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Flatliner Cold Planer Evaluation for Airfield Pavement Maintenance

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Abstract

The U.S. Army Engineer Research and Development Center evaluated tools and procedures for removing small surface irregularities in airfield pavement repairs that cause unacceptable roughness for aircraft. A desirable tool could grind pavement surfaces smooth and flush. A Flatliner cold planer skid steer attachment was identified as a potential device and was used in a field evaluation. The field evaluation considered production rate, smoothness of the treated pavement, and tooth wear for airfield pavement repairs made on Portland cement concrete, rapid-setting cementitious concrete, and asphalt concrete mixtures.

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Preface

This study was conducted under the U.S. Air Force Civil Engineer Center's (AFCEC) Airfield Damage Repair Modernization Program. Headquarters, AFCEC, located in Tyndall Air Force Base, Florida, provided funding for the research project described in this report. Jeb S. Tingle was the Airfield Damage Repair Program Manager.

The work was performed by the Airfields and Pavements Branch (GMA) along with the Materials Testing Center of the Engineering Systems and Materials Division (GM), U.S. Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Timothy W. Rushing was Chief, CEERD-GMA; Dr. Gordon W. McMahon was Chief, CEERD-GM; and Nicholas Boone, CEERD-GZT, was the Technical Director for Force Projection and Maneuver Support. The Deputy Director of ERDC-GSL was Dr. William P. Grogan, and the Director was Bartley P. Durst.

COL Bryan S. Green was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (US liquid)	3.785412 E-03	cubic meters
gallons per minute	6.309019 E-05	cubic meters per second
inches	0.0254	meters
mils	0.0254	millimeters
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
revolutions per minute	0.10471975	radians per second
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

1 Introduction

1.1 Background

The U.S. Air Force Air Combat Command initiated the Airfield Damage Repair (ADR) Modernization Program to improve capabilities for returning damaged airfields to service. A major component of the program includes new procedures and equipment for replacing the pavement surface layers with Portland cement concrete (PCC), rapid-setting cementitious concrete (RS), and asphalt concrete (AC) (Barna et al. 2010, Priddy et al. 2013a, Priddy et al. 2013b, Tingle et al. 2009, Priddy et al. 2008, and Priddy et al. 2007).

Repairing craters in airfield pavements involves marking the crater repair area, saw-cutting the edges of the repair, breaking and excavating material within the repair, backfilling the crater with acceptable materials, and then capping with an asphalt or cementitious surface layer. The equipment and methods available for placing the surface layer are occasionally incapable of providing an adequately smooth surface, as shown in Figure 1. Smoothness is a critical aspect of airfield pavements to prevent damage to aircraft. Typical pavement surface grinders have conical grinding teeth that are incapable of providing a pavement surface texture similar to the original pavement. The small ridges left by these devices can act as a tire hazard or allow aggregate to dislodge from the pavement, causing risks to jet engine damage. A smoothing attachment is needed that has flat teeth and can grind a pavement to an extremely smooth finish.

1.2 Objective

The Airfields and Pavements Branch (APB) of the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, Mississippi, was tasked by the U.S. Air Force Civil Engineer Center to evaluate a pavement smoothing attachment as a potential tool for removing irregularities in the surface of repairs made to small craters in airfield pavements. The evaluation included measuring the time required to perform the necessary grinding and the overall grinding efficiency. Specific objectives investigated were the ability of the cold planer to:

- Smooth a deficient crater repair to meet roughness tolerances

- Smooth upheaval around a crater
- Smooth pavement deficiencies near an aircraft arrestor system
- Trench pavement to create a bed for installing protective panels beneath an aircraft arresting system
- Trench pavement to create a flush AM2 airfield matting repair

Figure 1. Inadequate concrete pavement repair surface.

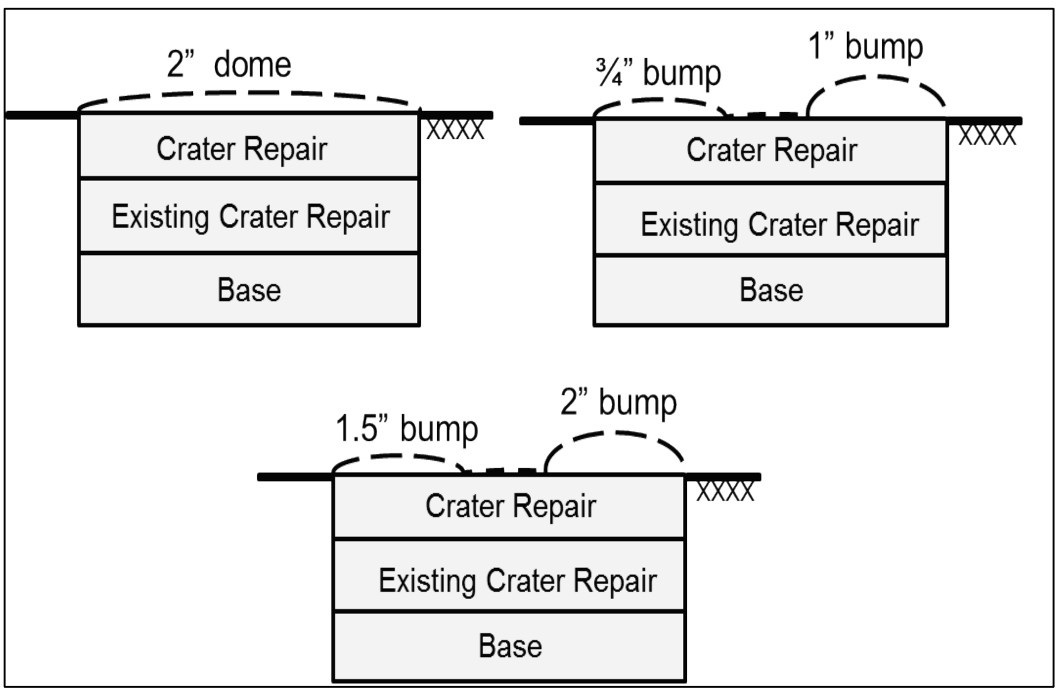
1.3 Scope

The scope of the study was to assess the efficiency and effectiveness of the selected pavement smoothing attachment through a field evaluation. The field evaluation consisted of building various surface deficiencies into twelve crater repairs and removing these deficiencies with a cold planer attachment. The Flatliner cold planer, designed and manufactured by Keystone Engineering Inc., was used for the field evaluation.

2 Test Site Preparation and Construction

The test site chosen for the evaluation was the ADR test site at the ERDC. The preparation consisted of constructing twelve crater repairs with various surface deficiencies. Of the twelve crater repairs, six were PCC, three were RS, and three were AC. The mix designs for these three materials are in Appendix B. Two different aggregate types were used in the PCC repairs since the type of aggregate has shown to be a major factor in the performance of concrete cutting in previous ADR crater repair studies (Edwards et. al 2015, Bell et. al 2015). These aggregates represented soft (limestone) and hard (chert) aggregates. Different surface deficiencies included “ridges” of varying heights and a large “dome” of excessive height as shown in Figure 2. Overall crater repairs were approximately 8.5-ft square.

Figure 2. Target deficiencies for crater repairs.



2.1 Demolition of existing craters

Prior to the construction of the target crater repairs, existing crater repairs had to be removed and cleaned. Approximately 1 ft of concrete was removed from the cap of the existing craters. This was performed by breaking the craters into small pieces using a Volvo EC220DL high impact jackhammer attachment for an excavator, shown in Figure 3.

Figure 3. Breaking existing crater repairs with high impact jackhammer.

Once the craters were broken into smaller, manageable pieces, a mini-excavator and skid steer with front bucket attachment was used to remove the remaining concrete and clean the test site, as shown in Figure 4. Once the debris was removed from the crater, crushed limestone was placed in the crater to a depth of approximately 8 in. below the surface and compacted to reduce the amount of capping material required.

Figure 5 shows the completed breakout of an existing crater repair as well as the props used to construct the target concrete crater repairs.

2.2 PCC crater repairs for target deficiencies

PCC pavement repairs with specific surface deficiencies were performed on 31 March 2015 (Figure 2). A total of nine personnel completed three PCC crater repairs on the south portion of the test site during the morning, herein labeled as Repair 1, Repair 2, and Repair 3. All personnel returned in the afternoon to complete PCC crater Repair 4, Repair 5, and Repair 6 on the north portion of the test site. Trowels, shovels, and rakes were used to form the concrete to the desired deficiencies. Short scaffolds that spanned the length of the repair were used to reach the inner portion of the repairs. Straight-edged metal beams were used to check levelness and heights of the ridges and dome. These techniques are shown in Figure 6,

Figure 7, and Figure 8. The desired slump for the PCC mix was 2 in. in order to easily shape the pavement surface. The design compressive strength of the PCC was 5,000 psi.

Figure 4. Removal of exiting crater repairs and site cleanup.

Figure 5. Completed breakout of existing crater.

Figure 6. Placing PCC in Repair 1.

Figure 7. Using short scaffold to form center of repairs.

Figure 8. Forming PCC deficiencies using straight-edge beam.

2.3 Rapid-setting concrete crater repairs for target surface deficiencies

The RS crater repairs for the target surface deficiencies shown in Figure 2 were completed on 23 June 2016. Using similar methods as described in Section 2.2 of this report, personnel removed and cleaned the existing craters prior to construction of the RS craters. The simplified volumetric mixer was used to place the RS and is shown in Figure 9.

A total of eleven personnel completed three RS concrete crater repairs on the south portion of the ADR test site during the morning, herein labeled as Repair 1A, Repair 2A, and Repair 3A. Trowels, shovels, and rakes were used to form the concrete to the desired deficiencies. Short scaffolds that spanned the length of the repair were used to reach the inner portion of the repairs. Straight-edged, metal beams were used to check levelness and heights of the ridges and dome. These techniques are shown in Figure 10 and Figure 11.

Figure 9. Simplified volumetric mixer during operation.

Figure 10. Placing RS concrete into crater Repair 1A.

Figure 11. Forming RS concrete repairs to desired surface deficiencies.

2.4 AC crater repairs for target deficiencies

On 25 June 2015, ten personnel began construction on the AC crater repairs for the target surface deficiencies shown in Figure 2. The AC mix was dumped on an adjacent, clean concrete pad close to the crater repairs, as shown in Figure 12. The material was then transported to Repair 4A, Repair 5A, and Repair 6A using a skid steer with front bucket attachment, as shown in Figure 13.

Using hand rakes and shovels, the material was shaped to obtain the target surface deficiencies. A small, tandem vibratory roller, shown in Figure 14, was used to compact the repairs. Multiple passes were made on the repairs to attempt to achieve the greatest density possible using the small roller. A walk-behind vibratory plate compactor was used to finish the surface of all repairs. Figure 15 shows a completed AC crater repair.

Figure 12. AC mixture placed on clean concrete slab.

Figure 13. AC transported to crater repairs using skid steer.

Figure 14. Compaction of AC using a small, tandem vibratory roller.

Figure 15. Completed AC crater repair.

Although much care and precision was taken to construct the target surface deficiencies shown in Figure 2, researchers found it difficult to create the actual target surface deficiencies. As a result, profilometer data and LiDAR data were obtained before and after grinding all crater repairs. These data collection techniques are further described in Chapter 3 of this report. Although Table 1 describes all the target deficiencies for each crater, the profile data provide a more accurate assessment of what was constructed. The LiDAR data provide accurate volumetric measurements of the crater repairs before and after removal of material using the cold planer. The analysis and results are based on the as-constructed surface deficiencies of the crater repairs and not the target surface deficiencies (Table 1).

Table 1. Description of crater repairs and target surface deficiencies.

Repair Name	Repair Type	Target Surface Deficiency
Repair 1	PCC (Chert gravel)	1.5-in. ridge, north edge 0.75-in. ridge, south edge
Repair 2	PCC (Chert gravel)	2.0-in. ridge, north edge 1.0-in. ridge, south edge
Repair 3	PCC (Chert gravel)	1.5-in. dome
Repair 4	PCC (Limestone aggregate)	1.5-in. ridge, north edge 0.75-in. ridge, south edge
Repair 5	PCC (Limestone aggregate)	2.0-in. ridge, north edge 1.0-in. ridge, south edge
Repair 6	PCC (Limestone aggregate)	1.5-in. dome
Repair 1A	RS	1.5-in. ridge, north edge 2.0-in. ridge, south edge
Repair 2A	RS	0.75-in. ridge, north edge 1.0-in. ridge, south edge
Repair 3A	RS	2.0-in. dome
Repair 4A	AC	1.5-in. ridge, north edge 2.0-in. ridge, south edge
Repair 5A	AC	0.75-in. ridge, north edge 1.0-in. ridge, south edge
Repair 6A	AC	2.0-in. dome

3 Test Methods

Procedures for evaluating the performance of the Flatliner cold planer included LiDAR 3-D imaging, profile measurements, time to effectively smooth the deficiencies within specified tolerances, and time to replace bits on the grinding drum. This chapter describes the methods and materials used to collect the data for the evaluation.

3.1 LiDAR 3-D imaging

APB researchers collaborated with ERDC's Environmental Laboratory to obtain LiDAR high-resolution 3-D scans of each crater repair before and after grinding to determine the total volume of material removed after planing with the Flatliner. To establish a high level of control and accuracy, a traditional land survey was performed on the entire test site. Two GPS points were established using RTK GPS and were sent to the Online Positioning User Service (OPUS) for precise corrections. Using the two GPS Control points, a conventional survey was performed using a robotic total station. Ten permanent control hubs (benchmarks), shown in Figure 16, were embedded at various locations within the test site. Figure 17 shows a survey rod with a LiDAR registration target on a benchmark during data collection.

Figure 16. One of ten survey benchmarks embedded within concrete test pad.

Figure 17. LiDAR registration target.

LiDAR scans were conducted using the Trimble FX 3-D LiDAR Scanner, shown in Figure 18, to obtain a preliminary 3-D model of the test site primarily focusing on the crater repairs of interest.

Figure 18. Trimble FX 3-D LiDAR Scanner.

All LiDAR scans were processed using the FX Controller and registered together using Trimble Realworks Advanced software packages. Surfaces were generated for all crater repairs before and after planing the surfaces with the Flatliner. An example of a LiDAR scan before planing, after one pass on each ridge of the Flatliner, and multiple passes with the Flatliner are shown in Figure 19, Figure 20, and Figure 21, respectively.

Figure 19. LiDAR scan prior to planing.

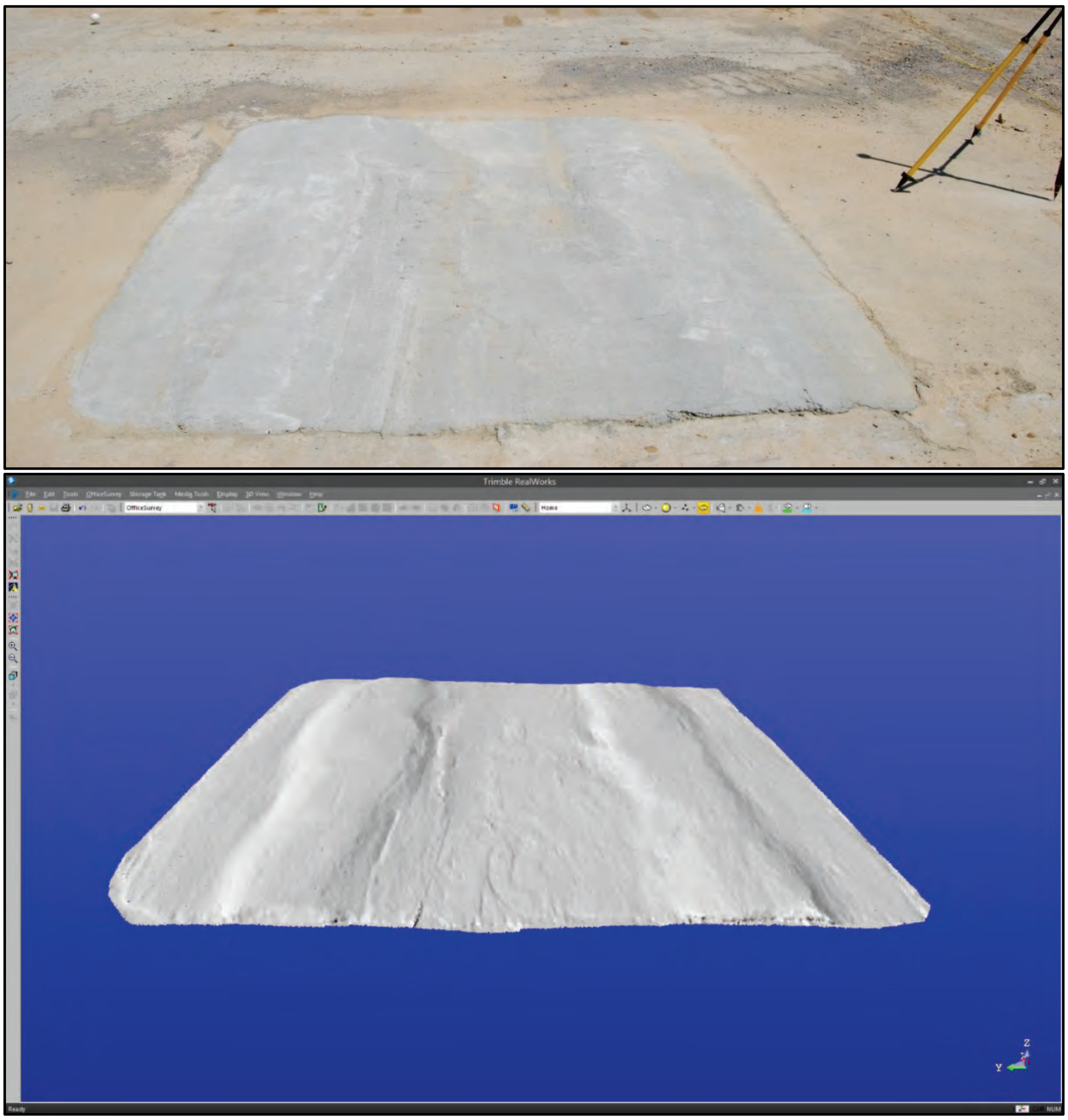
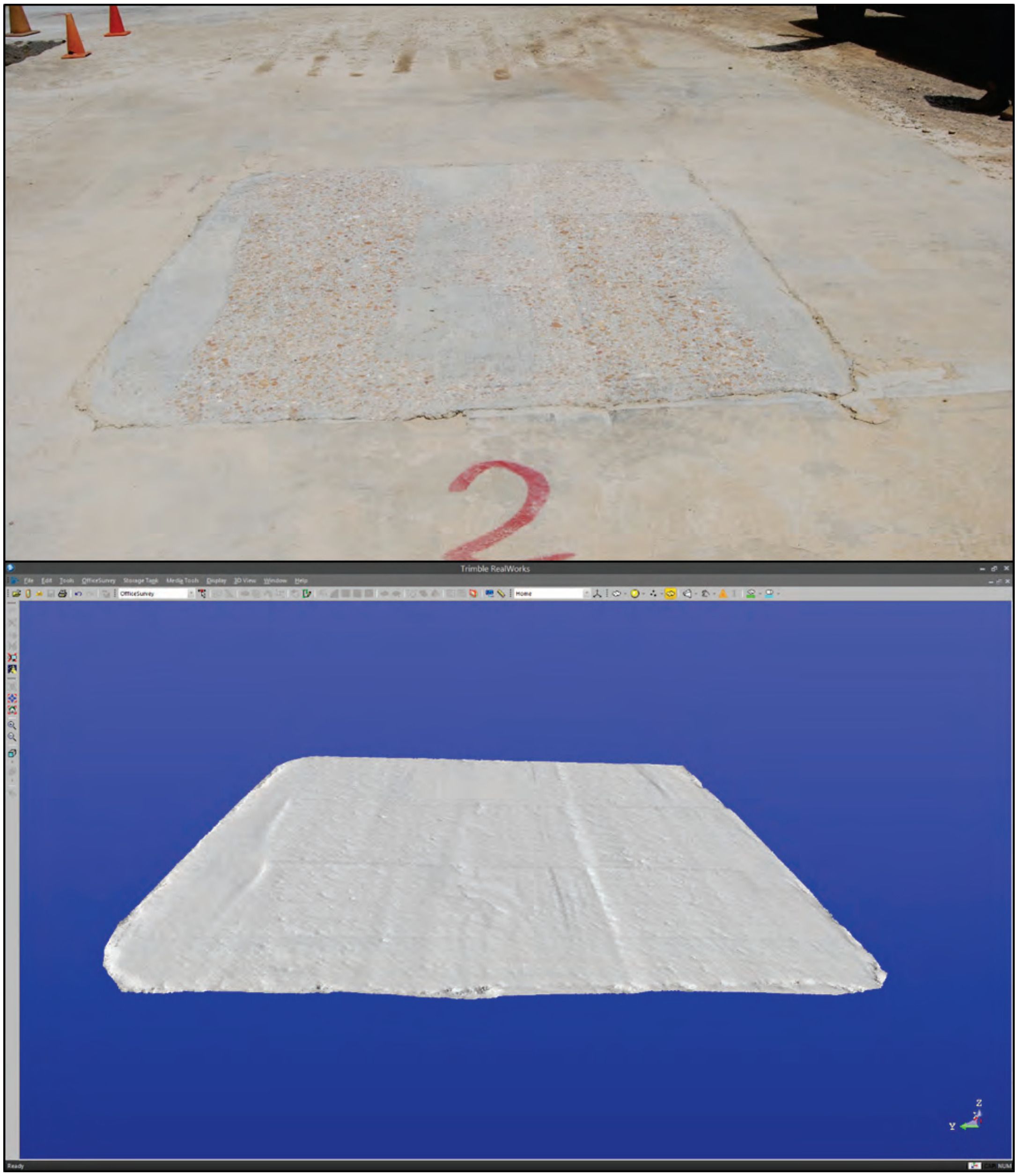


