ERDC/GSL TR-19-39

Geotechnical and Structures Laboratory

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U.S. Air Force Rapid Airfield Damage Repair (RADR) Program

Development of an Integrated Pavement Screed for Screeding Asphalt or Concrete Crater Repairs

Ben C. Cox and Nolan R. Hoffman

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Final report

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Abstract

An important task in the rapid airfield damage recovery (RADR) crater repair process is screeding the capping material, which may be either hot mix asphalt or rapid-setting concrete. The repaired surface must meet roughness quality check (RQC) requirements of ±0.75 in. to prevent fighter aircraft damage. Currently, the screeds recommended to meet RQC criteria for concrete repairs are cumbersome, slow, and require three or more personnel. Additionally, no screed has been identified to enable proper asphalt repairs. This project's objective was to evaluate prototype screeds (two asphalt, two concrete) and propose a single integrated screed for screeding either material to assist the RADR program in its efforts to develop lighter, leaner equipment. The new screed must also reduce manpower requirements, be less cumbersome to operate, and be able to perform small and large crater repairs.

All four prototype screeds evaluated within the scope of this study reduced manpower and created a satisfactory surface finish when properly employed. Key differences affecting results were screed board shape and the ability to control the grade of the screed. Ultimately, the telehandler-powered Autoskreed was selected as the most promising system because both asphalt and concrete screeding activities could be integrated into a single device. Additional attachments were designed and tested, and a final integrated screed design is presented in this report that satisfies the project's objectives.

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Preface

This study was conducted for the U.S. Air Force Civil Engineer Center (AFCEC), Tyndall Air Force Base, FL. The program manager was Dr. Robert Diltz of AFCEC. Mr. Jeb S. Tingle provided technical oversight of the project for ERDC.

The work was performed by the Airfields and Pavements Branch (GMA) of the Engineering Systems and Materials Division (GM), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Dr. Timothy W. Rushing was Chief, CEERD-GMA; Mr. Jeffrey G. Averett was Acting Chief, CEERD-GM; and Ms. Pamela G. Kinnebrew, CEERD-GZT, was Technical Director for Military Engineering. Mr. Charles W. Ertle II was Deputy Director, ERDC-GSL, and Mr. Bartley P. Durst was Director.

COL Ivan P. Beckman was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	0.1336	cubic feet
inches	0.0254	meters
miles per hour	0.44704	meters per second
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

1.1 Background

Rapid airfield damage recovery (RADR) includes recovery activities in response to an airbase attack to re-establish safe aircraft operations. Completing repairs in an expedient manner is key. Further, those repairs must utilize suitable materials, equipment, and construction techniques to reduce the need for subsequent repairs to maintain an operable pavement surface. The present U.S. Air Force (USAF) RADR program has a specific focus on lighter and leaner equipment, materials, and tactics. Pieces of equipment that are smaller (more easily deployable), more versatile (able to perform the role of and replace multiple pieces of equipment), or require fewer personnel to operate are examples of lighter, leaner equipment.

The screeding of material used to cap crater repairs (i.e., hot mix asphalt or rapid-setting concrete) is an important task in the ADR process since it determines the aircraft ride surface quality. The repair surface must meet roughness quality check (RQC) requirements of ±0.75 in. to be considered a flush repair to prevent damage to fighter aircraft (USAF 1992). For rapid-setting concrete, the concrete screeds used previously can consistently meet the RQC criteria; however, they require three personnel to operate effectively and have been described as cumbersome during after action reviews (AARs) in previous troop demonstrations (Carruth 2019). For asphalt, there is no currently established screed; the existing method utilizes a front end loader (FEL) to both place and strike off asphalt. This has been adequate, though not ideal, for small repairs (e.g., 8.5-ft square) but not for large repairs (e.g., 30-ft square).

1.2 Objectives and scope

The overall objective of this project was to propose a single, integrated screed device that meets the following criteria.

1. It can be operated by 2 persons (1 person is preferred).
2. It can perform larger repairs up to 15 ft in width in addition to small 8.5-ft repairs in less than 6 min.
3. It is universal to both rapid-setting concrete (RSC) and hot mix asphalt concrete (AC) materials.

4. It is less cumbersome to operate than current screeds.
5. Preferably, it can be operated by a telehandler, since that is the projected prime mover for the screed.

Several screeds have been previously evaluated by the U.S. Army Engineer Research and Development Center (ERDC) and Applied Research Associates (ARA). ERDC has evaluated commercially available RSC screeds (Carruth 2019), and ARA has evaluated AC screeds[1]. As a result of the study presented by Carruth (2019), two new RSC screed prototypes were fabricated and evaluated herein. This report considers several of the previously evaluated screed options alongside the two new prototypes. Modifications of these existing and prototype screeds were investigated in order to integrate both RSC and AC screeding abilities into a single device.

The objective of this project was accomplished through full-scale field testing at ERDC of small and large crater repairs with both RSC and AC. The preferred screed was included in a troop demonstration at the Silver Flag Exercise Site at Tyndall AFB, FL. This project was conducted from January to December 2017 with the troop demonstration occurring in August 2017.

1.3 Outline of chapters

Chapter 2 describes the experimental program utilized in this project. Chapter 3 presents ERDC screed test results. Chapter 4 discusses screed integration efforts. Chapter 5 discusses findings from the troop demonstration. Chapter 6 presents a final screed design recommendation based on work conducted in this project. Chapter 7 presents the conclusions and recommendations.

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[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

2 Experimental Program

2.1 Materials tested

2.1.1 Rapid-setting flowable fill

Rapid-setting flowable fill (FF) is a highly fluid mixture of cement, fine aggregate, and water that uses rapid-setting cement to quickly gain strength. Key advantages are that it is flowable, self-leveling, and self-consolidating. CTS Flowable Fill (Mil. Spec.) manufactured by the CTS Cement Manufacturing Corp. was used as the backfill, or base, material for AC and RSC repairs.

