rubblized pavements using the assumptions of flexible pavement response and characteristics indicated that, for the initial traffic loading case, the structure on-grade (MRG) might fail fairly quickly (a few hundreds or thousands of repetitions) but that the structure on stabilized base would probably last for many tens of thousands of repetitions.

Trafficking started on July 7, 2005, and continued until October 6, 2005, following the schedule in Table 1. (The loading was increased after 5,082 repetitions because none of the pavements showed any significant deterioration at that traffic level.) The standard NAPTF 66-repetitions per cycle wander pattern was used on both traffic lanes. The temperature of the asphalt varied between 66 and 85 degrees F (19 And 29 degrees C) during the period of testing. The average temperature of the asphalt was about 78 degrees F (26 degrees C).

Table 1. Trafficking schedule for CC2 overlay test items.

Dates (from-to)	Repetitions (from-to)	Test Items Trafficked	Load on North Lane*	Load on South Lane*
07/07/05 07/25/05	1 5,082	MRG-N, MRC-N, MRS-N MRG-S, MRC-S, MRS-S	4-wheel, 55,000 lbs	4-wheel, 55,000 lbs
07/26/05 08/12/05	5,083 11,814	MRG-N, MRC-N, MRS-N MRG-S, MRC-S, MRS-S	6-wheel, 65,000 lbs	4-wheel, 65,000 lbs
08/15/05 08/18/05	11,814 14,256	MRG-N, MRC-NW, MRS-N MRG-S, MRC-S, MRS-S	6-wheel, 65,000 lbs	4-wheel, 65,000 lbs
08/19/05 08/24/05	14,257 16,302	MRG-N, MRS-N MRG-S, MRC-S, MRS-S	6-wheel, 65,000 lbs	4-wheel, 65,000 lbs
09/13/05 10/06/05	16,303 25,608	MRG-N, MRS-N MRG-S, MRS-S	6-wheel, 65,000 lbs	4-wheel, 65,000 lbs

* Cold, unloaded tire pressures: 220 psi at 55,000 lbs and 260 psi at 65,000 lbs.

Pavement Performance

Traffic testing was continued until either structural failure was deemed to have occurred, or until it was estimated that failure was unlikely to occur within a reasonable number of passes at the applied load. During the traffic tests, the test items were monitored through a combination of visual surveys and non-destructive testing, including periodic straightedge rut depth measurements, surface profile measurements, and HWD deflection measurements. Cores were also extracted from the asphalt to monitor asphalt thickness and crack propagation. Data processing and analysis of the surface profile and HWD measurements is time consuming and the primary means of monitoring pavement performance as the trafficking progressed was from plots of the straightedge rut depth measurements prepared immediately after the measurements had been made.

A 16-foot (4.88 m) long straightedge was used for rut depth measurements. In each test item, the rut depth measurements, and profile measurements, were made at two different longitudinal positions located at one-third and two-thirds the distance into