Figure 20. LiDAR scan after one pass using the Flatliner.

Figure 21. LiDAR scan after multiple passes with the Flatliner.



Using the LiDAR 3-D scans, profiles of the surface for each crater were displayed with the Trimble RealWorks software. Figure 22 shows a profile view of one crater prior to planing (red line), after one pass with the Flatliner (green line), and multiple passes (yellow line). LiDAR scans before planing, after one pass, after multiple passes from top of image to bottom of all the crater repairs are shown in Figures 23 through 34.

Figure 22. Profile view of LiDAR scans at various pass intervals with the Flatliner.

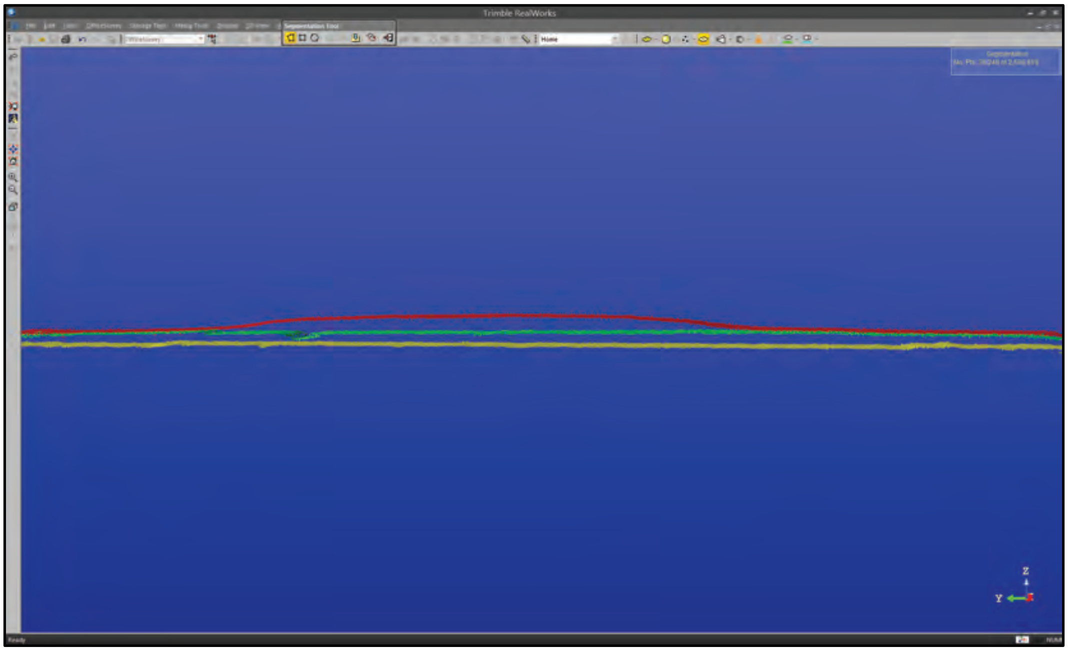


Figure 23. Crater Repair 1 LiDAR scans.

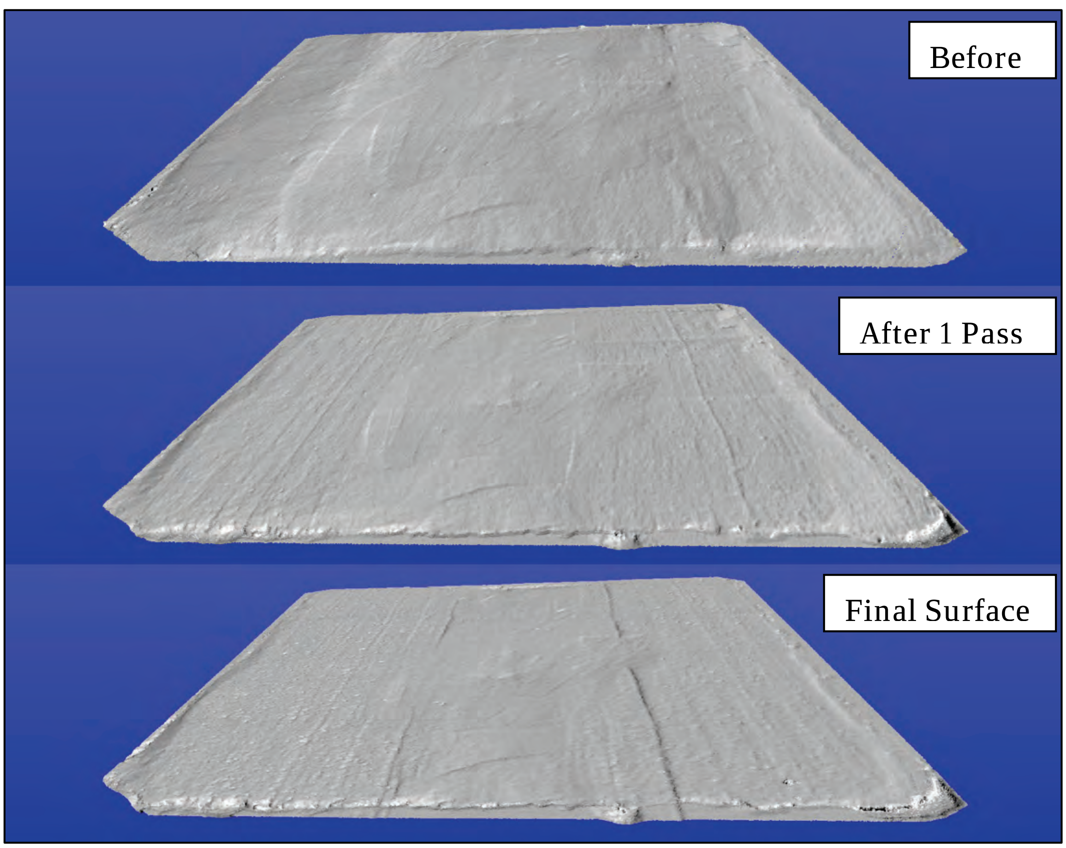


Figure 24. Crater Repair 2 LiDAR scans.

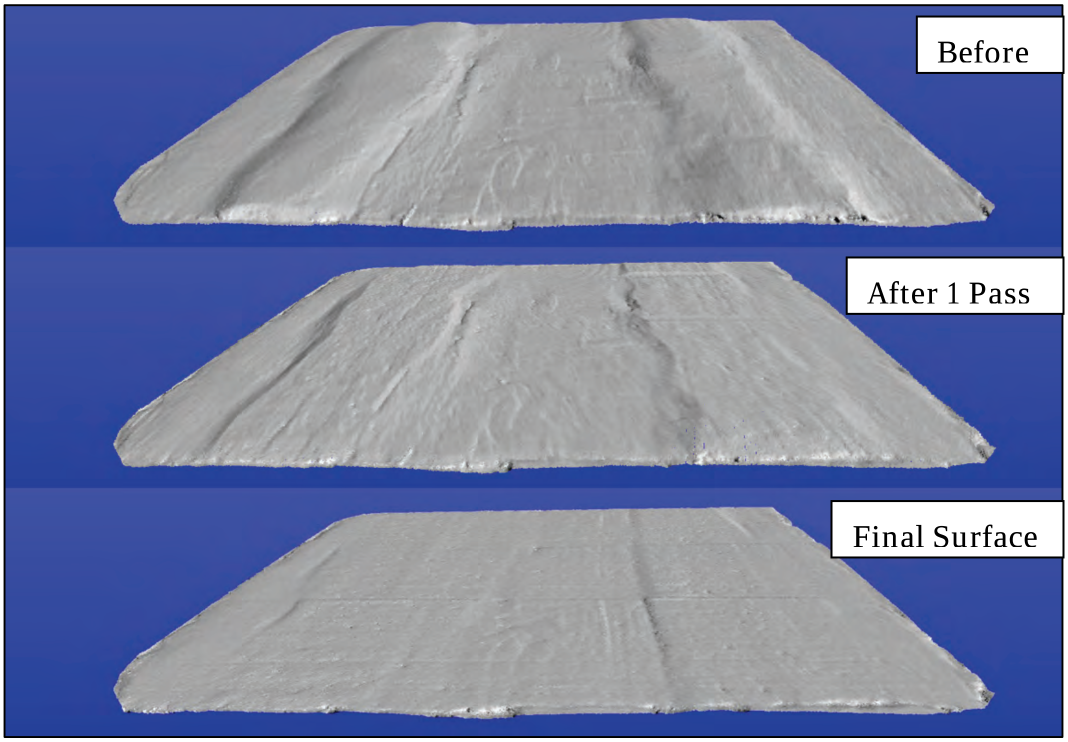


Figure 25. Crater Repair 3 LiDAR scans.

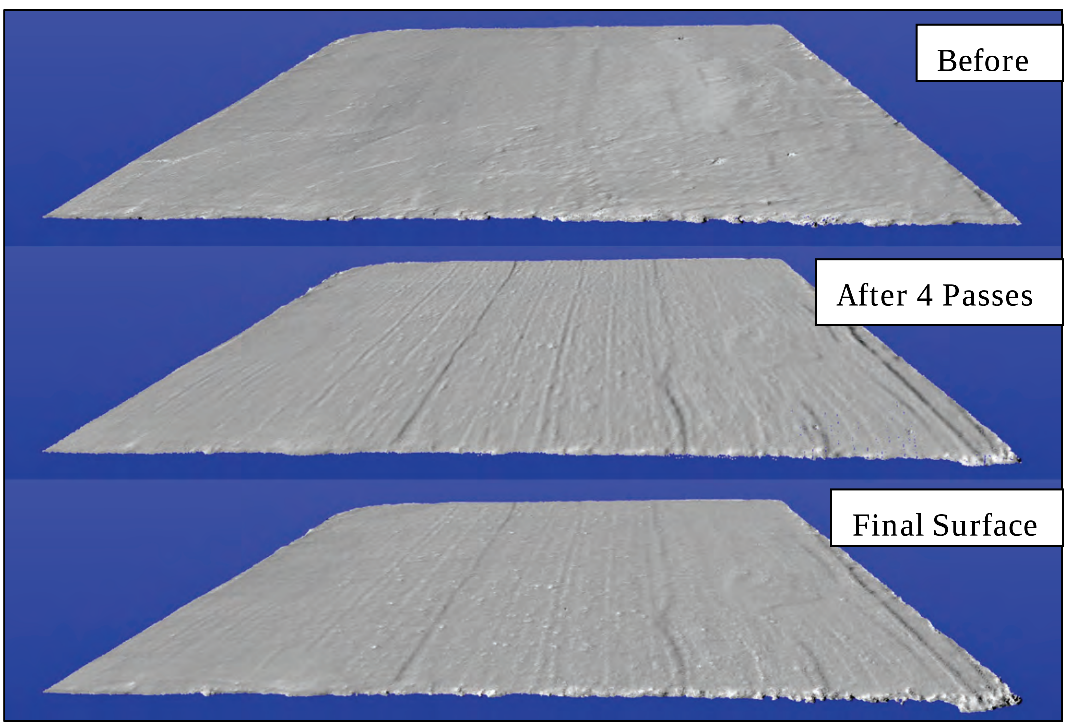


Figure 26. Crater Repair 4 LiDAR scans.

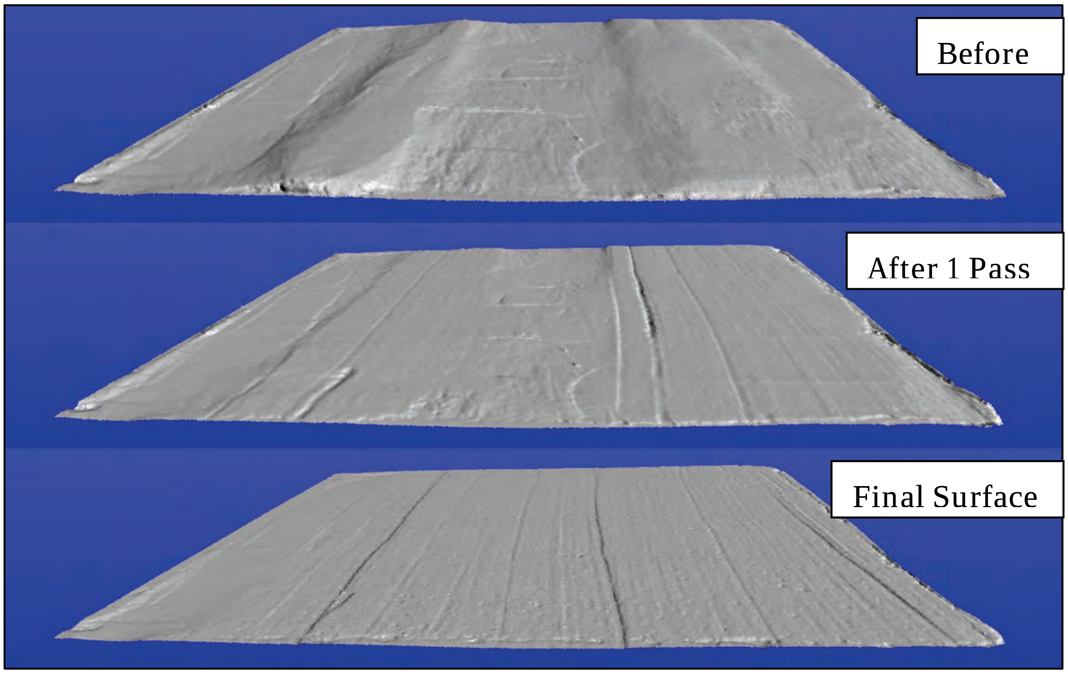


Figure 27. Crater Repair 5 LiDAR scans.

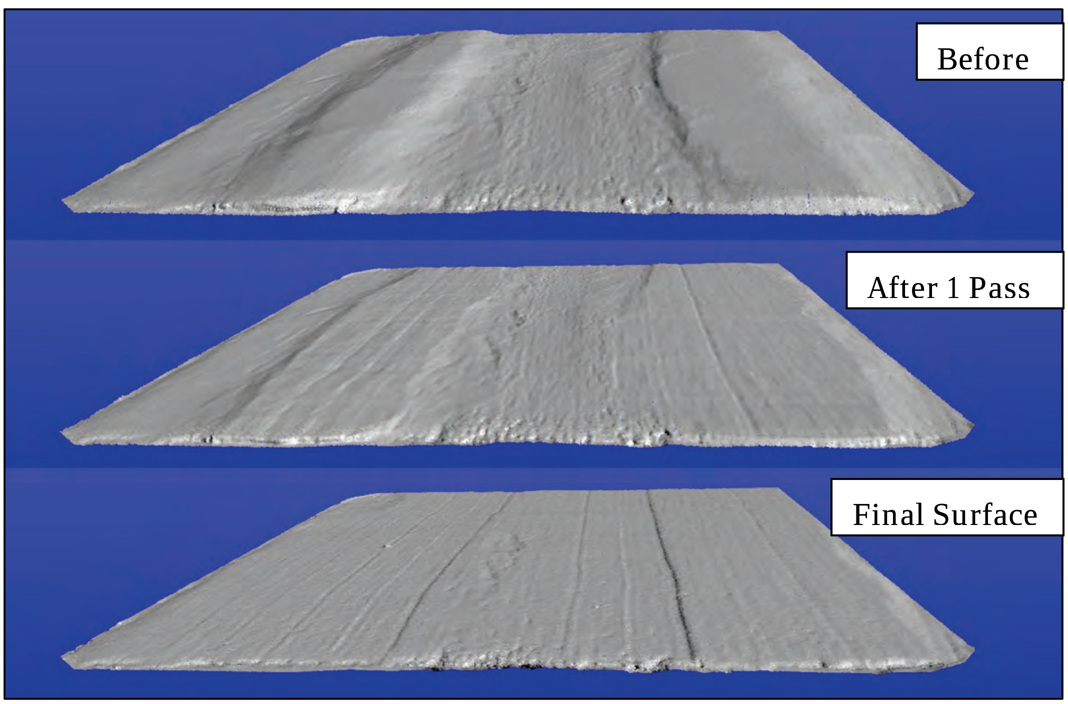


Figure 28. Crater Repair 6 LiDAR scans.