The CTS flowable fill tested in this project was the second batch of material supplied by CTS (denoted FF-CTS-2) during the process of formulating a product following military specification MIL-DTL-32527 that details requirements for rapid-setting flowable fill backfill materials (Table 2.1). The first batch of CTS flowable fill was evaluated in Cox and Carr (2018) and exhibited excessive strengths (ranging from 2,000 to 2,750 psi at 28 days). After reformulating their material, CTS provided FF-CTS-2 in 3,000-lb supersacks (approximately 1 yd^3) for further evaluation.

Table 2.1. MIL-DTL-32527 flowable fill performance specifications.

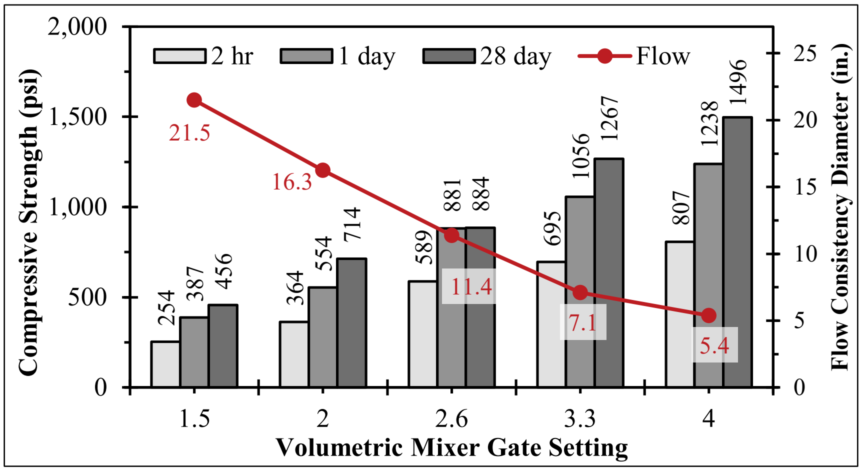
Test	Test Method	Placement Method	Criteria
Compressive Strength	ASTM D4832 (2016b)	Wet	≥ 750 psi at 28 days
		Dry	≥ 500 psi at 28 days
Initial Hardening	ASTM D6024/D6024M (2016c)	n/a	≤ 30 minutes
Segregation	ASTM C1610/C1610M (2017a)	Wet	< 5%
Linear Shrinkage	ASTM C426 (2016a)	Wet	< 2%

This project presented the opportunity to evaluate FF-CTS-2 since a crater backfill was required but its characteristics were not pertinent to the project so long as they were reasonably representative of typical FF backfills (typically Buzzi Unicem Utility Fill 1-Step 750 is used). During test site preparation described in Section 2.2.1, FF-CTS-2 was placed using the 7-yd^3 simplified volumetric mixer (SVM_7) described in Section 2.3.1.3.

During field placement with the SVM_7, FF-CTS-2 samples were also obtained from the mixer's chute at various water-cement (*w/c*) ratios for testing. Cylinders were cast for ASTM C39 (2018) compressive strength testing (three replicates), and ASTM D6103 (2017b) flow consistency tests were conducted (two replicates). These two tests represented a simplified screening method relative to the testing in Cox and Carr (2018) and were chosen primarily to assess flowability and strength in a balanced manner.

Figure 2.1 provides results from these tests for various SVM_7 gate settings (i.e., various *w/c* ratios). A gate setting of 2.6 was found to provide a consistency typically encountered when placing FF with the SVM_7. Minimum and maximum gate settings were chosen by adjusting the gate to where the FF was at the outer limits of being too wet or too dry to place.

Figure 2.1. Compressive strength and flow consistency of FF-CTS-2.



Note that gate settings in Figure 2.1 (i.e., 1.5 to 4) do not align with typical FF gate settings (i.e., 5.5 to 6.5). This was because the SVM_7 gate setting dial was repositioned during manufacturer servicing just prior to this test, which was not realized until during the test. Visually, the gate setting of 2.6 produced FF consistencies very similar to normal, and FF-CTS-2 yielded 28-day compressive strengths meeting the 750 psi requirement from Table 2.1. The SVM_7 gate issue is described further in Section 2.3.1.3.

2.1.2 Rapid-setting concrete

CTS Rapid Set® Concrete Mix (RSC) is a proprietary, pre-blended, rapid-setting concrete material that is used extensively in ADR operations for capping craters. Desirable attributes of RSC in the context of ADR are its fast set time (10 to 20 min) and its high early strength and load carrying capacity after only 2 hr of curing. RSC contains CTS's proprietary Rapid Set® Cement as well as 3/8-in. maximum size pea gravel. Military specification MIL-DTL-32526 governs requirements for rapid-setting concrete capping materials. RSC was acquired in 3,000-lb supersacks.

2.1.3 Hot mix asphalt

AC was obtained from a local supplier, APAC Mississippi, from either the Jackson, MS, plant or the Vicksburg, MS, plant. Throughout the project, three mixtures were tested (Table 2.2). These mixtures are defined as AC1 to AC3 herein.

AC1 (SC-1 Type 8) was a 75-blow Marshall-designed mixture while AC2 and AC3 were Superpave-designed mixtures. Mississippi Department of Transportation (MDOT) designations ST and MT refer to standard traffic and medium traffic based on the design compactive effort. For this project, properties of each mixture were not of great interest as long as the mixtures tested reasonably represented typical asphalt mixtures.

Multiple mixtures were tested rather than a single mixture because mixture properties were not critical to screeding operations. Taking this approach allowed AC to be obtained from the plant at any time rather than waiting for testing days in which the plant was producing the same mixture (the quantities of AC obtained on any given day for this project's testing were not enough for the plant to justify producing a single mixture solely for this project).

Table 2.2. Hot mix asphalt concrete mix design properties.