the test item. These locations were designated as NW and NE for the rubblized test items and SW and SE for the non-rubblized test items (N and S stand for north side and south side of the longitudinal centerline respectively). Figures 10 through 12 show the straightedge rut depth measurements for test items MRC, MRG, and MRS respectively.
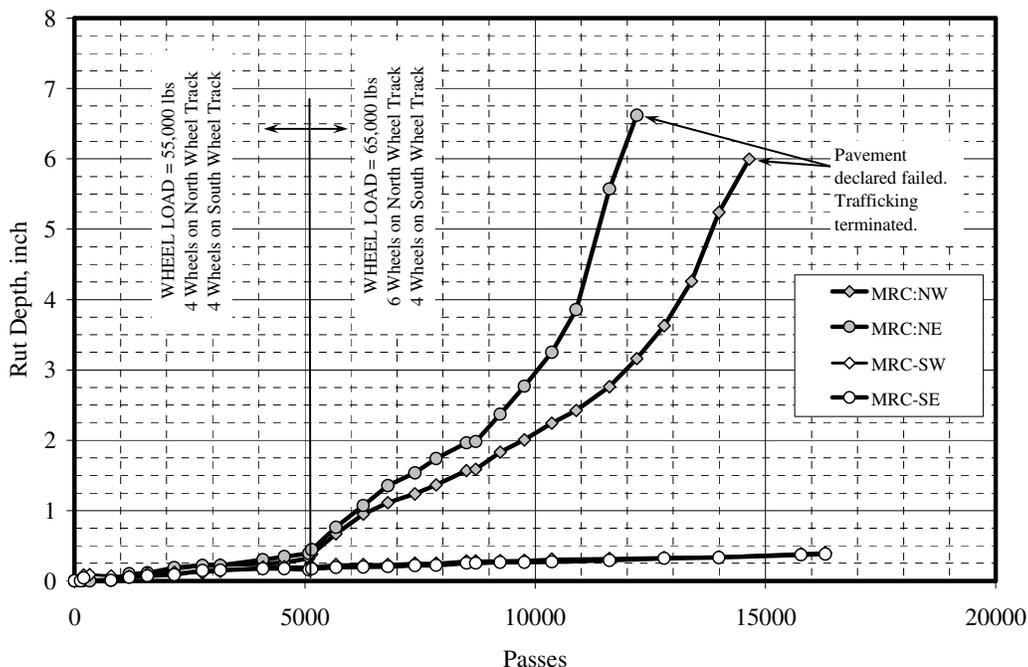
Figure 10. Straightedge Rut Depth Measurements in MRC (1 inch = 2.54 cm)
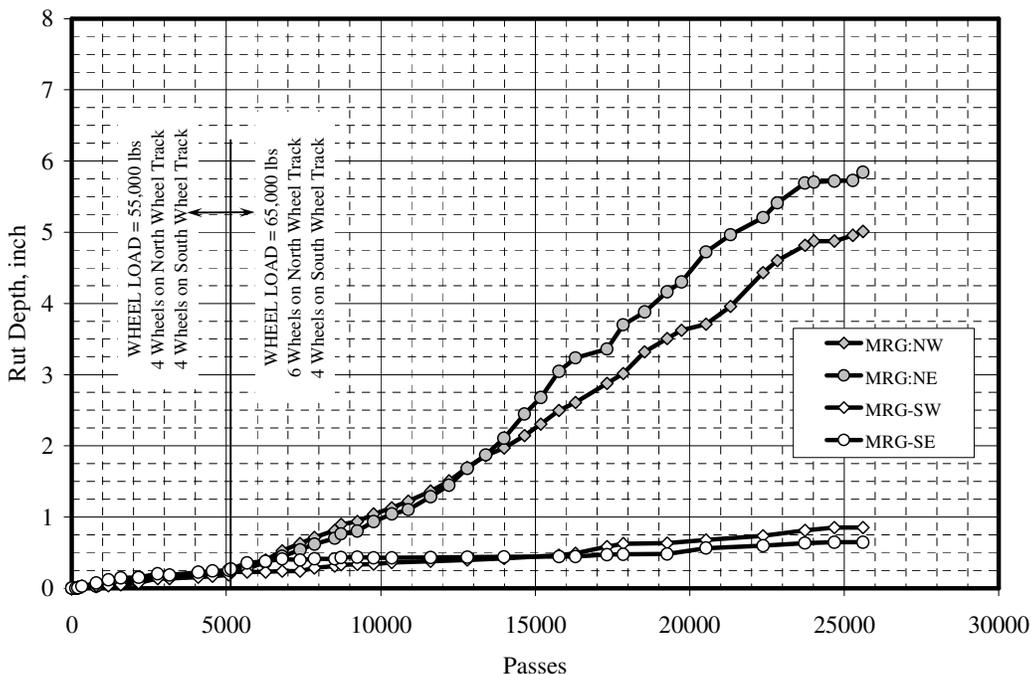
Figure 11. Straightedge Rut Depth Measurements in MRG (1 inch = 2.54 cm)
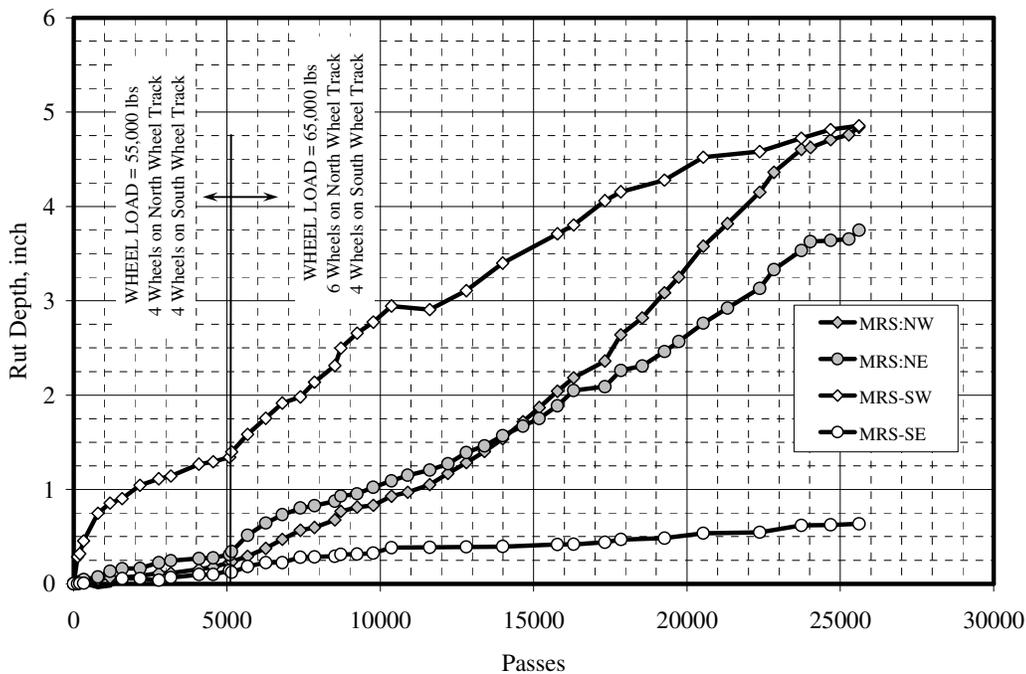
Figure 12. Straightedge Rut Depth Measurements in MRS (1 inch = 2.54 cm)