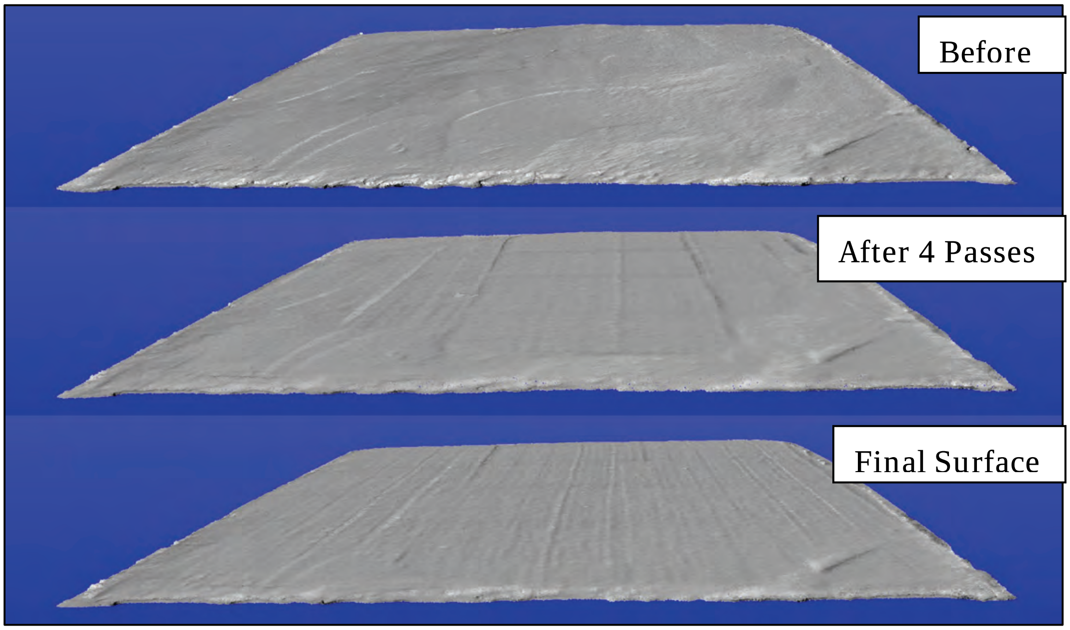


Figure 29. Crater Repair 1A LiDAR scans.

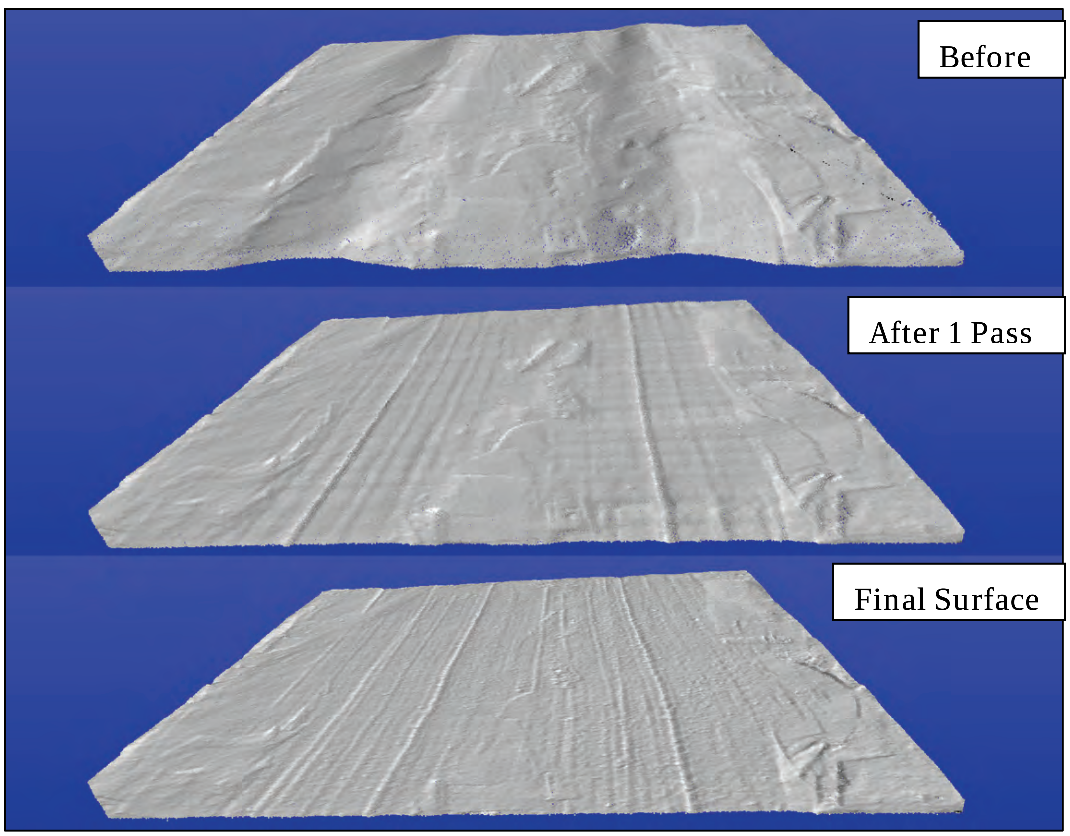


Figure 30. Crater Repair 2A LiDAR scans.

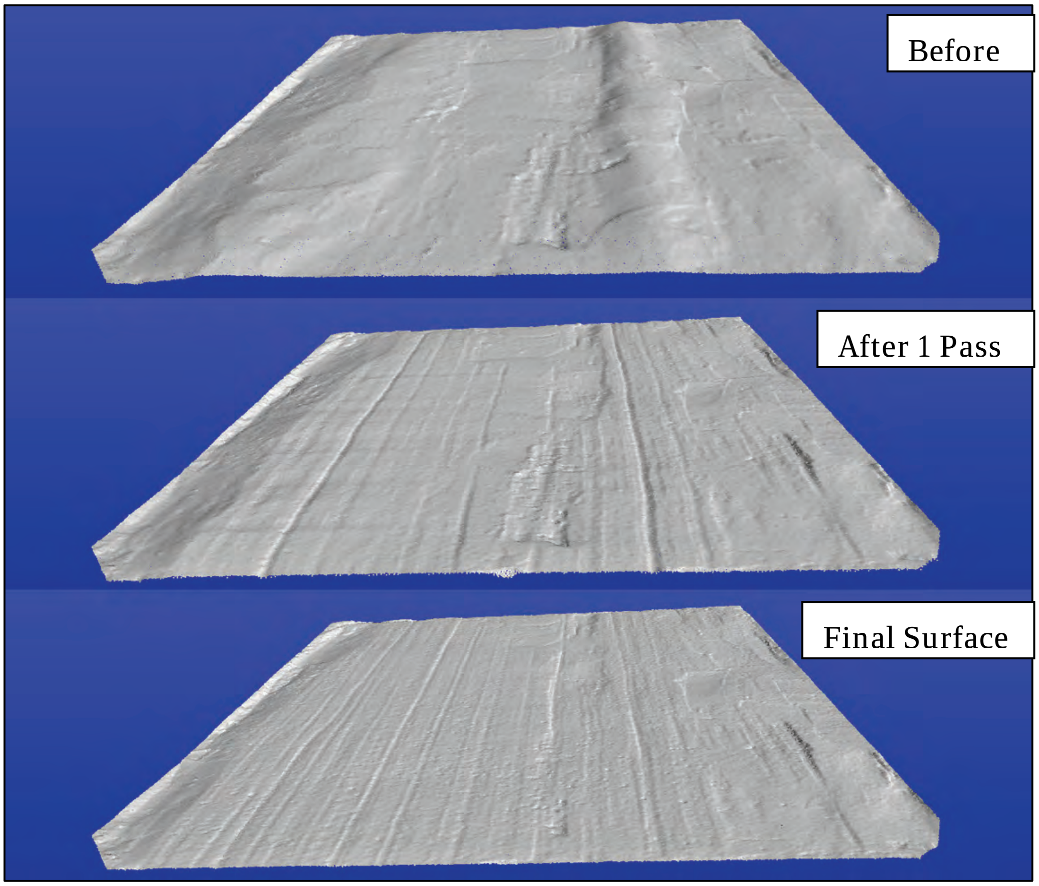


Figure 31. Crater Repair 3A LiDAR scans.

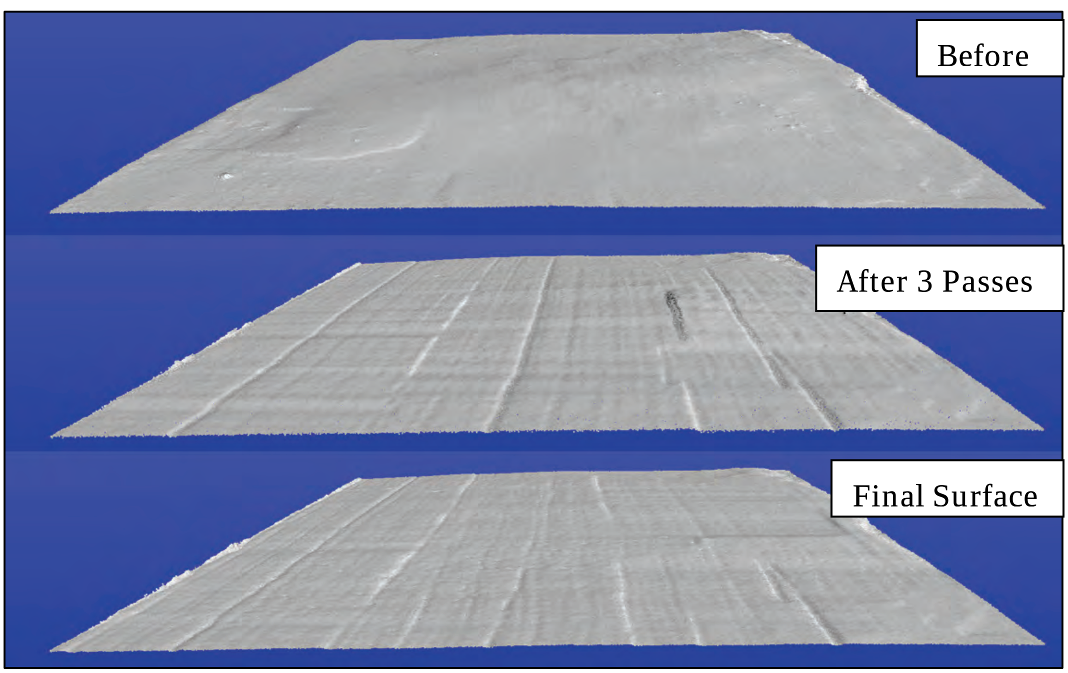


Figure 32. Crater Repair 4A LiDAR scans.

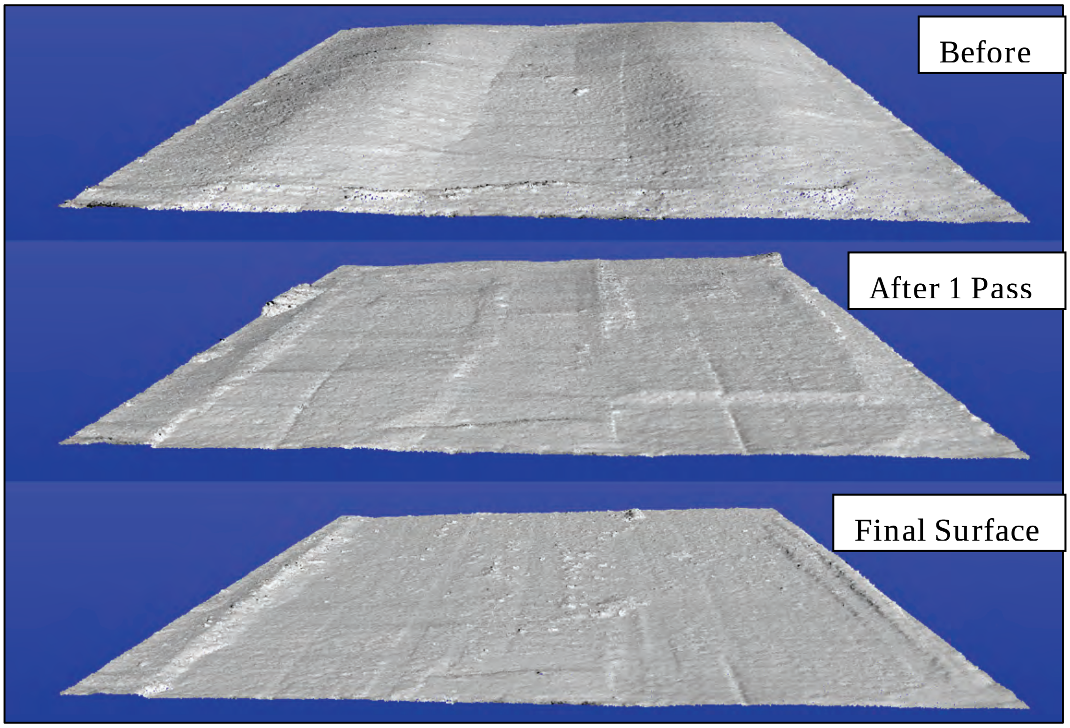


Figure 33. Crater Repair 5A LiDAR scans.

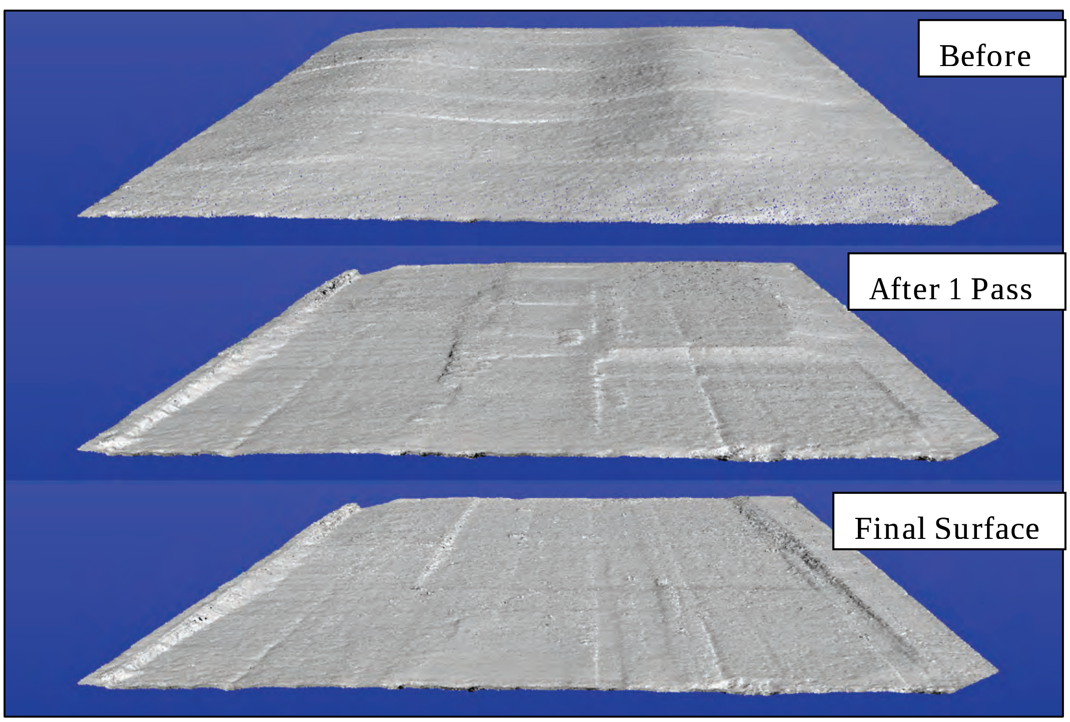
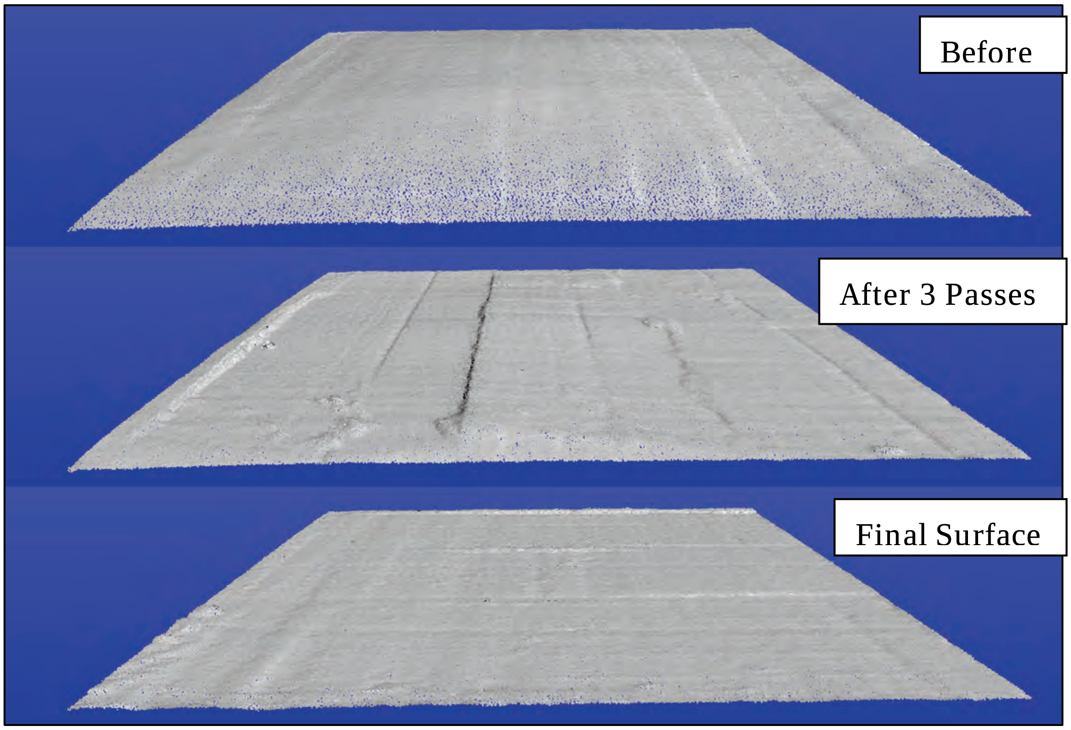


Figure 34. Crater Repair 6A LiDAR scans.