		AC1	AC2	AC3
Mix Designation		**SC-1 Type 8**	**ST 9.5 mm**	**MT 12.5 mm**
Design Compaction Effort		75 Blow	50 N_{des}	65 N_{des}
NMAS (mm)		9.5	9.5	12.5
Percent Passing (%)	1.0 in. / 25.0 mm	100	100	100
	3/4 in. / 19.0 mm	100	100	100
	1/2 in. / 12.5 mm	100	100	95
	3.8 in. / 9.5 mm	96	94	88
	#4 / 4.75 mm	70	64	64
	#8 / 2.36 mm	47	40	44
	#16 / 1.18 mm	35	29	33
	#30 / 0.60 mm	26	21	25
	#50 / 0.30 mm	11	10	12
	#100 / 0.15 mm	7	7	8
	#200 / 0.075 mm	4.9	4.9	5.4
3/4 in. Crushed Gravel (%)		0	0	40
1/2 in. Crushed Gravel (%)		40	62	22
#89 Limestone (%)		10	0	0
#11 Limestone (%)		20	7	7
Coarse Sand (%)		15	10	10
RAP (%)		15	20	20
Hydrated Lime (%)		0	1	1
P_{AC} (%)		6.1	5.9	5.4
$P_{ba,\,mix}$ (%)		0.34	0.78	0.89
P_{be} (%)		5.76	5.12	4.51
G_{sa}		2.669	2.646	2.647
G_{sb}		2.563	2.547	2.540
G_{se}		2.609	2.600	2.600
G_{mm}		2.386	2.385	2.403
VMA		16.1	15.4	14.1
VFA		75.2	74.0	71.6
D/B Ratio		0.85	0.97	1.20
TSR (%)		---	91.5	91.1
Stability (lbs)		2209	---	---

-- NMAS = nominal maximum aggregate size

-- P_{AC} = asphalt binder content

-- P_{be} = effective asphalt binder content

-- G_{sb} = aggregate bulk specific gravity (g/cm^3)

-- G_{mm} = mixture maximum specific gravity (g/cm^3)

-- VFA = voids filled with asphalt

-- TSR = tensile strength ratio

-- RAP = reclaimed asphalt pavement

-- $P_{ba,\,mix}$ = absorbed asphalt content, mix mass basis

-- G_{sa} = aggregate apparent specific gravity (g/cm^3)

-- G_{se} = aggregate effective specific gravity (g/cm^3)

-- VMA = voids in mineral aggregate

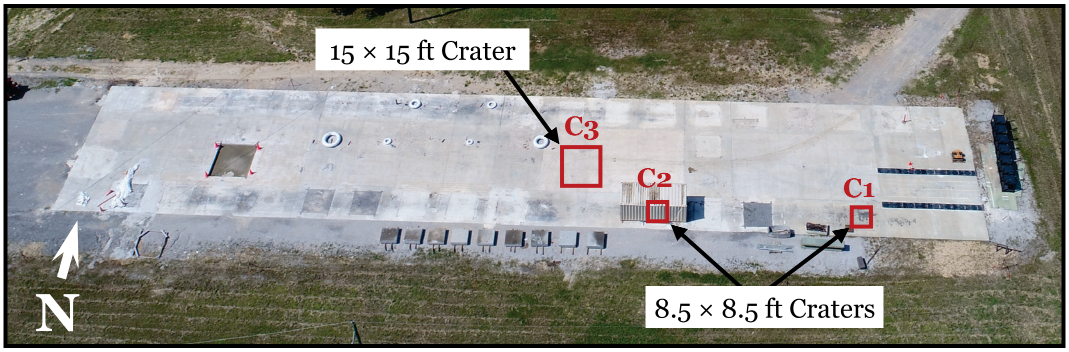
-- D/B Ratio = ratio of dust to effective binder content

2.2 Field test sites

2.2.1 ERDC Outdoor Pavement Test Facility

Most testing conducted in this report occurred at the ERDC Outdoor Pavement Test Facility, Vicksburg. There are several test sections at this facility; the test section selected for this project is shown in Figure 2.2. It is a 50-ft by 285-ft concrete test section composed of 12.5-ft by 15-ft slabs with concrete thicknesses ranging from 11 to 13 in.

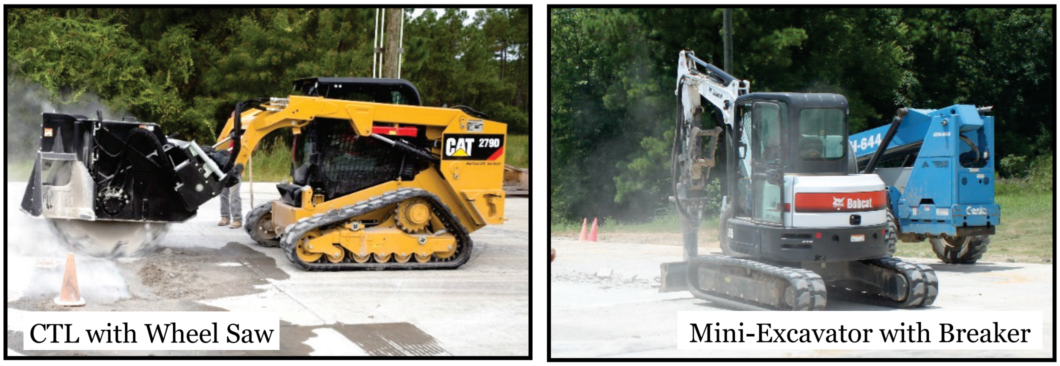
Figure 2.2. Aerial view of the ERDC test section.