Except at the MRS-SW location, all of the test items showed similar rut depths during the first 5082 passes (55,000-lbs wheel load, 4-wheel landing gear configuration). In particular, there was no discernible difference between the performance of the rubblized and non-rubblized pavements. It was also observed visually that the surface deflections of the rubblized pavements under load were negligible and the response of the rubblized pavements appeared to be very similar to that of the non-rubblized pavements. Instrumentation was not installed in the pavements to measure surface deflections so this observation cannot be verified to any degree of accuracy. But the surface deflection of a flexible pavement under load can be readily observed visually, and without any magnifying aid. The surface deflection of a rigid pavement cannot be observed visually. It was therefore decided that the load should be increased to the largest extent practically allowed by the test vehicle loading system and tires to increase the possibility of inducing significant distress in the rubblized pavements. From 5083 passes to the end of trafficking, six-wheel triple-dual-tandem loading at 65,000 lbs (29.5 tonnes) wheel load was applied to the rubblized pavement and four-wheel dual-tandem loading at 65,000 lbs (29.5 tonnes) was applied to the non-rubblized pavements. The six- and four-wheel configurations at increased loading both had the same dual and tandem spacings of 54 and 57 inches (137.2 and 144.8 mm).

At the MRS-SW location (non-rubblized), a test pit (5-feet by 4-feet) was opened in the concrete slab (for subgrade evaluation) prior to the placement of the HMA overlay. The concrete that was used to re-fill the test pit was severely broken up and a depression formed at this location during the placement and compaction of the HMA

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overlay. This severely weak area caused significant local accumulation of rutting during the early trafficking period.

After approximately 10,000 passes in MRC, 13,000 passes in MRG, and 15,000 passes in MRS, significant upheaval in the HMA layer at the longitudinal joints just outside the traffic path was observed in the rubblized test items. After this number of passes, the rut depth measurements are exaggerated because the straightedge was resting on top of the upheavals outside the traffic path. More accurate rut-depth measurements have been computed from the surface profile measurements. Maximum rut depths from the transverse profiles at the end of trafficking were 4 inches (10 cm) on MRC-N, 2.5 inches (6.4 cm) on MRG-N, and 2 inches (5.1 cm) on MRS-N. Significant structural upheaval was also observed outside the wheel track on MRC-N and MRC-N, but neither the straightedge measurement nor the transverse profile measurements can separate the contributions of the underlying structural response and the asphalt upheaval movement. Measurements of the transverse profiles of the structural layer interfaces are currently being analyzed from trench data. These measurements are expected to give a more definitive estimate of the true structural response of the rubblized pavement structures.

The NE end of MRC was the first area of the rubblized pavements to show signs of failure. This failure was not representative of the structural performance of the test item as a whole because one of the pre-overlay test pits (for subgrade evaluation) was located where the pavement failed. A weakened support system resulted because the replaced subbase aggregate material could not be compacted to the same density as in the original construction. A depression in the pavement surface was observed at this location after about 400 load repetitions. The depression migrated longitudinally towards the east until it was about 15 feet (4.6 m) long, but the structure continued to support the full traffic load until it appeared to be in danger of suffering complete structural collapse at 11,814 passes. The weakened area did not migrate back into the west half of the test item and the declared structural life of MRC-NW of 14,256 passes is believed to be a true representation of the structural performance of the test item. Also, MRC-NW did not appear to be in danger of complete structural collapse as had MRC-NE. Trafficking in MRG and MRS was terminated after 25,608 passes. From visual inspection at the end of trafficking, MRG-N appeared to be suffering from structural upheaval outside the wheel track but MRS-N did not. More definitive estimates of the structural condition of the test items will be possible after analysis of the posttraffic trench data.

Conclusions

Full-scale traffic tests were completed on three rubblized and three non-rubblized rigid airport pavements which had been overlaid with five inches (12.7 cm) of hot mix asphalt. One of the rubblized pavements was observed to definitely suffer structural failure. Another of the rubblized pavements was probably suffering severe structural deterioration at the end of trafficking but retained sufficient structural capacity to support the applied load. The third rubblized pavement did not appear to

be suffering severe structural deterioration at the end of trafficking despite having accumulated significant levels of rutting and asphalt shear flow. None of the non-rubblized pavements suffered significant structural deterioration or significant levels of rutting. Nor was any reflection cracking evident at the surface of the non-rubblized pavements, but this is to be expected because the tests were performed indoors during warm weather. The test results should be found to be useful in determining structural characteristics of rubblized pavements for use in thickness design procedures.

Acknowledgement/Disclaimer

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