3.2 Profile measurements

Profile measurements were recorded using a profiler device (Figure 35) developed by the APB. The profiler device was constructed by drilling multiple holes through a 9-ft-long, 1.5-in.-wide by 3.5-in.-tall straight-edge timber. The holes were driven large enough for the spike nails to slide freely within the device, projecting the pavement surface as the spacing between the timber and nail head. The spacing between each nail head center was approximately 1.75 in., providing 64 height measurements across the crater. Variances in height were measured with a ruler and recorded from north to south across the crater repairs. These data were collected for each crater repair in three locations: west edge, center, and east edge. These data were used to provide profiles of the as-constructed repairs.

Figure 35. Profile measuring device.

3.3 Time trials

A standard stopwatch was used to record and sum the time for the Flatliner to make one pass over each of the surface deficiencies in each crater repair. In addition to recording the time of each pass, the time to plane the surface smooth was summed and recorded. Numerous passes were sometimes needed to plane the surface of larger deficiencies.

3.3.1 Grinding efficiency

During the planing of the crater repairs, the time needed to flush the surface of the crater repair with the surrounding concrete and the volume removed (as determined by the LiDAR 3-D scans) were used to determine how efficient the Flatliner was able to flush the surface to acceptable tolerances. This information is important to know when constructing expeditionary repairs on active runways, taxiways, and aprons. If the repairs fail to meet smoothness criteria, the time needed to plane the surface is valuable to airfield managers, airfield personnel, and base/ground control.

3.3.2 Replacing bits

On 19 May 2015, personnel removed and replaced all 108 bits on the Flatliner's drum (3 ft wide). Four persons successfully completed this task in approximately 2 hr and 15 min. This process was completed by using two persons, each with a socket wrench, starting on opposite sides of the drum and loosening each bit so it could easily be removed by hand (shown in Figure 36. The other two persons followed behind, cleaning the bit housing, installing a new bit, and hand tightening the new bit. Once finished with loosening all the old bits, the new bits were tightened to 100 ft-lb of torque. A close up view of the Flatliner's bits and housing is shown in Figure 37. This process was completed two more times within this study. Detailed instructions on replacing the bits of the Flatliner are in Appendix A: Flatliner operator's manual.

Figure 36. Replacing bits on Flatliner's drum.

Figure 37. Close up view of the Flatliner bits and housing.

4 Flatliner Evaluation on Surface Deficiencies

A total of four demonstrations were conducted on the target surface deficiencies using the Flatliner. At the completion of each demonstration, the bits were checked and/or changed. In addition, profilometer data and LiDAR data were recorded between planing passes to quantify grinding efficiency. The same ERDC operator for the Flatliner was used throughout the duration of this study for consistency.

4.1 PCC with chert aggregate and limestone aggregate

On 19 May 2015, the first demonstration of the Flatliner on crater Repairs 1, 2, 3, 4, 5, and 6 was performed. These crater repairs included three PCC mixtures with chert aggregate and three PCC mixtures with limestone aggregate. The details of these repairs are presented in Table 1. For this demonstration, Repairs 1, 2, 4, and 5 each received one pass down each ridge of the craters. The planing of the 1.5-in. ridge (north side of crater Repair 1) is shown in Figure 38. The surface of crater Repair 1 is shown in Figure 39 after one pass. The time was recorded for each pass to assess the grinding efficiency of the Flatliner.

Figure 38. Planing 1.5-in. ridge of crater Repair 1 on north side of repair.

Figure 39. Surface of crater Repair 1 after one pass with Flatliner.

Crater Repairs 3 and 6 each contained a 1.5-in. dome and received four equal passes across the crater starting on the north side and working south as shown in Figure 40.

Figure 40. Planing 1.5-in.dome of crater Repair 6 with four equal passes.

At the completion of the first demonstration, the entire test section was cleaned, and profilometer data and LiDAR scans were completed. Once the data were collected, the second demonstration commenced on 01 June 2015 when all crater repairs received multiple passes. All crater repairs were planed to the point of flush with the surrounding pavement, to the human eye determined by researchers.

4.2 RS concrete and AC

On 08 July 2015, the third demonstration was performed. This demonstration included three RS crater repairs (crater Repairs 1A, 2A, and 3A) and three AC repairs (crater Repairs 4A, 5A, and 6A) as described in Table 1. As with the first demonstration, each ridge on crater Repairs 1A, 2A, 4A, and 5A received only one pass. Crater Repairs 3A and 6A each received three equal passes across the repairs, as shown in Figure 41. The entire test section was cleaned, and profilometer data and LiDAR scans were conducted.

Figure 41. Planing 2-in.dome of crater Repair 6A with three equal passes.

The fourth and final demonstration commenced on 09 July 2015 when all crater repairs received multiple passes. The repairs were planed to the point of flush with the surrounding pavement, to the human eye determined by researchers. Repair 1A and Repair 4A are shown in Figure 42 and Figure 43, respectively.

Figure 42. Repair 1A (RS) after multiple passes with the Flatliner.

Figure 43. Repair 4A (AC) after multiple passes with the Flatliner.

5 Results and Discussion

Data that were collected during the grinding of each crater included LiDAR 3-D imaging, profile measurements, time to effectively smooth the deficiencies, and time to replace bits on the grinding drum. This chapter of the report presents and discusses the data collected during the course of the evaluation.

5.1 LIDAR 3-D imaging

As previously discussed in Section 3.1, LiDAR scans were taken before, after one pass, and after multiple passes with the Flatliner. With these scans, researchers were able to process the data and accurately compute the total volume removed after each planing phase. These data were also used with Trimble RealWorks software to create 3-D imaging of each crater repair, as shown in Figure 44.

Figure 44. LiDAR 3-D scan of crater Repair 2A prior to planing with Flatliner.

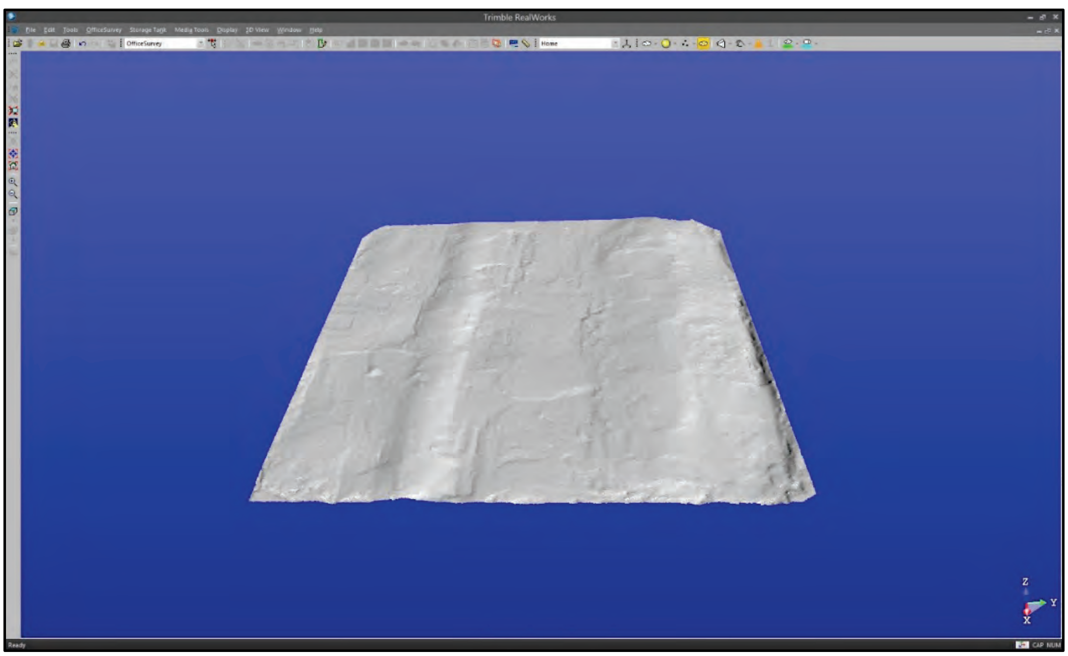


Table 2 contains the LiDAR post-processed data with respect to volume removed after single and multiple passes with the Flatliner. These data were used in conjunction with the time trials to assess the grinding efficiency of the Flatliner.

Table 2. Post-processed LiDAR data, volume of material removed.

Crater Repair	Crater Repair Material	Volume Removed, First Pass (ft^3)	Volume Removed, Multi-Pass (ft^3)	Total Volume Removed (ft^3)
1	PCC (Chert)	1.351	0.919	2.271
2	PCC (Chert)	1.007	1.658	2.665
3	PCC (Chert)	3.030	-0.018	3.012
4	PCC (Limestone)	2.499	2.496	4.995
5	PCC (Limestone)	1.715	1.965	3.680
6	PCC (Limestone)	2.655	1.258	3.913
1A	RS	2.696	0.430	3.126
2A	RS	1.167	1.058	2.225
3A	RS	4.207	0.213	4.420
4A	AC	6.840	4.607	11.447
5A	AC	5.772	2.548	8.320
6A	AC	8.317	2.697	11.014

5.2 Profile measurements

Profile measurements (described in Section 3.2) were also collected prior to and after one pass and after multiple passes with the Flatliner. Three data sets for each crater and planing phase were recorded, including the west-third, center-third, and east-third. To quantify the height of material (PCC) the Flatliner can remove after one pass, the center-third of crater Repairs 1, 2, 3, 4, 5, and 6 are represented in Figures 45 through 50.

After analyzing the data from Figures 45 through 50, the Flatliner was capable of removing approximately 0.8 in. of PCC with one pass. Also, the different aggregates (chert and limestone) used in the concrete mixture did not seem to affect how much volume the Flatliner could remove, although the chert mixtures tended to require more time to remove.

Figure 45. Profile view of crater Repair 1 before and after planing phases.

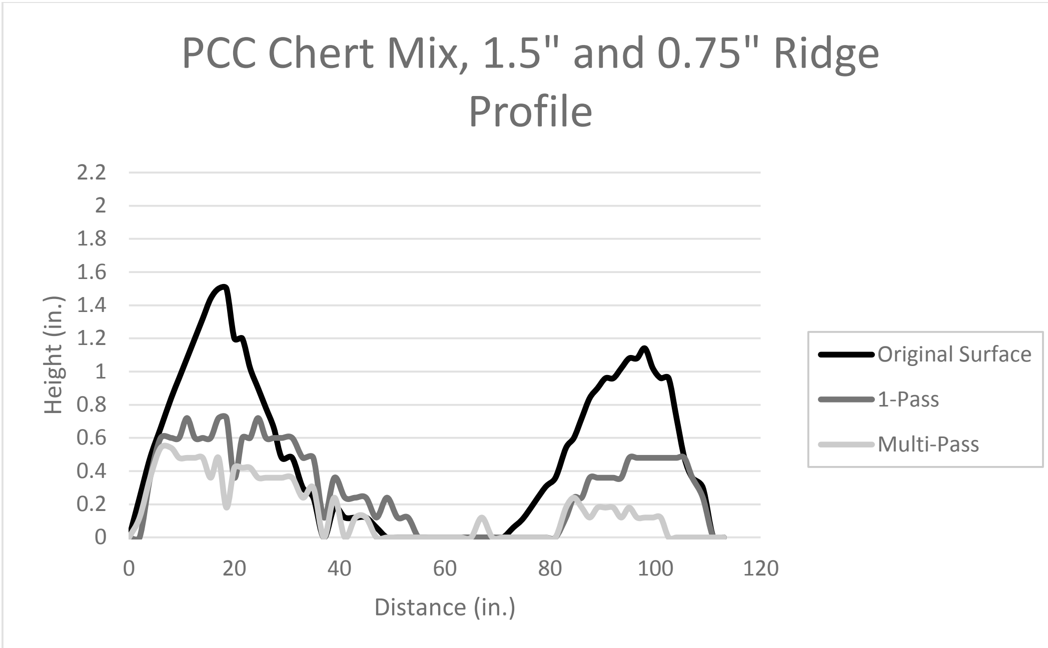


Figure 46. Profile view of crater Repair 2 before and after planing phases.

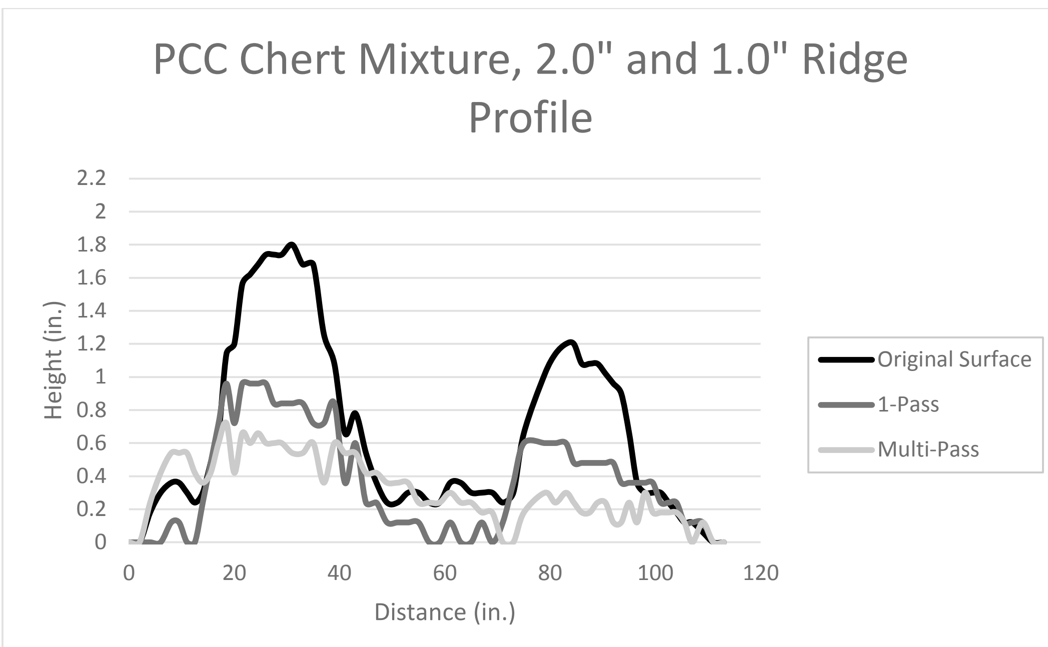


Figure 47. Profile view of crater Repair 3 before and after planing phases.

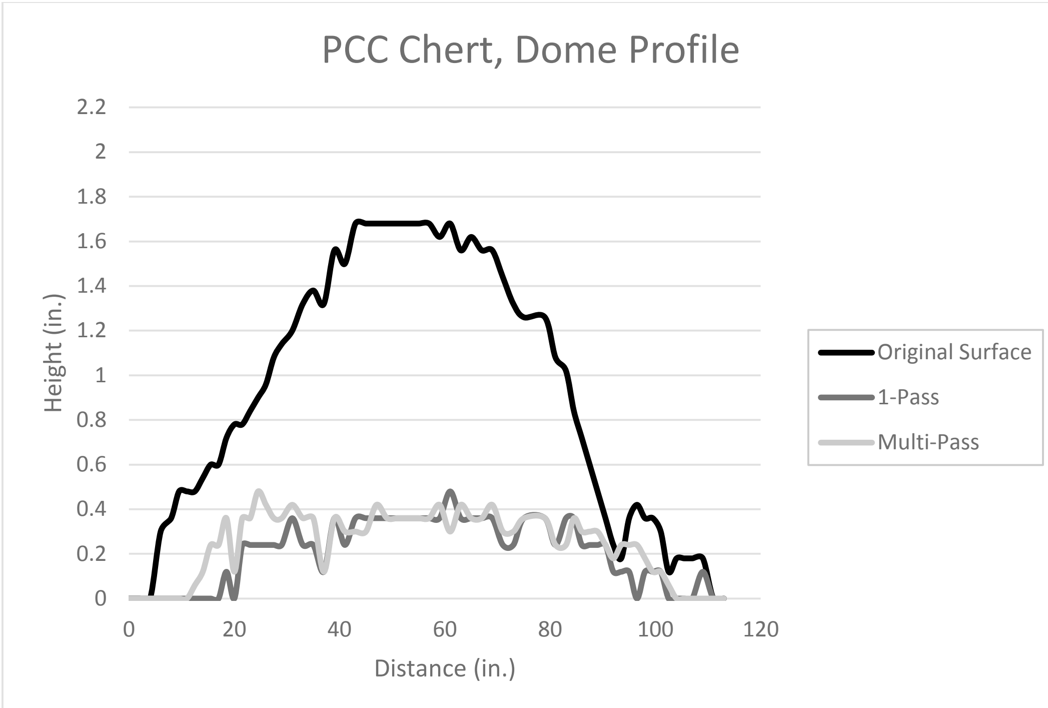


Figure 48. Profile view of crater Repair 4 before and after planing phases.

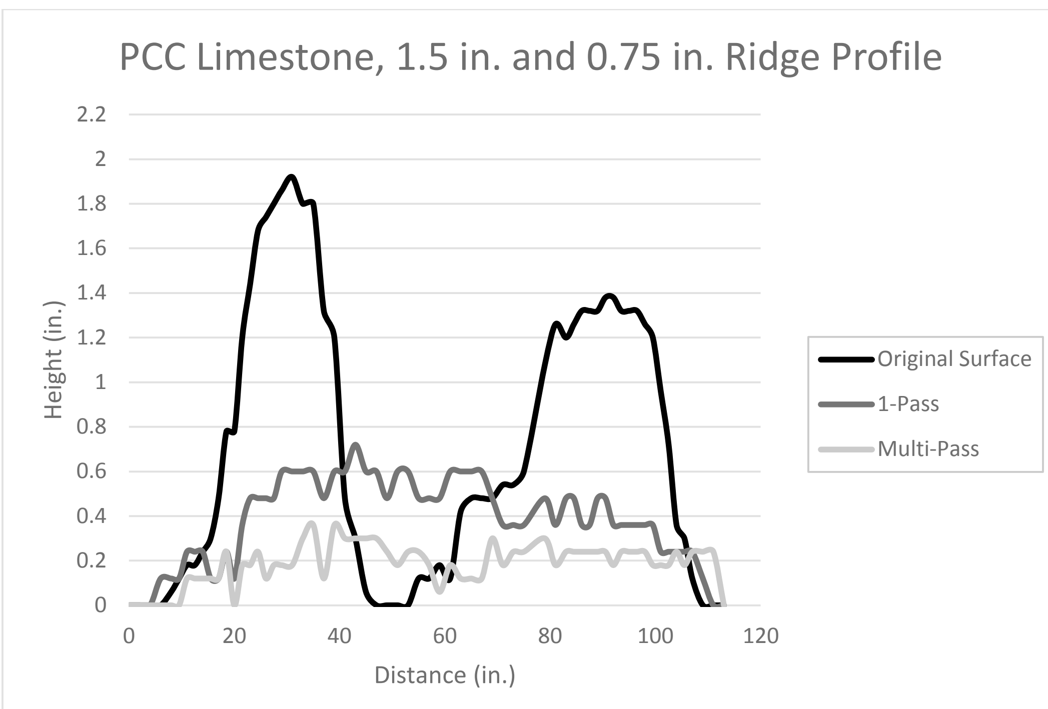


Figure 49. Profile view of crater Repair 5 before and after planing phases.