Three test craters, two small 8.5-ft by 8.5-ft craters and one large 15-ft by 15-ft crater, were constructed at the ERDC test section and are shown as C1 to C3 in Figure 2.2. These three craters were reused for successive repairs (after a series of repairs, the repairs were excavated, and the test craters were reused for the next repair series). Note that typical dimensions of a large crater are 30 ft by 30 ft; however, repairs of a large crater with RSC are traditionally conducted by forming the large crater into four 15-ft by 15-ft quadrants. Therefore, a 15-ft by 15-ft crater is all that is needed to simulate a large crater repair with respect to screeding. With AC repairs, a 30-ft by 30-ft crater would typically be repaired in three 10-ft wide lanes. The 15-ft by 15-ft crater was large enough to pave two 7.5-ft wide lanes and approximate typical screeding practices.

The test craters were produced from intact slabs as illustrated in Figure 2.3. Markings either 8.5- or 15-ft square were painted on the slabs and then saw-cut using a compact track loader (CTL) and CTL wheel saw. Concrete within the cuts was then broken and removed using a mini-excavator with breaker head and bucket attachments. Each crater was then excavated to a depth of 24 in. prior to backfilling.

Figure 2.3. Producing test craters.



As shown in Figure 2.4, each crater was backfilled with 20 in. of FF-CTS-2 using the SVM so that the remaining depth of each crater was 4 in. Strips of 0.75-in. plywood were clamped to a magnesium straight bar such that the straight bar could be dragged across the concrete surface and the plywood would strike off the FF-CTS-2 at the 4-in. depth.

Figure 2.4. Placing FF-CTS-2 backfill in test craters.

A backfill thickness of 20 in. is extremely conservative from a structural perspective but was selected to provide a foundation that could withstand repeated use of the test craters with each repair series. The 4-in. test crater depth was selected primarily to accommodate AC repairs. Standard practice according to the RADR interim tactics, techniques, and procedures (TTPs) outlined in *Interim Process for Rapid Airfield Damage Repair, Revision 11.2* (2018) is to place a single lift of AC that is 4 in. thick. For RSC, the typical cap thickness is 10 in. However, these craters were not subjected to load testing but were only evaluated for finish characteristics; therefore, a 4-in. cap was deemed reasonable and allowed the same test craters to be used for both AC and RSC repairs, while also providing an RSC material savings.

Figure 2.5a shows one of the final prepared test craters ready for capping. Prior to capping, crater depths were measured according to a 1-ft grid as shown in Figure 2.5b. Table 2.3 provides crater depth data.

Figure 2.5. Prepared test craters.

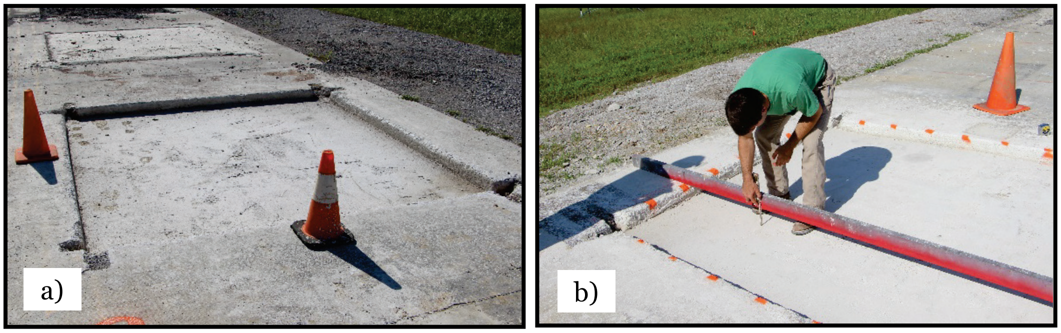


Table 2.3. Measured depths of test craters.

	C1	C2	C3
Avg Depth (in.)	4.2	4.2	4.2
St. Dev. (in.)	0.13	0.11	0.15
COV (%)	3.1	2.6	3.6
Min. Depth (in.)	4.0	3.9	3.6
Max. Depth (in.)	4.5	4.4	4.5

-- St. Dev. = standard deviation *-- COV = coefficient of variation*

2.2.2 Silver Flag Exercise Site

One of the screeds tested in this project was used during a troop demonstration of RADR equipment at the Silver Flag Exercise Site (referred to hereafter as Silver Flag) at Tyndall Air Force Base, FL, in September 2017. Work was conducted on the south end of the runway with the south connecting taxiway being used as a storage and staging area for equipment and materials. The work conducted during the RADR demonstration is primarily described in Bell et al. (2019), and only information pertinent to the pavement screed is discussed in this report.

2.3 Equipment and screeds

2.3.1 Equipment

Various pieces of heavy equipment were used throughout this project. This equipment either belonged to ERDC, was rented for the project, or was borrowed from Silver Flag's equipment fleet during the RADR demonstration.

2.3.1.1 Compact track loader

Figure 2.6 shows a Caterpillar 279C CTL, or skid steer, which was used primarily during AC repairs to charge the crater with AC from the stockpile. It was also frequently used for cleanup tasks. These CTLs are rubber-tracked machines with high-flow hydraulics and quick-connect fittings that are used extensively in modernized ADR processes because they are versatile and efficient for many purposes. While there are many CTL attachments that may be used during RADR operations, the only attachment used in this project was a bucket attachment.

Figure 2.6. Caterpillar 279C compact track loader.

2.3.1.2 Telehandlers

Figure 2.7 shows three telehandlers that were utilized during this project; Table 2.4 provides key specifications. The Genie GTH-644 was used solely to move supersacks of RSC and load them into the SVM. The Caterpillar TL1055C was used for all repairs conducted at the ERDC test section. The Genie GTH-1256 AF was used during the RADR demonstration and is the Air Force version of the GTH-1256, which has been fielded as a part of the USAF major repair kit. It should be noted that the GTH 1256 is a 12,000-lb capacity machine, while the GTH-1256 AF has a 10,000-lb capacity. A telehandler is the projected preferred prime mover for any screed attachments that are to be included in the RADR base recovery process.

Figure 2.7. Telehandlers.

Table 2.4. Telehandler specifications.