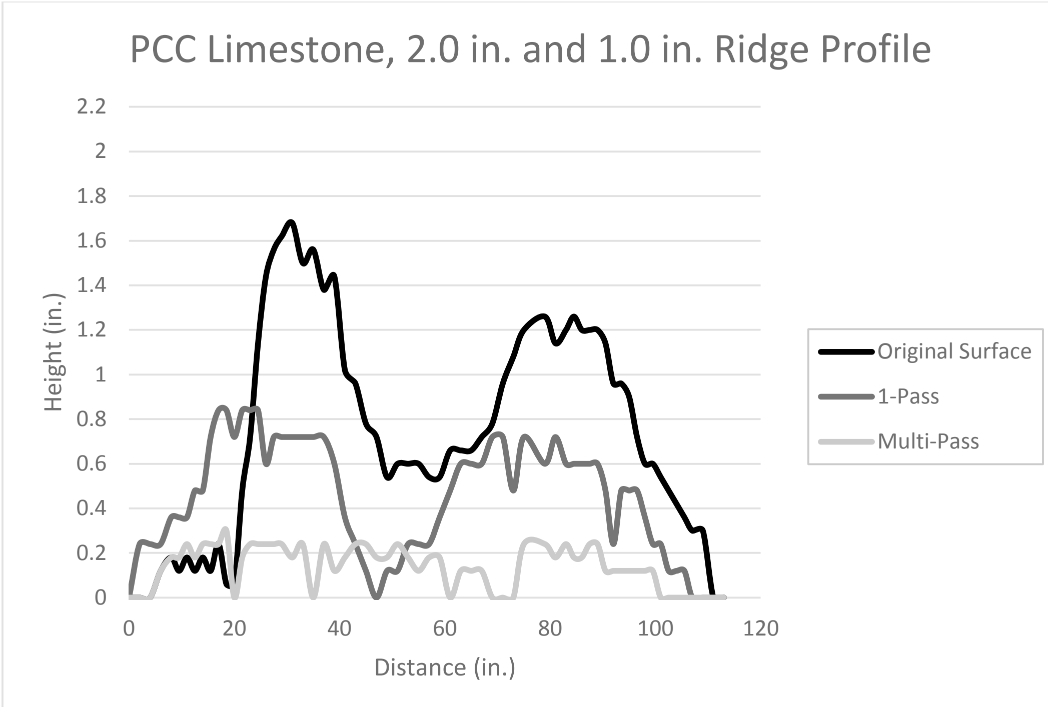
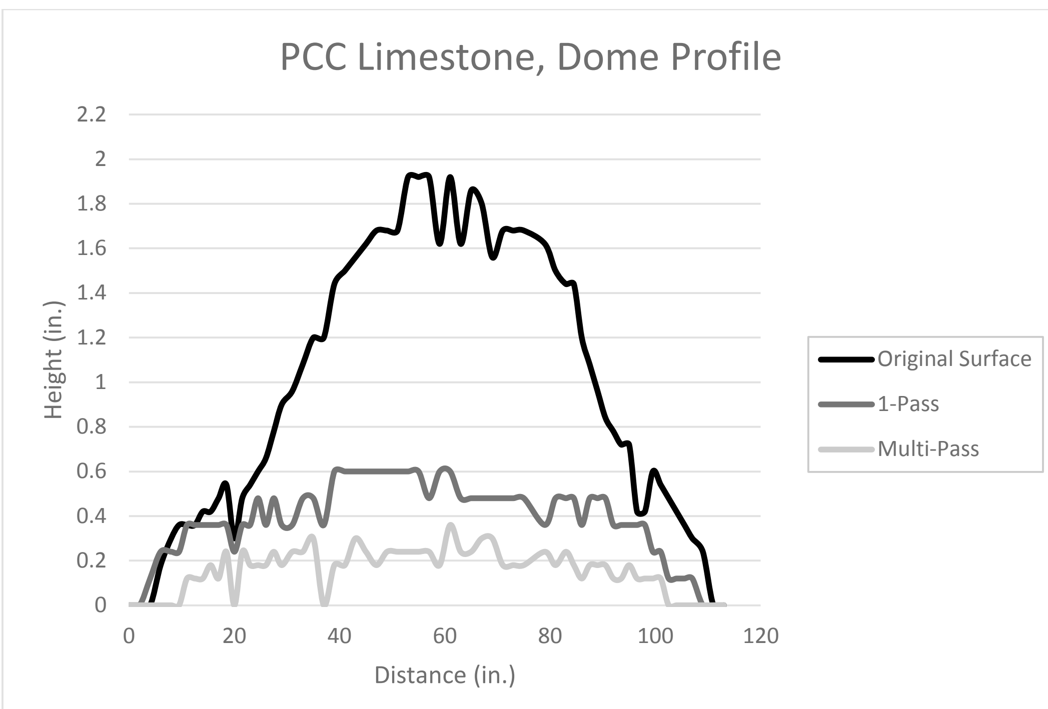


Figure 50. Profile view of crater Repair 6 before and after planing phases.



To quantify the height of material (RS concrete and AC) the Flatliner can remove after one pass, the center-third of crater Repairs 1A, 2A, 3A, 4A, 5A, and 6A are represented in Figure 51 through 56.

Figure 51. Profile view of crater Repair 1A before and after planing phases.

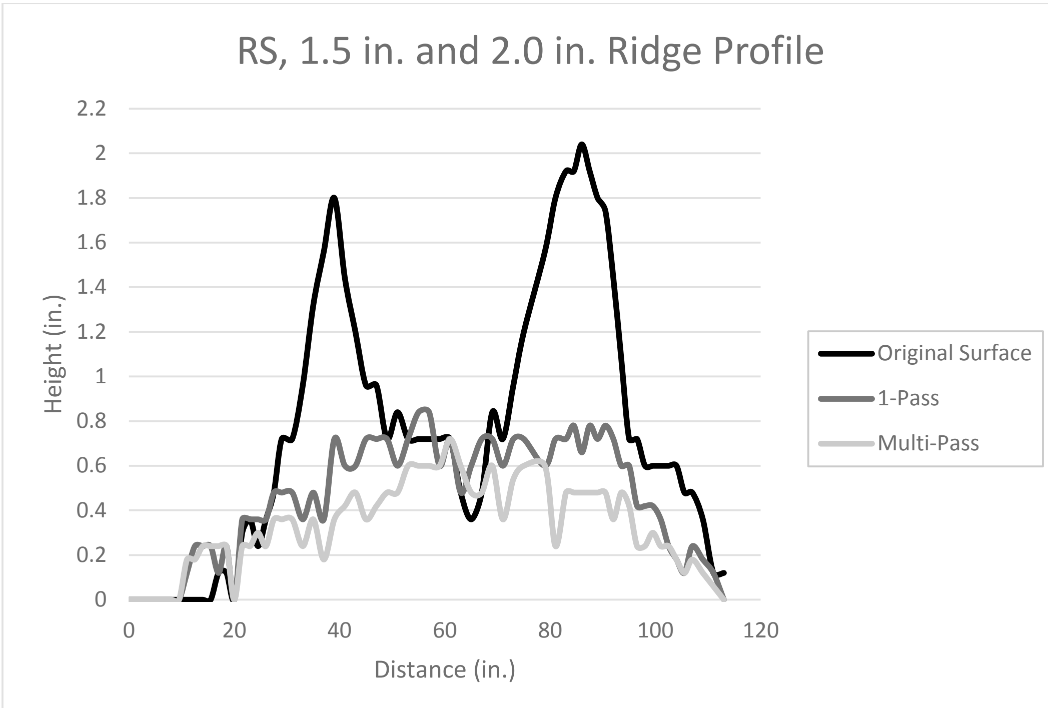


Figure 52. Profile view of crater Repair 2A before and after planing phases.

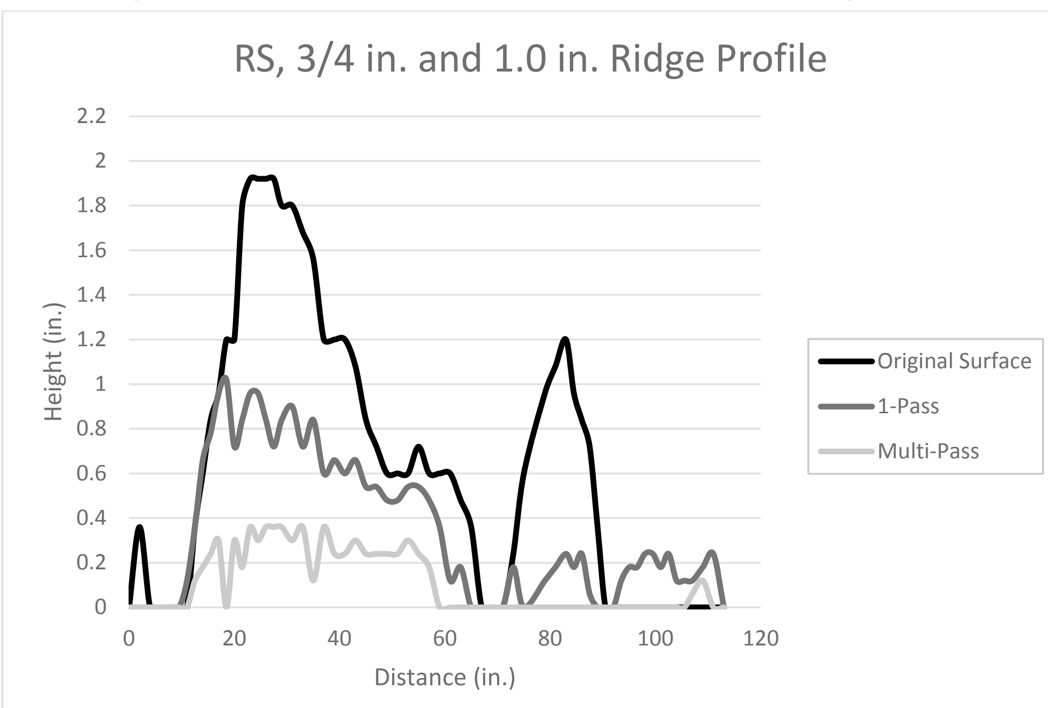


Figure 53. Profile view of crater Repair 3A before and after planing phases.

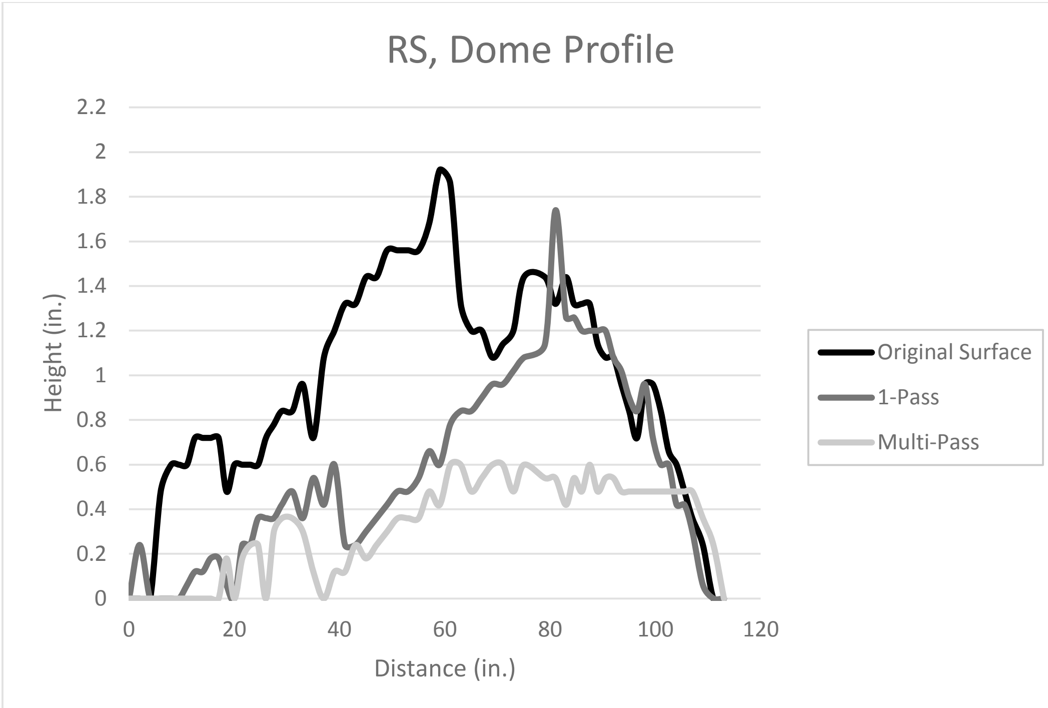


Figure 54. Profile view of crater Repair 4A before and after planing phases.

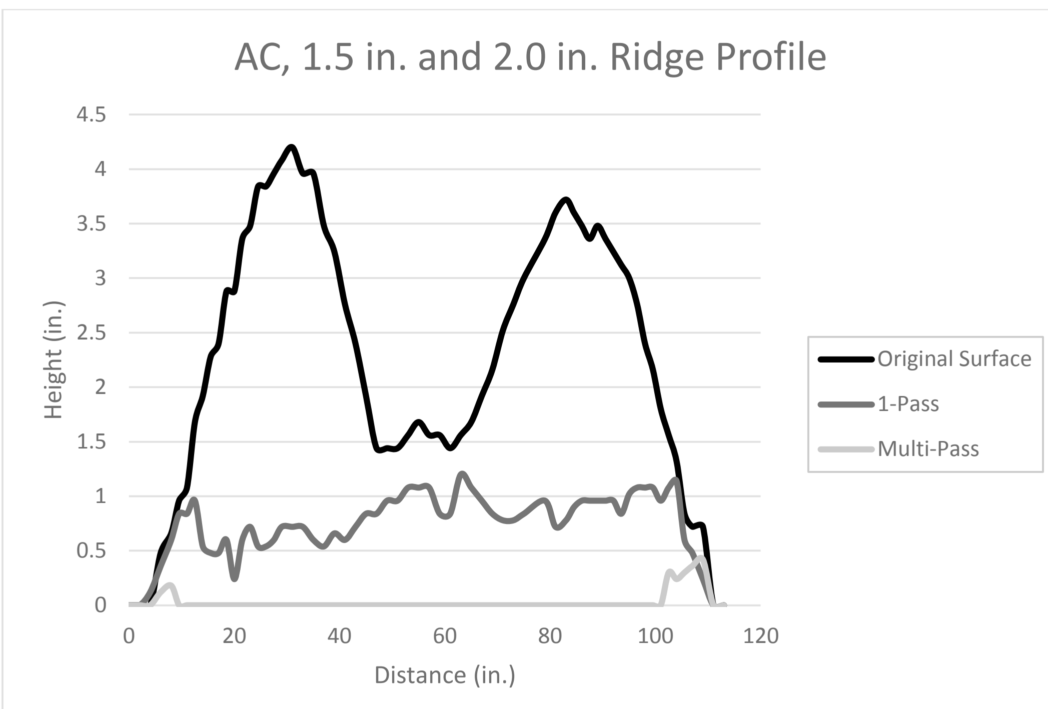


Figure 55. Profile view of crater Repair 5A before and after planing phases.

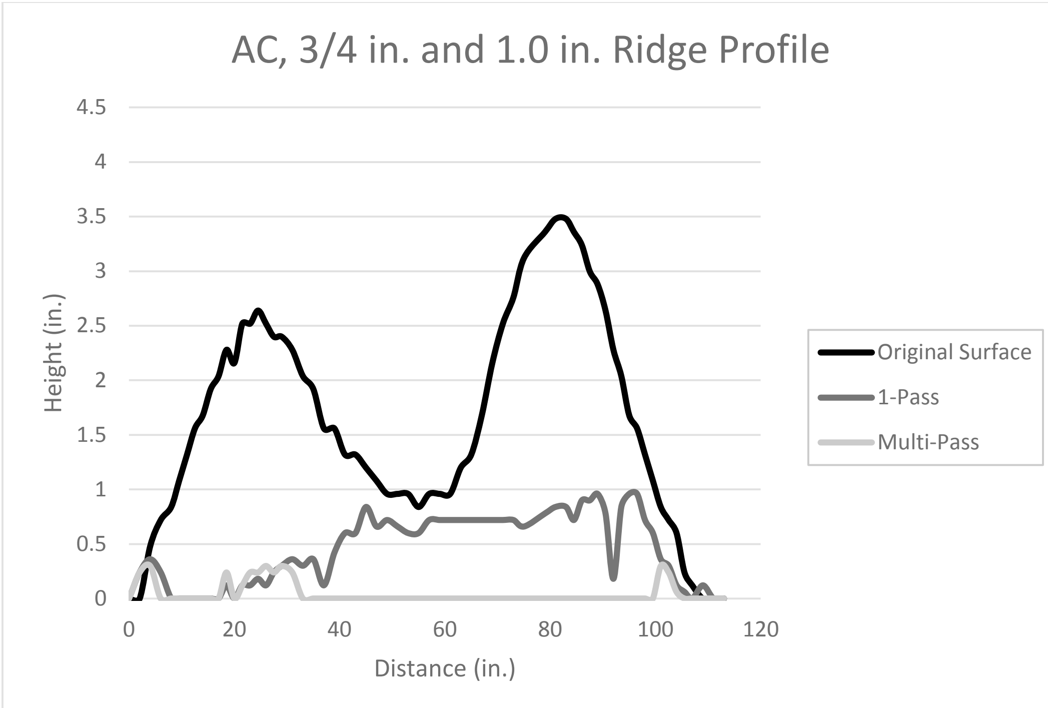
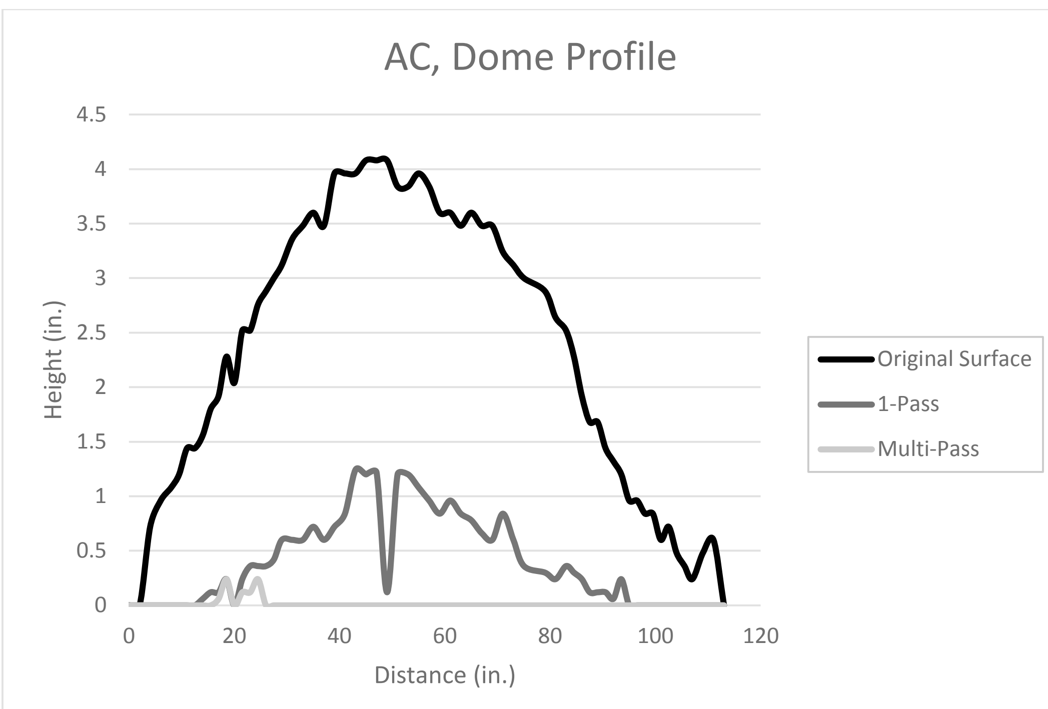


Figure 56. Profile view of crater Repair 6A before and after planing phases.



After analyzing the data from Figures 51, 52, and 53, the Flatliner was capable of removing approximately 1 in. of RS concrete with one pass, which was approximately the same average achieved on the PCC crater repairs. After analyzing the data from Figures 54, 55, and 56, the Flatliner was capable of removing approximately 2.47 in. of AC with one pass.

5.3 Time trials

The time needed for the Flatliner to make each pass was recorded and the data compiled during the duration of all demonstrations. Only the time during operation was recorded (Table 3). The time required for lining up passes and moving positions was not recorded.

Table 3. Compiled time of the Flatliner during operation.

Crater Repair	Repair Material	One pass (minutes)[1]	Multi-pass (minutes)[2]	Total (minutes)[3]
1	PCC (Chert)	2.23	2.62	4.85
2	PCC (Chert)	2.26	3.38	5.64
3	PCC (Chert)	26.00	No Record[4]	26.00 [4]
4	PCC (Limestone)	1.88	9.78	11.66
5	PCC (Limestone)	2.33	5.38	7.71
6	PCC (Limestone)	12.00	3.05	15.05
1A	RS	3.02	1.90	4.92
2A	RS	3.05	3.00	6.05
3A	RS	9.03	6.63	15.66
4A	AC	6.13	1.78	7.91
5A	AC	4.08	1.15	5.23
6A	AC	9.83	2.18	12.01

[1] The total time to make one complete pass for each ridge on crater Repairs 1, 2, 4, 5, 1A, 2A, 4A, and 5A. Total time to make equal passes across entire surface of "Dome" on crater Repairs 3, 6, 3A, and 6A.

[2] The total time to plane the surface of the crater repairs to flush with surrounding pavement.

[3] The sum of all times to plane the surface of the crater repairs to flush with surrounding pavement.

[4] Time for equal single pass across entire surface, no record for multi-pass times.

Note that the first two craters of each material type consist of two ridges; therefore, two single passes were made over these craters. For the PCC repairs, the average time to cover the 8-ft crater length was 1 min. That time increased to about 1.5 min over the RS craters. Slowing down the grinding speed allowed more removal of material when comparing the PCC chert mix to the RS repair, so the resulting grinding efficiency remained similar. The AC repairs required longer planing times than the other repairs for the first pass of the Flatliner. This occurred because the operator had to slow the machine to avoid digging holes in the repair since the Flatliner removed the AC so easily. The operator took great care not to dig holes in the pavement. The operator experienced greater control when planing cementitious repairs.

The third crater repair of each material type was the dome-shaped repair. These repairs consisted of about 4 to 6 passes to complete the first sweep, greatly extending the time period to cover the area. Overall, the Flatliner was operated at about 10 ft/min on all repairs.

5.3.1 Grinding efficiency

The grinding efficiency was calculated by taking the volume removed (Table 2) and dividing that by the time during operation (Table 3). The grinding efficiency of the Flatliner is presented in Table 4.

Table 4. Grinding efficiency of the Flatliner on various crater repair surfaces.

Crater Repair	Repair Material	Efficiency, one pass (ft^3/minute)	Efficiency, multi-pass (ft^3/minute)	Overall Efficiency (ft^3/minute)
1	PCC (Chert)	0.606	0.351	0.468
2	PCC (Chert)	0.446	0.491	0.473
3	PCC (Chert)	0.117	N/A	N/A
4	PCC (Limestone)	1.329	0.255	0.428
5	PCC (Limestone)	0.736	0.365	0.477
6	PCC (Limestone)	0.221	0.412	0.260
1A	RS	0.893	0.226	0.635
2A	RS	0.383	0.353	0.368
3A	RS	0.466	0.032	0.282
4A	AC	1.116	2.588	1.447
5A	AC	1.415	2.216	1.591
6A	AC	0.846	1.237	0.917

The Flatliner was measured as being capable of removing a maximum of 0.606 ft^3 per minute of PCC with chert aggregate, 1.329 ft^3 per minute of PCC with limestone aggregate, 0.893 ft^3 per minute of RS, and 1.415 ft^3 per minute of AC. In general, these results are in line with expectations that the rate of removal would be related to the hardness of the material being removed. The ranking of material in terms of hardness is RS, PCC with chert aggregate, PCC with limestone aggregate, and AC.

The Flatliner operated at the greatest efficiency when it was removing areas with sharp contrasts to the surrounding pavement (i.e., bumps). The Flatliner was most efficient during the first pass. When a surface deficiency was narrow and wide, a greater thickness of material could be removed. As the surface became more even with the surrounding grade, the Flatliner became less efficient. This decline was expected and thought to approach a value of zero when the pavement was perfectly smooth.

5.3.2 Replacing bits

All 108 bits were changed a total of three times throughout this evaluation. The bit replacement took place before grinding each material type. The average time to change all 108 bits on the Flatliner's 3-ft drum was approximately two hr with four moderately experienced personnel. More detailed instruction on replacing the bits can be found in Appendix A: Flatliner operator's manual.

6 Conclusions and Recommendations

6.1 Conclusions

The Flatliner cold planer attachment was evaluated for its ability to smooth various surface deficiencies in different cementitious and asphaltic pavement repairs. Overall, it was an excellent tool that resulted in much smoother pavement surfaces compared to traditional milling heads. With one pass over a pavement, the Flatliner could remove at least 0.8 in. of material in all surface types investigated. The following conclusions address the specific objectives of the technology.

Smooth a deficient crater repair surface to meet roughness tolerances. The Flatliner was an excellent tool for smoothing localized areas in a pavement surface. It performed well in soft and hard PCC, RS concrete, and AC pavements and could correct smoothness deficiencies to within acceptable ranges. The Flatliner is more suitable for short wavelength roughness (i.e., bumps) than for long wavelength roughness (i.e., improper grade). The guide extending from the front of the planer needs to bridge the repair area to get the best results in terms of overall surface grade after planing. The Flatliner could remove over 1 in. of material in a single pass on most repairs; obtaining a flush surface required multiple passes.

Smooth upheaval around a crater. The Flatliner could be used to smooth upheaval around a crater as long as the crater diameter was small (i.e., single slab). If the crater had a large diameter (i.e., 25 ft), the Flatliner would be inefficient at trying to meet the necessary grade tolerances. It is more efficient at removing small areas of localized damage.

Smooth pavement deficiencies near an aircraft arrestor system. Although not directly evaluated, the Flatliner could be used to smooth pavement areas around an aircraft arrestor system. The Flatliner would work best at planing a transverse joint created near the arresting system's panels or at the interface where a different pavement material was used surrounding the system (i.e., 200 ft either side of the cable).

Trench pavement to create bed for installing protective panels beneath an aircraft arresting system. Although not directly evaluated, the Flatliner would not perform well at either trenching the bed to install the protective panels or smoothing the bed after milling with a more aggressive cutting wheel. The Flatliner is designed to grind pavement above the surface. Although the cutting wheel does protrude below the protective housing, it is constrained by the housing when trying to cut very far into the pavement. The Flatliner would need to be redesigned to achieve effective trenching.

Trench pavement to create a flush AM2 matting repair. For the same reasons provided in the previous statement, the Flatliner would not perform well at trenching pavement to create a flush AM2 matting repair.

6.2 Recommendations

Based on the data provided in this report and observations during the field trials, the Flatliner cold planer is recommended as a tool to repair surface pavement irregularities associated with conducting crater repairs or with maintenance and rehabilitation of pavements. The Flatliner is not recommended for smoothing large pavement areas or as a trenching device where cutting into the existing pavement grade is desired.

References

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Appendix A: Flatliner operator's manual

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FLATLINER

Because Roads Should NOT Have a Pulse

SKID STEER GRINDING ATTACHMENT

Operator's Manual

Edition 1: 11/1

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Introduction

RESPONSIBILITY OF THE OWNER/RENTER/LESSEE OF FLATLINER ATTACHMENT:

The purpose of this manual is to assist you and your organizations in operating and maintaining your skid steer attachment. It gives you the information to safely operate your attachment, to optimize its performance and to properly maintain the attachment. However, many operating situations will be unique to the particular job and variations from the manual will be needed.

Read this manual and all of its contents before operating your GRINDING ATTACHMENT.

Require all operators to read this manual carefully and become familiar with the unit's operating procedures before attempting to operate the attachment.

Observe all safety information listed within the manual, on the attachment and the powering device.

The grinding attachment will require cleaning and routine maintenance.

Use only Flatliner certified parts for service. Substitute parts will void the warranty and may not meet safety or operational standards.

Flatliner parts can be ordered by calling your Flatliner Representative or by calling 317-271-6196.

A replacement manual can be ordered from your Flatliner Representative or by calling 317-271-6192 to request a copy.

Specifications

The power source must be equipped with an auxiliary hydraulic system that is capable of supplying flow to the hydraulic motor. The grinding attachment is intended for smoothing asphalt surfaces by grinding the area above the zero point. The performance of the unit can vary greatly depending upon how it is operated and the material it is grinding. Please follow the recommended operating procedures listed below for maximum productivity.

FLATLINER SPECIFICATIONS:

	FL24	FL36	FL48
Grinding Width	25”	37”	49”
Grinding Depth	0-1”	0-1”	0-1”
Number of bits	72	108	144
Hydraulic Horsepower (HHP) Requirement	35	50	70
Operating Weight (lbs)	2600	3000	3400
Planetary Capacity	19 oz (Half Full)		
Planetary Lubrication	90 Weight Gear oil with EP additives		

***HHP = GPM x PSI**

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Safety

Safety is the primary concern in the design of this product. However, much of the equipment's safe operation and accident prevention falls on the operator and the manor by which the equipment is installed, operated and maintained.

TRAINING:

- Read attachment manual before installation.
- Read all power source manuals before installation.
- Operators and all installation and maintenance personnel must be instructed and capable of the safe installation of equipment and equipment's controls.
- Learn how to quickly stop the engine and the attachment in case of an emergency.
- Follow all safety rules listed below. If you do not understand ANY part of this manual and need assistance, see your Flatliner Representative or call 317-271-6192.

WARNING: FAILURE TO FOLLOW THESE SAFTEY INSTRUCTIONS MAY RESULT IN INJURY OR DEATH.

SAFETY IN INSTALLATION:

- Operators and all installation and maintenance personnel must be instructed and capable of the safe installation of equipment and equipments controls.
- Hydraulics must be connected as instructed in this manual and the power source's manual.
- After connecting all hoses, check that all control lever positions function as instructed in the Operator's Manual.

- Do not allow anyone to operate this equipment without proper instructions and without reading all attachment and power source manuals.
- Keep hands and body away from pressurized lines.
- Do not use hands or other body parts to check for leaks.
- Always wear protective clothing and shoes.
- Use protective equipment for eyes, hair, hands, hearing, respiratory and head.
- Hydraulic fluid under pressure can penetrate skin and will cause serious injury or death.
- **Make sure that all operating, installation and service personnel know that if hydraulic fluid penetrates skin, it must be surgically removed immediately by a doctor or serious injury, or death will result.**
- CONTACT A PHYSICIAN IMMEDIATELY IF FLUID ENTERS SKIN OR EYES.
- Never allow untrained persons or children to operate equipment.
- A counterweight may be required for machine stability during installation and operation.
- When connecting hoses or performing hydraulic maintenance, remove any air in the hydraulic system by operating all hydraulic functions several times.
- Check that all control lever positions are exactly as stated in the Operator's Manual before use.
- Protective hose sleeves must be secured onto a metal hose fitting and be used on all hydraulic hoses within 24 inches of the operator.

- Make sure all hydraulic hoses, fittings, and valves are in good condition and in the proper position away from other moving parts and not twisted or pinched or leaking before starting power unit or using equipment. Replace any damaged hoses, fittings, and valves immediately.

- Check that all lubrication points have been properly lubed and greased before use.

- Be sure the attachment is properly secured, adjusted, and in good operating condition before running or starting attachment or engine.

- Power unit must be equipped with ROPS and seat belt and be used at all times.

- Make sure all safety decals are installed. Replace if damaged or missing. Call your Flatliner Representative or call 317-271-6192 for replacement decals).

- Make sure all safety features are installed and functioning properly on both the grinding attachment and the power source.

- Fully inspect work area before using the attachment for loose objects that could be ejected from the unit or other safety hazards that could cause injury or death.

- **Always engage the parking brake, turn off engine and remove the ignition key before maintaining or servicing the attachment.**

SAFETY IN OPERATION:

- **Improper operation can cause the attachment and power source to tip over resulting in serious injury or death.**
- Keep power unit lift arms and attachment as low as possible.
- Do not operate unit with lift arms and attachment raised.
- Turn the power source only on level ground.
- Do not run across slopes, instead run up and down.
- Keep the heavy end of the equipment uphill.
- Do not overload the machine or carry loads that exceed the operating capacity of the power source.
- Do not allow bystanders in the area when installing, operating, or servicing equipment.
- **Know your environment! Contact with overhead power lines and other high voltage items, underground cables, gas lines, and other hazards can cause serious injury or death.**
- Do not operate or transport equipment while under the influence of alcohol or drugs.
- Operate only when optimal lighting is present.
- Keep hands, feet, hair, and clothing away from equipment while engine is running.
- **Fully inspect work area before using the attachment for loose objects that could be ejected from the unit or other safety hazards that could cause injury or death.**

- Do not lift or carry anybody or other unapproved objects on the attachment or power unit.
- Always make sure the area down and behind the power unit is clear before reversing the unit.
- Do not operate the grinding attachment on steep slopes.
- Do not stop, start, or change directions suddenly on slopes.
- Watch for hidden hazards in the work and transport zones during operation.
- If either unit makes contact with an obstruction, fully inspect attachment and power unit for any damage and repair before resuming operation.
- **Never adjust or work on attachment while the power unit or attachment is running or the key is in the ignition. Serious injury or death could result.**
- **Before making any adjustments or performing any service to the grinding attachment engage the parking brake, turn off engine and remove the ignition key.**

SAFETY IN MAINTENANCE:

- **NEVER perform service or maintenance with engine running.**
- **NEVER go underneath the attachment.**
- Read Operator's Manual for service instructions or call your Flatliner Representative or 317-271-6192 with any questions.
- Do not modify the equipment in anyway.

- Use only Flatliner certified parts for service. Substitute parts will void the warranty and may not meet safety or operational standards.

- Always wear protective clothing and shoes.

- Use protective equipment for eyes, hair, hands, hearing, respiratory and head.

- Do not allow bystanders in the area when operating, attaching, removing, assembling, or servicing equipment.

- Be sure attachment is properly secured and adjusted before putting it in use.

- Make sure coupler lock pins are fully extended.

- When removing front wheel pins, be sure to support the front of the depth skid to prevent hands or feet from being crushed.

- Do not disconnect hydraulic lines until all system pressure is relieved. Lower unit to ground, stop engine, and operate all hydraulic control levers.

- Mechanical and/or hydraulic system failure can cause equipment to drop unexpectedly.

- Tighten all bolts, nuts, and screws to proper torque.

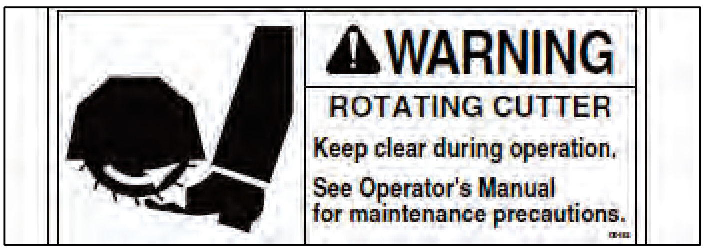
- After servicing equipment double check that it has been reassembled properly. If you have any questions please contact your Flatliner Representative or 317-271-6192.