Specification	Genie GTH-644	CAT TL1055C	Genie GTH-1256 AF
Power (hp)	99	142	142
Max Travel Speed (mph)	17	20	15
Overall Height (ft)	8.92	8.42	8.92
Wheelbase (ft)	10.83	12.00	12.00
Operating Weight (lb)	21,480	34,160	39,394
Max Lift Height (ft)	44	55	56
Max Forward Reach (ft)	27	43	41
Max Lift Capacity (lb)	6,000	10,000	10,000
Max Load at Max Height (lb)	6,000	5,000	5,000
Max Load at Max Reach (lb)	2,000	2,500	2,000

2.3.1.3 Simplified volumetric mixers

Figure 2.8 shows the 7-yd^3 simplified volumetric mixer (denoted the SVM$_7$ herein) that is a tow-behind mixer designed by CemenTech Inc. with input from ERDC for the modernized ADR program. It is pre-calibrated for both rapid-setting flowable fill and concrete.

Figure 2.8. Simplified volumetric mixer (7 yd^3).

The SVM_7 is towed with a vehicle capable of pulling at least 20 tons (typically a dump truck). Key components of the SVM_7 are a single dry material hopper (approximately 7-yd^3 capacity), a conveyor belt feed system, a water pump to meter mix water at a fixed pump speed, two 200-gal water tanks, a washout tank, and a replaceable mixing auger mounted in a discharge boom at the rear of the mixer. The SVM_7 is also equipped with two retractable catwalk platforms, a bin entry platform, a replacement auger, and two supersack piercing points.

Material consistency (i.e., *w/c* ratio) is controlled by adjusting a strike-off gate that changes the thickness of dry material on the conveyer belt feeding the mixing auger. Gate settings range from 1 to 12. Raising the gate (i.e., increasing the gate setting) introduces more dry material to the mixing auger and, thus, lowers *w/c* ratio, and vice versa. Typical gate settings during production for rapid-setting flowable fill and concrete range from 4 to 8.

Note that, during equipment repairs and upgrades performed by the manufacturer prior to this work, the strike-off gate system was disassembled, serviced, and reassembled. When the gate was reassembled, the gate setting indicator dial was not aligned properly. This was discovered once the SVM_7 was loaded with material for backfilling the test craters, but the gate setting dial was not able to be reset until the SVM_7 was emptied. The gate setting offset was estimated to be about 3 (e.g., typical gate setting of 5.5 would be 2.5 on the incorrect gate setting dial). This issue was not of great concern to the project since gate settings are frequently adjusted during placements to adjust mixture consistency until it appears suitable visually; however, it means that exact gate settings were not able to be reported consistently through the project.

Figure 2.9 shows the 2-yd^3 simplified volumetric mixer (denoted SVM_2) that was designed as a lighter, leaner SVM_7 alternative for the RADR program. Operationally, it is nearly identical to the SVM_7 with the exception that its dry material hopper is approximately 2 yd^3.

Figure 2.9. Simplified volumetric mixer (2 yd^3).

2.3.1.4 Steel wheel rollers

Figure 2.10 shows two steel wheel rollers that were used in this project for compacting AC repairs; Table 2.5 provides roller specifications. A smaller 47-in. roller was rented for most of the work in this project as it is relatively similar to the roller supplied in the Sustainment Pavement Repair (SuPR) kit. A larger 59-in. roller was rented for one repair series as it was closer in size to that used in the original asphalt screed study.[1] It was used to compare any differences in compacted AC density and, consequently, roll-down factors necessary for AC.

Figure 2.10. Steel wheel roller compactors.

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[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Table 2.5. Steel wheel roller specifications.

Specification	CAT CB24B	CAT CB44B
Power (hp)	36	102
Operating Weight (lb)	6,003	18,056
Max Travel Speed (mph)	7.5	7.5
Wheelbase (in.)	71	130
Drum Diameter (in.)	28	44
Drum Width (in.)	47	59
Static Linear Load (lb/in.)	63	155
Min Centrifugal Force per Drum (lb)	3,282	6,744
Max Centrifugal Force per Drum (lb)	7,374	17,310
Nominal Amplitude – High (in.)	0.021	0.025

2.3.2 Screeds

Six screeds were used during this project: the simple strike off (SSO), the bucket strike off (BSO), a magnesium bar screed, the Wyco Screed King, the hydraulic-powered Autoskreed prototype (ASHyd), and the telehandler-powered Autoskreed prototype (ASTH). The SSO and BSO were originally designed to be asphalt screeds while all others were designed for concrete. Modifications were made to the ASTH to better suit it for AC repairs; these modifications are described in Chapter 4.

2.3.2.1 Simple Strike Off

The SSO (Figure 2.11) was designed and built by ARA during the original asphalt screed study.[1] As the name implies, it is a simple device composed of several easily obtainable steel shapes (e.g., L sections and rectangular tubing). The nominal width and height of the SSO screed blade is 11 ft and 1 ft-4 in., respectively. The screed blade is positioned at a 60° angle. The fork pockets are large to accommodate a variety of telehandlers; several bolts can be adjusted to take up play within the fork pockets. A chain and chain binder are used to secure the SSO to the fork carriage.

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[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

The screed blade strike off height (i.e., the grade height) is adjusted by raising or lowering jacks on either side that control skis on which the SSO rides. End gates are incorporated into the grade control skis to direct AC in front of the screed blade. Because the grade control skis and end gates are a single unit, the SSO has a fixed screeding width that is the full width of the SSO.

Figure 2.11. Simple Strike Off.

2.3.2.2 Bucket Strike Off

The BSO (Figure 2.12) is another asphalt screed also designed by ARA in cooperation with an external fabrication shop.[1] It consists of a custom long, shallow bucket that was modified to directly couple to a telehandler in place of the fork attachment. For this reason, a vertical float mechanism was incorporated that allows approximately 3 in. of vertical travel between the bucket and the telehandler boom. This was intended to provide some forgiveness to the operator and prevent the need for constant boom angle adjustments while extending the boom across the repair. The bucket was made as wide as possible while trying to minimize the volume of material it would hold, reducing the load on the telehandler. The bucket was nominally 11 ft wide by 1 ft-6 in. deep by 2 ft tall.