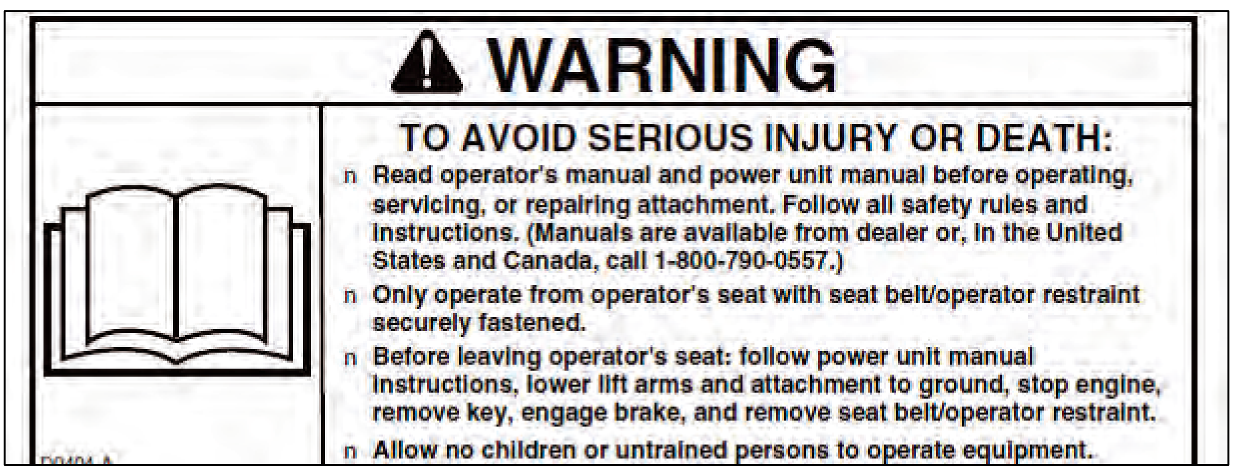
- Make sure all safety decals are installed and replace if damaged or missing.

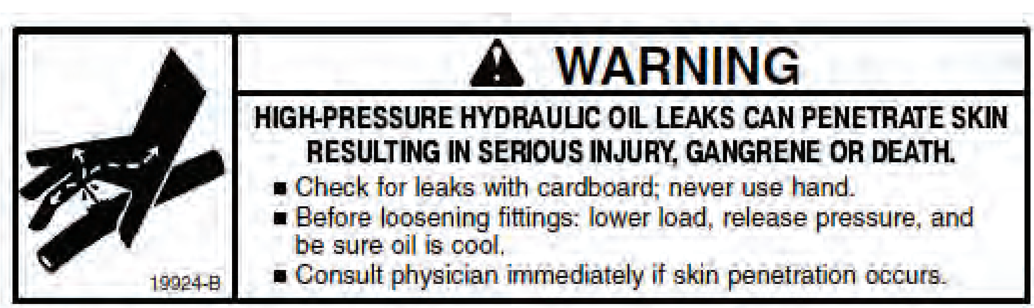
- **Always engage the parking brake, turn off engine and remove the ignition key before maintaining or servicing the attachment.**

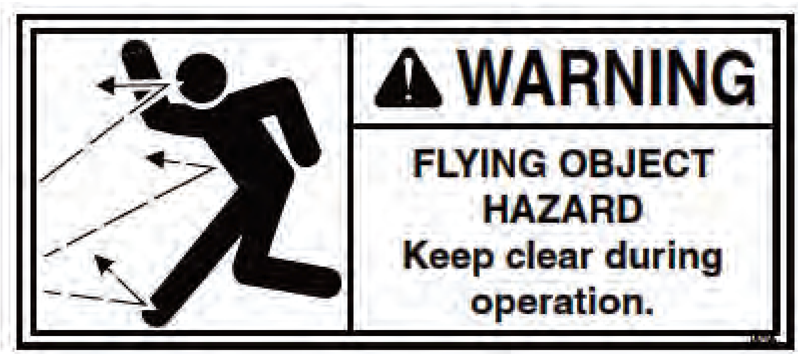
DECALS

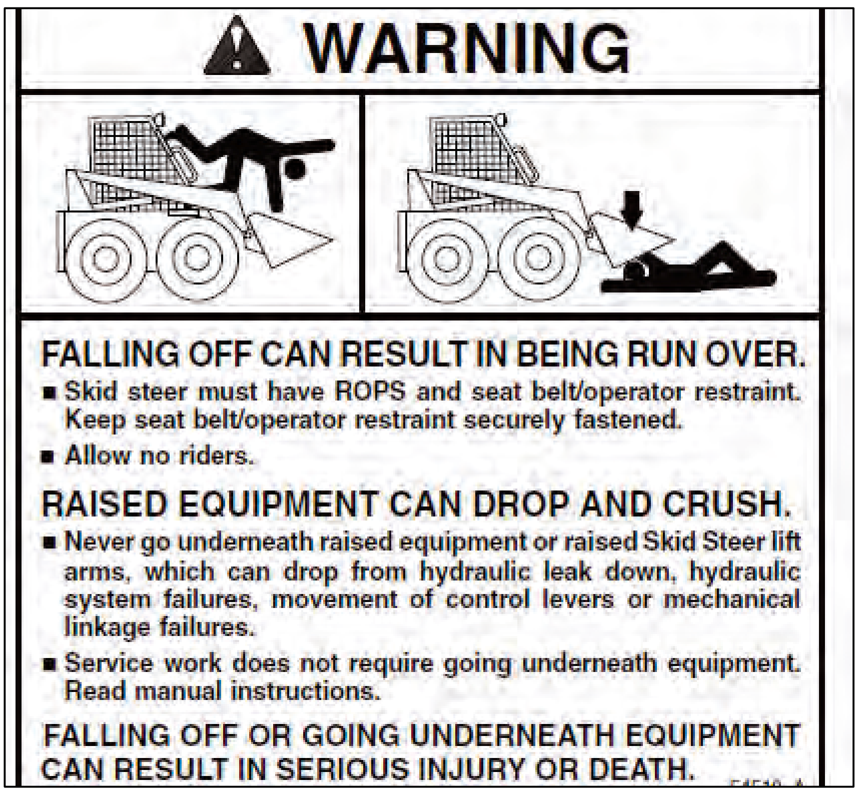
Review all safety and instructional decals carefully before operation. Replace immediately if damaged or missing. Call your Flatliner Representative or 317-271-6192 if a replacement decal is needed.

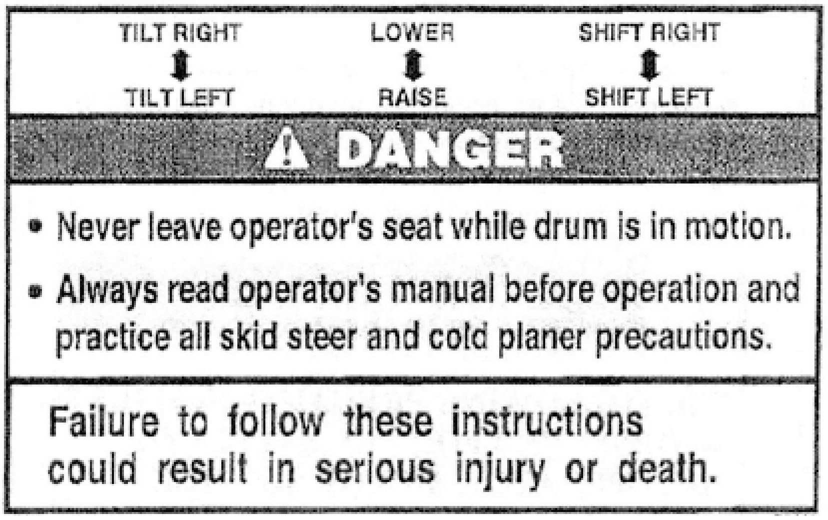







WARNING
FLYING OBJECT HAZARD
Keep clear during operation.


WARNING
FALLING OFF CAN RESULT IN BEING RUN OVER.
■ Skid steer must have ROPS and seat belt/operator restraint. Keep seat belt/operator restraint securely fastened.
■ Allow no riders.
RAISED EQUIPMENT CAN DROP AND CRUSH.
■ Never go underneath raised equipment or raised Skid Steer lift arms, which can drop from hydraulic leak down, hydraulic system failures, movement of control levers or mechanical linkage failures.
■ Service work does not require going underneath equipment. Read manual instructions.
FALLING OFF OR GOING UNDERNEATH EQUIPMENT CAN RESULT IN SERIOUS INJURY OR DEATH.


TILT RIGHT
TILT LEFT
LOWER
RAISE
SHIFT RIGHT
SHIFT LEFT
DANGER
• Never leave operator's seat while drum is in motion.
• Always read operator's manual before operation and practice all skid steer and cold planer precautions.
Failure to follow these instructions could result in serious injury or death.


CAUTION
CRUSHING HAZARD
Do not raise or roll back the lift arms when the valve arm is lowered into the cab.
FAILURE TO FOLLOW THESE INSTRUCTIONS COULD RESULT IN SERIOUS INJURY.

Operation

Follow all safety rules listed above under “Safety”. Review and follow all safety decals on the attachment and power source.

***WARNING: Failure to do so could result in serious injury or death.**

Operator must be instructed and capable of the safe installation, operation, maintenance and transportation of the equipment.

ATTACHING THE GRINDER:

1. Position the coupler pins in the disengaged position.

2. Rotate the attachment plates on the power source forward to engage the mounting plate on the grinding attachment.

3. Pull the power source forward and tilt the attachment plates back until there is complete engagement between the mounting plate and the attachment plates.

4. Rotate the attachment plates on the power source until the grinding attachment is locked into place. The locking pins should be secure and engaged.

5. Place the grinding attachment on the ground.

6. Engage the parking brake on the power source.

7. Stop the engine.

8. Remove the engine key.

ATTACHING THE HOSES:

Insufficient hydraulic power will result in poor performance.

1. Attach three hydraulic hoses from the attachment to the quick coupler on the power source (motor pressure, return and case drain).

2. Verify all hoses are securely fastened.

***WARNING: Motor seal failure will occur if the case drain is not attached or if the hose is bent, kinked or cut.**

ZEROING THE DRUM:

An initial zeroing of the drum is required upon delivery of the unit and after any readjustment made to the front ski to insure the drum is cutting parallel to the surface. In addition, a periodic zeroing of the drum is needed as the carbide bits wear.

1. Zero on a level surface.

2. Null both the right and the left back wheels down to where the drum is just barely striking the surface. Making sure it is an even depth from left to right.

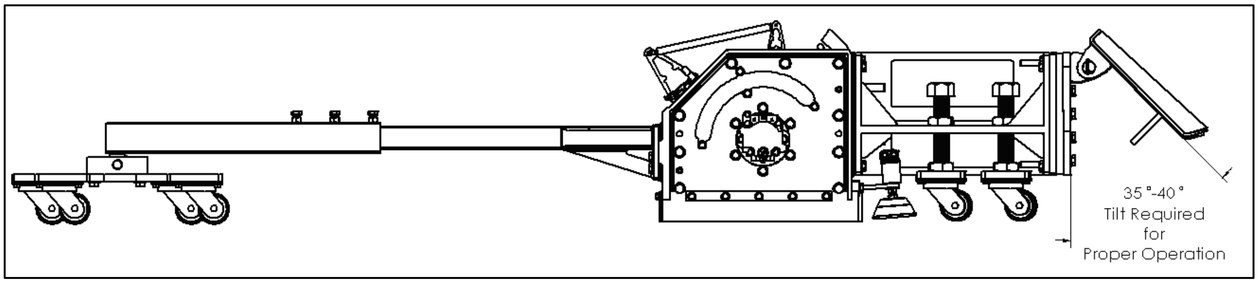
    - Turning the wheel clockwise will bring the cutter drum up.

    - Turning the wheel counterclockwise will take the cutter drum down.

    - 1 complete turn= 1/12”

3. Set the smaller set of back wheels a ¼ to ½ turn above the back wheels.

GRINDING PROCEDURE:



- **NEVER open the drum access door during operation. Both latches should be securely fastened before being powered. Serious injury or death could result.**

- Never place the lift arms into the “float” position.

- The drum should not be in contact with the surface upon engaging the hydraulic power to the unit.

- Tilt the lift arms forward so the front wheels and back wheels are resting on the surface.

- Engage and disengage the drum only when the machine is at idle.

- Slowly begin moving forward and then quickly engage the hydraulic power to the grinding unit.

- While grinding make sure the machine is at full power.

- When the unit stops grinding shut off the power and then lift the unit up.

- Multiple passes for longer bumps may be needed.

WARNING: Never adjust or work on attachment while the power unit or attachment is running or the key is in the ignition or serious injury or death could result. Before making any adjustments or performing any service to the grinding attachment, engage the parking brake, turn off engine and remove the ignition key.

Service

BIT REPLACEMENT:

To insure a smooth pattern, match the length of the replacement bit to the existing bits on the drum. This can be done by grinding the bottom of a new replacement bit or using a used bit that has been worn to the same length.

1. Position drum so the broken bit(s) are positioned at the top of the opening of the cutter drum door.

2. Remove worn bit(s).

3. Clean bit holder pocket extensively.

4. Place new bit in holder and make sure the bottom of the bit is seated to the top of the bit holder pocket.

5. Insert tapered wedge and tighten bolt to 100 foot pounds.

WARNING: Never adjust or work on attachment while the power unit or attachment is running or the key is in the ignition or serious injury or death could result. Before making any adjustments or performing any service to the grinding attachment engage the parking brake, turn off engine and remove the ignition key.

CLEANING AND LUBRICATION:

- The attachment should be cleaned, lubricated and inspected after each use.

- Always use protective equipment for eyes and body.

- Remove all debris from grinding attachment.

- Brush all eight wheels on the attachment to remove any buildup of material.

- Inspect machine and replace worn or damaged parts or safety decals.

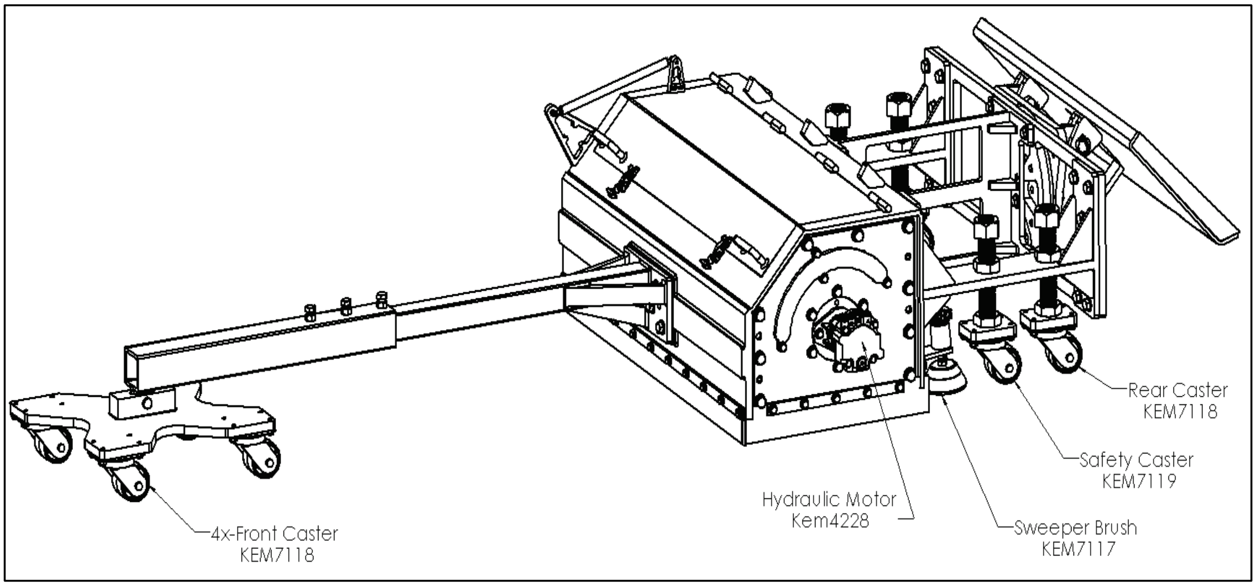
- Lubricate the grease points on all wheels as well as the drum bearing with a grease gun.

NOTE: Gear Casing lubrication must be changed within the first 50 hours of operation. After the initial 40 hour change has been completed, the lubricant will only need to be changed once a year or every 300 hours (whichever occurs first). A 90 Weight gear lube with EP additives should be used.

WARNING: Never adjust or work on attachment while the power unit or attachment is running or the key is in the ignition or serious injury or death could result. Before making any adjustments or performing any service to the grinding attachment engage the parking brake, turn off engine and remove the ignition key.

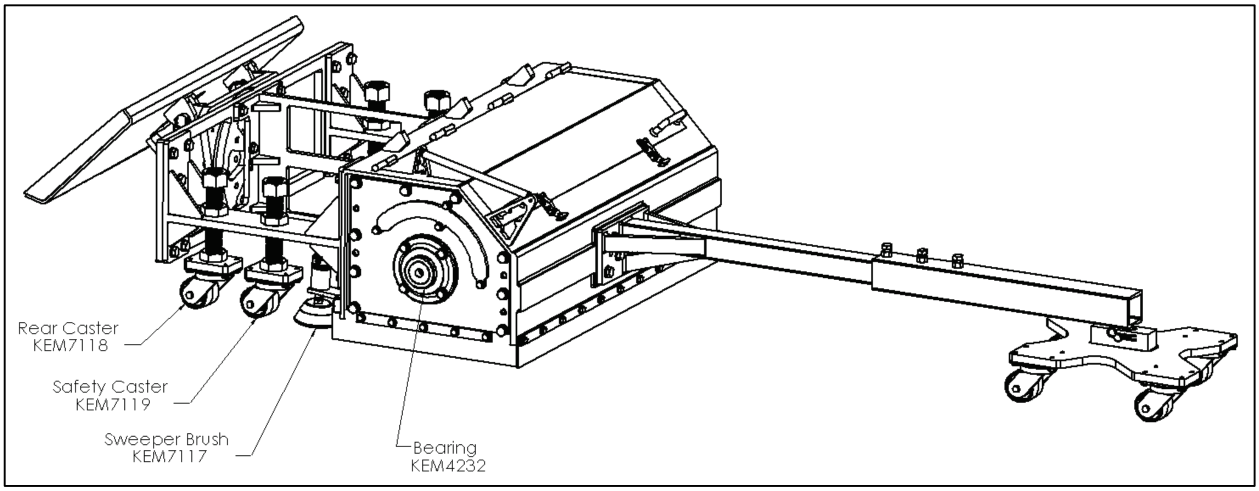
Parts

DRIVE SIDE:



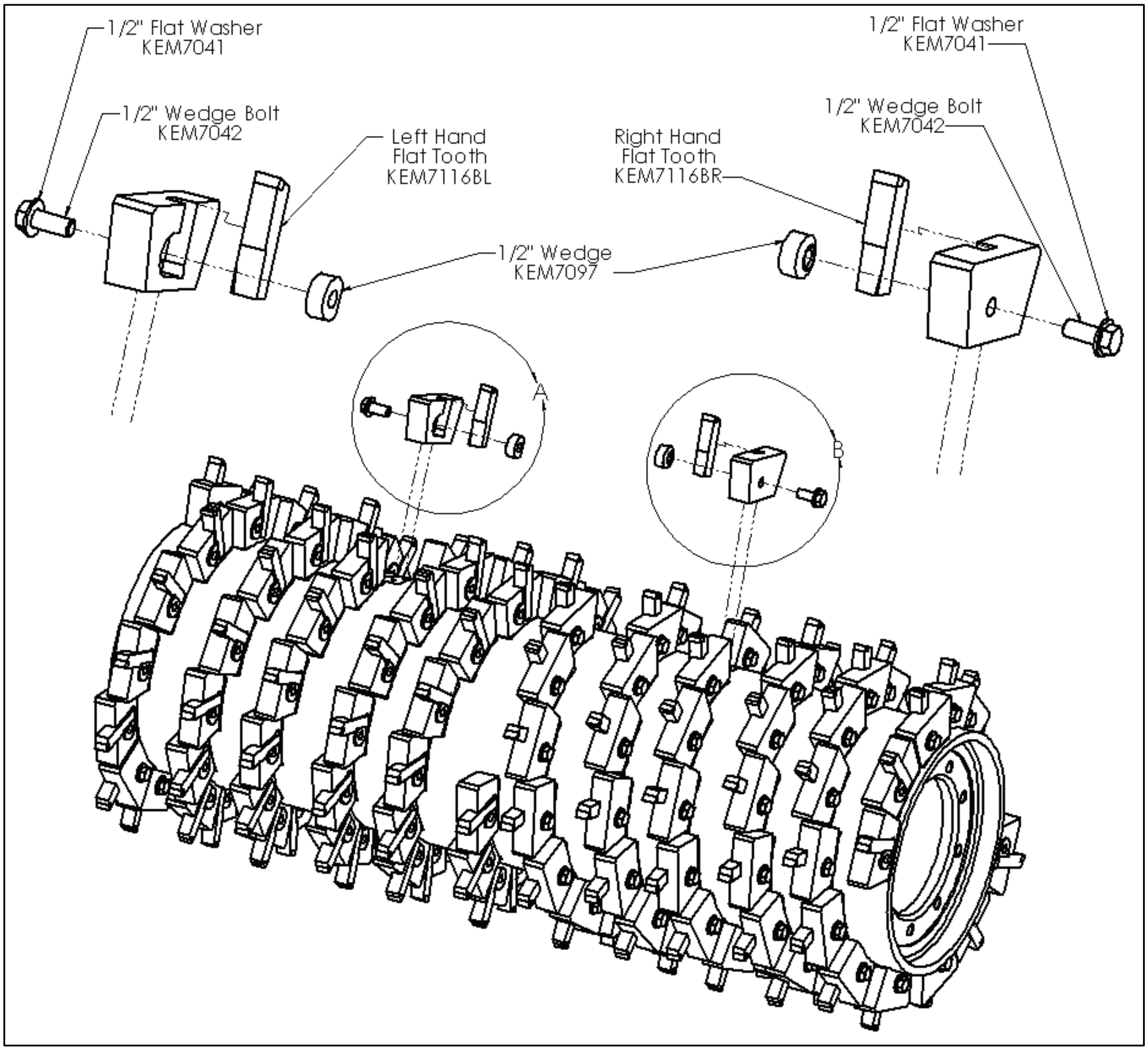
DESCRIPTION	Front Caster (QTY 4)	Hydraulic Motor	Sweeper Brush	Safety Caster	Rear Caster
PART NUMBER	KEM7118	KEM4228	KEM7117	KEM7119	KEM7118

BEARING SIDE:



DESCRIPTION	Rear Caster	Safety Caster	Sweeper Brush	Bearing
PART NUMBER	KEM7118	KEM7119	KEM7117	KEM4232

FLATLINER DRUM:



DESCRIPTION	½" Flat Washer	½" Wedge Bolt	Left Hand Flat Tooth	Right Hand Flat Tooth	Wedge
PART NUMBER	KEM7041	KEM7042	KEM7116BL	KEM7116BR	KEM7097

Appendix B: Mix designs for crater repairs

PCC mix design

MMC Materials, Inc.

Central MS Area

FORM 1 - Mix Design Submittal

Project Description: Waterways

Constructor: Malouf Construction

Mix Number: V5010161

Specified Slump: 4 Inches

Project Location: Vicksburg, MS

Concrete Supplier: MMC Materials Inc

Specified Compressive Strength: 5000 PSI

Specified Air Content: Non-AEA %

Material Properties and Source

Cementitious Material	Type	Supplier	Source	Specific Gravity
Portland Cement	Type I/II	Holcim	St. Gen. MO	3.15
Fly Ash	Class C	Headwaters	White Bluff	2.59

Admixtures	Type	Supplier	Dosage Range	Dosage	Dosage
Pozzolith 700N	Type A	BASF	1.5-7 fl oz/cwt	2.0 fl oz/cwt	13.0 fl oz/yd3

Note: Dosage rate will require adjustments for field and environmental conditions.

Aggregate Size	Supplier	Type	Sp. Gr. SSD	Absorption	F.M.
#57	Green Bro-CS	Rock	2.52	2.7%	6.99
Sand	Green Bro-CS	Natural	2.62	0.7%	2.77

Water: Local Water Association

Batch Quantities

Material	SSD Quantities lb/yd^3	Absolute Volume yd^3
Portland Cement	526	2.68
Fly Ash	132	0.82
Mix Water	262	4.20
#57	1800	11.45
Sand	1219	7.46
Air Content,%	1.5%	0.41
Total Mass, lb	3939	27.00

W/C ratio: 0.40

Water - Gal/Yard: 31.5

Unit Weight: 145.9 lbs/ft3

Mix Design Information:

Mix Description: 5000 PSI Non-AEA

Comments:

Temperature Control EXCLUDED

Designed by: Kyle Beckman

Title: Regional QA Director

Mix Revision #: 0

SINCE 1927 MMC MATERIALS, INC.

Central MS Area

FORM 1 - Mix Design Submittal

Project Description: Waterways

Constructor: Malouf Construction

Mix Number: V5040161

Specified Slump: 4 Inches

Project Location: Vicksburg, MS

Concrete Supplier: MMC Materials inc

Specified Compressive Strength: 5000 PSI

Specified Air Content: Non-AEA %

Material Properties and Source

Cementitious Material	Type	Supplier	Source	Specific Gravity
Portland Cement	Type I/II	Holcim	St. Gen, MO	3.15
Fly Ash	Class C	Headwaters	White Bluff	2.59

Admixtures	Type	Supplier	Dosage Range	Dosage	Dosage
Pozzolith 700N	Type A	BASF	1.5-7 fl oz/cwt	3.0 fl oz/cwt	17.0 fl oz/yd3
Note: Dosage rate will require adjustments for field and environmental conditions.					

Aggregate Size	Supplier	Type	Sp. Gr. SSD	Absorption	F.M.
#57	Warren Paving	Stone	2.67	0.7%	6.97
Sand	Green Bro-CS	Natural	2.62	0.7%	2.77

Water:	Local Water Association

Batch Quantities

Material	SSD Quantities lb/yd^3	Absolute Volume yd^3
Portland Cement	451	2.29
Fly Ash	113	0.70
Mix Water	267	4.27
#57	1850	11.11
Sand	1343	8.22
Air Content,%	1.5%	0.41
Total Mass, lb.	4024	27.00

W/C ratio: 0.47
Water - Gal/Yard: 32.0
Unit Weight: 149.0 lbs/ft3

Mix Design Information:

Mix Description: 5000 PSI Non-AEA #57 L/Stone
Comments:
Temperature Control EXCLUDED

Designed by: Kyle Beckman
Title: Regional QA Director

Mix Revision #: 0

AC mix design

APAC MS INC. GREENVILLE, MS

BITUMINOUS HOT MIX DESIGN FOR SC-1 Private Surface COURSE(S)

PROJECT NO.'(S) Old Mix Code 537 DATE: 10/13/20008
COUNTY'(S) New Mix Code 211790 CONTR. Apac-Ms. (Jackson)

Type Material	1/2" Crushed Grvl.	Milled Rap	Coarse Sand				Agg. Blend % Passing	Job Mix % Passing	Spec. Design Range
Aggregate Source	Green Bros. CrystalSprngs.	Apac Stockpile	Green Bros. CrystalSprngs.						
Blend (%)	46	20	34						
Sieves	Gradation (Percent by Weight Passing)								
1 1/2"	100.0	100.0	100.0				100.0	100	
1"	100.0	100.0	100.0				100.0	100	
3/4"	100.0	100.0	100.0				100.0	100	
1/2"	100.0	98.0	100.0				99.6	100	100
3/8"	97.0	95.0	100.0				97.6	98	87-100
No. 4	55.0	75.0	95.0				72.6	73	54-80
No. 8	29.0	58.0	84.0				53.5	54	32-63
No. 16	16.0	48.0	78.0				43.5	44	
No. 30	9.0	34.0	66.0				33.4	33	12-33
No. 50	6.0	20.0	20.0				13.6	14	6-20
No. 100	4.0	11.0	1.7				4.6	5	
No. 200	2.9	6.1	0.3				2.7	2.7	2-10
App. Grav.	0.000	0.000	0.000	0.000	0.000	0.000	ERR	JM Temp.	
Bulk Grav.	0.000	0.000	0.000	0.000	0.000	0.000	ERR	Air Voids	
% Abs. (M)	ERR	ERR	ERR	ERR	0.00	ERR	ERR	VMA	
% Clay	0.0	0.0	0.0	0.4	0.0	0.0	0.00	Max.Grav.	
% Crushed	93.6	92.2	100.0	0.0	100.0	100.0	93.7	Comb. BSG	ERR
PI - 40Mtl.	0.0	0.0	0.0	0.0	0.0	0.0	0.00	Hump. Ratio	60.4

Anti-Strip Rate 0.00 % by weight of AC
TSR
A. C. 5.50 A. C. Source Ergon 67-22
Remarks: % AC in Rap 5.00 % New AC 4.50
% Rap Used 20.0

Absorbed A.C.	
Effective A.C.	5.50
% LS Retained # 4	6.2%
% LS Passing # 8	84.0%

The percentage of Asphalt Cement (AC-30) to be used with the above blend of mineral aggregates for the SC-1 Private Surface Course(s) is 4.50 % by weight of the total mixture.

SUBMITTED BY: Design Lab

RS concrete MSDS

CTS Cement | Professional Cement Products
Rapid Set® Concrete Mix Datasheet

Rapid Set®

CONCRETE MIX

VERY RAPID HARDENING CONCRETE
High Strength & Superior Durability

Highlights:

- ***FAST***
  Sets in 20 minutes; ready for traffic in 1 hour
- ***DURABLE***
  Formulated for long life in critical applications
- ***STRUCTURAL***
  For repair and new construction
- ***MULTI-PURPOSE***
  Use for concrete repair, formed work, setting posts, footings, floors, machine bases, and more

MANUFACTURER:
CTS Cement Manufacturing Corp.
11065 Knott Ave.
Cypress, CA 90630
Tel: 800-929-3030
Fax: 714-379-8270
Web: www.ctscement.com
E-mail: info@ctscement.com

PRODUCT NAME:
Rapid Set® CONCRETE MIX
Very Rapid Hardening Concrete

DESCRIPTION:
CONCRETE MIX is a high-performance, fast-setting, multipurpose concrete repair material. Durable in wet environments, CONCRETE MIX is a blend of Rapid Set® hydraulic cement and quality aggregates. CONCRETE MIX is non-metallic and no chlorides are added. Mix CONCRETE MIX with water to produce a workable, quality concrete material that is ideal where fast strength gain, high durability and low shrinkage are desired. CONCRETE MIX sets in 20 minutes and is ready for traffic in 1 hour.

APPLICATIONS:
Use CONCRETE MIX for general and structure concrete repair, construction of pavements, formed work, footings, setting posts, industrial floors and machine bases. For freeze thaw durability, in some geographical areas, CONCRETE MIX contains an air-entraining admixture.

ENVIRONMENTAL ADVANTAGES:
Use CONCRETE MIX to reduce your carbon footprint and lower your environmental impact. Production of Rapid Set cement emits far less CO_2 than portland cement. Contact your representative for LEED values and environmental information.

RECOMMENDED USE:
Apply CONCRETE MIX in thicknesses from 2" to 24" (5 to 61 cm). For thinner sections, use Rapid Set® Cement All® or Rapid Set® Mortar Mix. Not intended for high heat applications above 300°F. For bonding applications, a minimum one test section should be prepared to evaluate the suitability of the materials and procedures.

SURFACE PREPARATION:
For repairs, application surface shall be clean, sound and free from any materials that may inhibit bond, such as oil, asphalt, curing compound, acid, dirt and loose debris. Mechanically abrade surface and remove all unsound material. Apply CONCRETE MIX to a thoroughly saturated surface with no standing water.

www.ctscement.com

Rapid Set®

CONCRETE MIX

VERY RAPID HARDENING CONCRETE
High Strength & Superior Durability

MIXING:
The use of a power-driven mechanical mixer, such as a mortar mixer or a drill-mounted mixer, is recommended. Organize work so that all personnel and equipment are in place before mixing. Use clean potable water. **Rapid Set® CONCRETE MIX may be mixed using 3.5 to 4.5 quarts (3.3 to 4.2 L) of water per 60-lb (27-kg) bag. Use less water to achieve higher strengths. Do not exceed 4.5 quarts (4.2 L) of water per bag.** For increased fluidity and workability use Rapid Set® FLOW Control® plasticizing admixture from the Rapid Set® Concrete Pharmacy®. Place the desired quantity of mix water into the mixing container. While the mixer is running, add CONCRETE MIX. Mix for the minimum amount of time required to achieve a lump-free, uniform consistency (usually 1 to 3 minutes). Do not retemper.

PLACEMENT:
CONCRETE MIX may be placed using traditional construction methods. Organize work so that all personnel and equipment are ready before placement. Place, consolidate and screed quickly to allow for maximum finishing time. Use a method of consolidation that eliminates air voids. Do not wait for bleed water; apply final finish as soon as possible. CONCRETE MIX may be troweled, floated or broom finished. On flatwork, do not install in layers. Install full-depth sections and progress horizontally. To extend working time, use Rapid Set® SET Control® set retarding admixture or cold mix water. Do not install on frozen surfaces. CONCRETE MIX may be applied in temperatures ranging from 45°F to 90°F (7°C to 32°C).

CURING:
Water cure all CONCRETE MIX installations by keeping exposed surfaces wet for a minimum of 1 hour. Begin curing as soon as the surface starts to lose its moist sheen. When experiencing extended setting time due to cold temperature or the use of retarder, longer curing times may be required. The objective of water curing shall be to maintain a continuously wet surface until the product has achieved sufficient strength.

YIELD & PACKAGING:
CONCRETE MIX is available in 60-lb (27-kg) bags. One 60-lb (27-kg) bag of CONCRETE MIX will yield approximately 0.5 cubic feet.

SHELF LIFE:
One year when stored in cool, dry conditions, out of direct sunlight.

USER RESPONSIBILITY:
Before using Rapid Set products, read current technical data sheet, bulletins, product label and material safety data sheet at www.ctscement.com. It is the user's responsibility to review instructions and warnings for any Rapid Set product in current technical data sheet, bulletins, product label and material safety data sheet prior to use.

WARNING: DO NOT BREATHE DUST. AVOID CONTACT WITH SKIN AND EYES.
Use material in well-ventilated areas only. Exposure to cement dust may irritate eyes, nose, throat, and the upper respiratory system/lungs. Silica exposure by inhalation may result in the development of lung injuries and pulmonary diseases, including silicosis and lung cancer. Seek medical treatment if you experience difficulty breathing while using this product. The use of a NIOSH/MSHA-approved respirator (P-, N- or R-95) is recommended to minimize inhalation of cement dust. Eat and drink only in dust-free areas to avoid ingesting cement dust. Skin contact with dry material or wet mixtures may result in moderate irritation to thickening/cracking of skin to severe skin damage from chemical burns. If irritation or burning occurs, seek medical treatment. Protect eyes with goggles or safety glasses with side shields. Cover skin with protective clothing. Use chemical resistant gloves and waterproof boots. In case of skin contact with cement dust, immediately wash off dust with soap and water to avoid skin damage. Wash skin areas exposed to wet concrete with cold, running water as soon as possible. In case of eye contact with cement dust, flush immediately and repeatedly with clean water and consult a physician. If wet concrete splashes into eyes, rinse eyes with clean water for at least 15 minutes and go to the hospital for further treatment.

PROPOSITION 65 WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

Please refer to the MSDS and www.ctscement.com for additional safety information regarding this material.

LIMITED WARRANTY:
CTS CEMENT MANUFACTURING CORP. (CTS) warrants its materials to be of good quality and at its option, within one year from date of sale, will replace material proven defective or refund purchase price thereof, and such replacement or refund shall be the limit of CTS's responsibility. Except for the foregoing, all warranties expressed or implied, including merchantability and fitness for a particular purpose, are excluded. CTS shall not be liable for any consequential, incidental, or special damages arising directly or indirectly from the use of the materials.

PHYSICAL DATA

Set Time, ASTM C-191 Mod.**	
Initial set	20 minutes
Final set	35 minutes
Compressive Strength, ASTM C39 Mod.**	
1 hour*	3000 psi
3 hours	3600 psi
1 day	4500 psi
7 days	5500 psi
28 days	6000 psi
Slant Shear Bond Strength, ASTM C882 Mod.**	
1 day	1200 psi
28 days	2200 psi
Splitting Tensile, ASTM C496 Mod.**	
7 days	600 psi
28 days	700 psi
Flexural Strength, ASTM C78 Mod.**	
7 days	500 psi
28 days	550 psi
Length Change, ASTM C157 Mod. (max)**	
28 days in air	-0.04
28 days in water	0.02

*After final set
**Data obtained at 4" slump by ASTM C143 at 70°F (21°C)

www.ctscement.com

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

John F. Rushing, Anthony J. Falls, and Craig A. Rutland

5d. PROJECT NUMBER
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5e. TASK NUMBER

5f. WORK UNIT NUMBER
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Geotechnical and Structures Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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14. ABSTRACT

The U.S. Army Engineer Research and Development Center evaluated tools and procedures for removing small surface irregularities in airfield pavement repairs that cause unacceptable roughness for aircraft. A desirable tool could grind pavement surfaces smooth and flush. A Flatliner cold planer skid steer attachment was identified as a potential device and was used in a field evaluation. The field evaluation considered production rate, smoothness of the treated pavement, and tooth wear for airfield pavement repairs made on Portland cement concrete, rapid-setting cementitious concrete, and asphalt concrete mixtures.

15. SUBJECT TERMS
Airfield damage repair
Cold planer
Skid steer attachment
Pavement roughness

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER *(include area code)***
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		81	