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[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 2.12. Bucket Strike Off.

Grade control skis on jacks were originally incorporated on each side of the BSO; however, they were insufficiently braced, bent during repair trials,[1] and removed. Adjustable end gates separate from the grade control skis were fabricated and clamped onto the leading edge of the BSO bucket. Like the BSO itself, these incorporated a vertical float feature. Being adjustable, the screeding width was variable from 0 to 11 ft.

2.3.2.3 Magnesium bar

The magnesium bar screed (Figure 2.13) is a simple concrete screed that has been used successfully in previous ADR demonstrations and is included in the USAF SuPR kit and ADR Tool Trailer. The standard bar for an 8.5-ft crater repair is 1.5 in. by 3.5 in. by 12 ft, weighing approximately 10 lb. Longer or shorter bars are also available. The bar is durable enough to resist warping after repeated use and light enough to be easily moved from repair to repair. It does not provide any vibration, and it can also be somewhat difficult to operate with larger repairs or concrete of a thicker consistency. The magnesium bar screed, also referred to as a mag bar, was used herein primarily as one benchmark for comparing other screeds.

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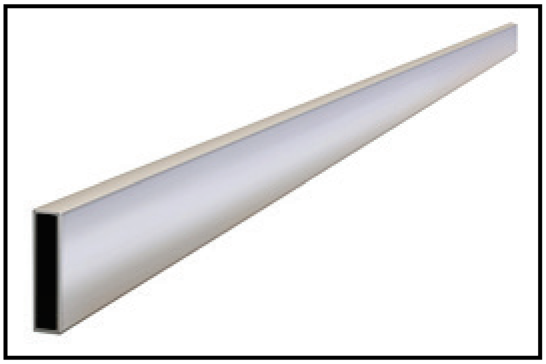
[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 2.13. Magnesium bar screed.



2.3.2.4 Wyco Screed King

The Wyco Screed King (Figure 2.14) is a manual vibratory concrete screed that has also been used in previous ADR demonstrations and is included in both the USAF SuPR kit and ADR Tool Trailer. The screed bar is intended to both strike off and float concrete at the same time while the motor provides vibration. The screed bar can be obtained in multiple widths, and a 10-ft bar was used herein. Similar to the magnesium bar, the Screed King was used as a second benchmark for comparing other screeds as the Screed King is currently the primary screed for ADR operations.

The Screed King requires the operator to walk through the repair to drag the screed across it. This can be somewhat cumbersome. The screed is relatively lightweight as well, which lends to its tendency to ride up over the repair material rather than striking it off. As a result, two additional operators are required to apply pressure to the ends of the screed bar in order to keep it in contact with the ground and maintain a flat repair. Otherwise, it is an economical screed that can be easily transported and has had satisfactory results in previous troop demonstrations.

Figure 2.14. Wyco Screed King.

2.3.2.5 Hydraulic Autoskreed

The hydraulic Autoskreed (ASHyd) (Figure 2.15) is a self-contained concrete screed that was designed and built by Nasby Fabrication based on a similar CTL attachment they built and demonstrated to ERDC previously as described in Carruth (2019). One recommendation provided to Nasby as a result of the Carruth (2019) testing was to remove several of the more technologically advanced features of their CTL version such as laser leveling systems. Another recommendation was to do away with a CTL as the platform vehicle; otherwise, one CTL in the RADR process would need to be solely dedicated to the Autoskreed as it required some time to attach/detach the Autoskreed from the CTL.

Figure 2.15. Hydraulic Autoskreed (ASHyd).

Nasby Fabrication developed two new Autoskreed models based on ERDC recommendations. The ASHyd discussed in this section is moved and positioned near a crater by a telehandler. Once positioned, the ASHyd operates independently using an onboard hydraulic power supply to extend the screed boom over the repair and electric jacks to raise or lower the screed board to the desired elevation. The hydraulic boom and the electric jacks are operated by a handheld remote, allowing the operator to act as his own spotter. It also has two 12 V electric vibrator motors to aid in consolidating and finishing the repair surface. Table 2.6 provides pertinent specifications of the ASHyd.

Table 2.6. ASHyd specifications.

Dimensions	
Overall Height (ft)	4.5
Overall Length (ft)	13.7
Overall Width w/out Screed Board (ft)	8.0
Screed Board Width (ft)	12.0 to 17.0 (with 2.5 ft extensions)
Controls	
Hydraulic Power Supply	Honda GX-690 Gasoline Motor, 24 HP, 13 Gal Hydraulic Tank, 7 Gal Fuel Tank
Grade Control	(2) 12 VDC Electric Jacks
Vibrators	(2) Vibco DC-500 Vibrators, 12 VDC, 4000 VPM, 450 lb force
Operation	Remote Controlled (hydraulic boom and grade control)

The ASHyd is built primarily of a tubular steel frame, and the screed board is made of 2- by 8-in. aluminum tubing to reduce weight, primarily to prevent any tipping issues when the boom is fully extended. The screed board has two fold-down extension wings that give it the capability to screed 8.5-ft small craters or 15-ft large craters (i.e., one quadrant of a formed 30-ft large crater). A 0.5- by 2-in. strip of Nylatron® (a self-lubricating, high-wear-resistant thermoplastic) was screwed to the bottom side of the screed board as a tough sacrificial part to protect the screed board.

2.3.2.6 Telehandler Autoskreed

The telehandler-powered Autoskreed (ASTH) (Figure 2.16) is the second model developed by Nasby Fabrication based on ERDC recommendations and is a simpler concrete screed relative to the ASHyd. Unlike the ASHyd that has its own hydraulics and boom, the ASTH utilizes the boom on a telehandler to extend over and screed a repair. The ASTH has no separate, onboard engines or hydraulics, which results in a lower maintenance screed solution. Table 2.7 provides pertinent ASTH specifications.

Figure 2.16. Telehandler Autoskreed (ASTH).

Table 2.7. ASTH specifications.

Dimensions	
Overall Height (ft)	5.5
Overall Length (ft)	6.5
Overall Width w/out Screed Board (ft)	8.0
Screed Board Width (ft)	12.0 to 17.0 (with 2.5 ft extensions)
Controls	
Vibrators	(2) Vibco DC-500 Vibrators, 12 VDC, 4000 VPM, 450 lb force
Screed Board Suspension	(2) Coilover Shocks, 140 lb/in.
Video Monitoring	Voyager WVOS541 Wireless 12 VDC Camera and Monitor

The ASTH is lifted by a telehandler via fork pockets, secured to the fork carriage, and then moved to a crater. The ASTH is set in contact with the pavement surface and leveled, which requires a combination of adjusting the ASTH leveling jacks and the telehandler fork tilt, boom angle, and possibly (though often unnecessary) the front stabilizer jacks.

Nasby Fabrication developed the ASTH around the Genie GTH-1256, to ensure both the ASTH and the telehandler boom could be level when the ASTH is at the screeding position. This prevents the telehandler forks (and ASTH) from climbing or diving as the boom is extended, which would occur if the boom is not level and require the operator to periodically adjust the boom angle. Nasby Fabrication used the GTH-1256 as their reference telehandler since it is commercially available and they were able to rent it for sizing and fitting the ASTH. It was later discovered that the GTH-1256 and GTH-1256 AF specifications, specifically dimensions, are not identical.

Because the ASTH could be subjected to greater vertical forces than the ASHyd due to the use of the telehandler, a spring-loaded suspension feature was incorporated into the ASTH. Initially, this was intended to make it easier for the ASTH screed board to glide over any pavement surface irregularities such as contraction joints. It was found that a better use of the spring system was to compress the springs slightly prior to screeding to provide a degree of forgiveness to the operator. If the telehandler boom was not perfectly level, any climbing or diving as the boom was extended could be visually monitored by whether the springs extended or further compressed, and the operator could adjust accordingly (e.g., before the screed climbed up enough that it was lifted off the pavement).

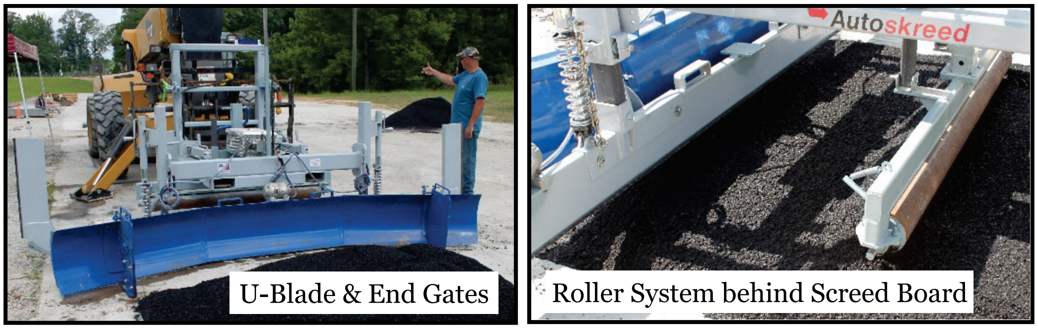
Like the ASHyd, the ASTH was equipped with two 12 V electric vibrator motors. For power, a cable runs from the ASTH and connects to the telehandler’s battery via alligator clips. The power cable is long and fitted with heavy-duty magnets at fixed intervals along its length that are used to attach the cable to each section of the telehandler’s telescoping boom. The power cable also has a small control box that sits in the telehandler cab so the operator can turn the vibrators on or off.

A 12 V camera, using the same telehandler-supplied power, was mounted above the front of the ASTH. A wireless receiver/monitor can be positioned in the operator’s cab. This was included with the ASTH in attempt to yield 1-man operation with the operator acting as his own spotter.

Overall, the ASTH is made of all steel tubing components, and the screed board is made of 2- by 8-in. steel tubing to resist the potentially greater stresses a telehandler may apply relative to those experienced by the ASHyd. The screed board dimensions are identical to that of the ASHyd. It also includes a sacrificial 0.5- by 2-in. strip of Nylatron® screwed to the bottom side of the screed board.

In an effort to adapt the ASTH for AC repairs as well, Nasby Fabrication built several additional attachments shown in Figure 2.17. These were a U-blade attachment that pinned onto the front of the ASTH screed board, two combination end gate and grade skis, and a roller system that was intended to allow the ASTH to effectively float across the screed AC at a consistent elevation.

Figure 2.17. ASTH asphalt attachments from Nasby Fabrication.



2.4 Crater repairs and screeding procedures

Repairs discussed in this section refer to repairs conducted by ERDC at the Outdoor Pavement Test Facility with both RSC and AC. RSC repairs were also conducted during the RADR demonstration at the Silver Flag site and are discussed in Chapter 5. Asphalt repairs were not included in the RADR demonstration. Table 2.8 summarizes the tests performed in this project.

Table 2.8. Screed test plan.

	RSC Repairs		AC Repairs		
Screed	Large Crater	Small Crater	Large Crater	Small Crater	Mix
SSO	1	2	1	2	AC3
BSO	1	2	1	2	AC1
ASHyd	1	2	—	2	AC1
ASTH	1	2	1	2	AC1
ASTH-Mod	—	—	1	1	AC2

– ASTH-Mod is the ASTH including modifications to improve asphalt screeding operations
– Number represents number of craters tested

2.4.1 Concrete repairs

All concrete repairs at the Outdoor Pavement Test Facility were conducted with RSC placed with the SVM7. Craters C1 to C3 were repaired in succession to prevent excessive buildup of RSC inside the SVM_7. Citric acid is often used as a set retarder for RSC, but it was not used in this work.

The initial SVM_7 gate setting was 5.5. It was adjusted as necessary by the operator who was monitoring the RSC consistency; those changes were not recorded since strength properties were not of interest to this project. During the placement, technicians used concrete rakes to distribute RSC around the crater, building up material near the downhill side of the crater from which screeding would begin. Prior to beginning the placement or during the placement, the screed operator would position the screed on the downhill side of the crater.

Once the SVM_7 operator believed sufficient RSC had been placed, the screed operator began screeding with the assistance of a spotter. For most repairs, the screed operator was the telehandler operator since most of the screeds evaluated were telehandler attachments. For the ASHyd, the screed operator could function as his own spotter. Depending on the RSC consistency and the quality of the finish, one screed pass was often insufficient, and it was common to make multiple passes until the finish quality was acceptable or the RSC set to the point no more passes were possible without tearing the surface. The following subsections describe any procedural details specific to each screed (note these procedures were the initial operating procedures used or those prescribed by the manufacturer – any procedural improvements are discussed in Chapter 3 results).

Following screeding, the screed was used to push excess RSC several feet away from the repair so that it could be more easily cleaned. Excess RSC was cleaned up using shovels and a CTL with a bucket. Minor hand troweling was performed to clean the edges of the repair. Meanwhile, the screed was moved to a washout area to be cleaned with a pressure washer before preparing for the next repair.

2.4.1.1 Simple strike off

The SSO was tested with the grade control skis raised all the way up so that they were flush with the lower edge of the screed bar. The telehandler forks were leveled so that the grade control skis were level and in full contact with the parent slab. For the large crater, which was wider than the SSO, two passes were required (a left-hand and a right-hand); as a result, one grade control ski was riding on the parent slab while the other was unsupported inside the crater. This required the spotter and operator to frequently adjust the boom angle to attempt to keep the screed on grade.

2.4.1.2 Bucket strike off

The BSO was tested by resting the blade of the BSO bucket on the parent slab. The bucket was angled so that the blade of the bucket was parallel with the parent slab. Techniques for when the BSO was used for large crater repairs were similar to the SSO because it was not wide enough to span the entire crater.

2.4.1.3 Hydraulic Autoskreed

Using the remote control, the ASHyd operator first lowered the screed bar by extending the left and right jacks until it was in contact with the parent slab. The vibrators were then turned on, and the boom was extended to screed the repair. Once extended over the repair, the screed bar was raised and the boom retracted.

2.4.1.4 Telehandler Autoskreed

The ASTH required a considerable amount of leveling prior to screeding because the ASTH was designed to work properly when the telehandler was level from side-to-side, the telehandler boom was level, and the forks/ASTH was level with the screed bar resting on the parent slab. The purpose of this was to prevent the operator from needing to make adjustments to the boom angle when screeding. To assist leveling, the screed bar could be adjusted up or down either by detaching and reattaching the screed bar assembly to the screed frame at a different bolt position or by raising or lowering the jacks on the screed bar assembly.

Once level, the telehandler operator lowered the screed to the pavement and then several more inches to compress the preload travel springs to their midpoint (i.e., approximately 3 in.). The vibrators were then turned on, and the telehandler boom was extended to screed the repair.

2.4.2 Asphalt repairs

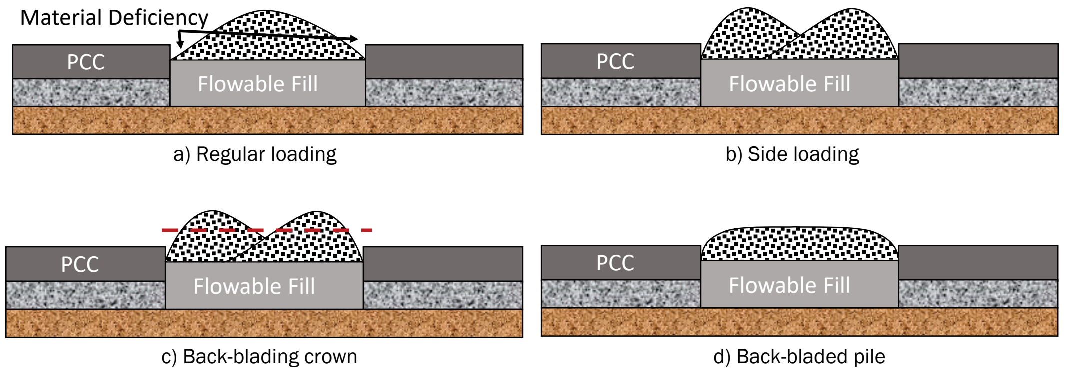
Asphalt mix type was not considered a critical variable in this project as it would likely have no meaningful effect on screeding operations. To maintain testing flexibility, the mix being produced at the nearest APAC

Mississippi plant on the day of testing was used. This approach led to three mixes (AC1 to AC3) being tested throughout the project.

Mix was delivered to the ERDC test section by a dump truck and dumped in a single pile on concrete. Loads were typically around 12 tons which was sufficient to repair two small and one large crater. Haul times were approximately 15 min from the APAC Vicksburg plant (AC1) or 60 min from the APAC Jackson plant (AC2 and AC3).

As soon as possible after mix delivery, a CTL with a bucket was used to transfer AC from the pile to the crater being repaired. Since none of the screeds being tested were equipped with augers for lateral AC distribution in front of the screed bar, the CTL operator side-loaded each bucket by scooping from the pile at an angle. By alternating loading the left and right sides of the bucket, AC was more evenly dispersed in the transverse direction when loading the crater. Immediately after a load was placed in the crater, it was back-bladed by angling the CTL bucket down and dragging it backwards across the crown of the pile (i.e., pre-strike-off). This was to further distribute AC as well as to prevent excess such that it would spill over the top of the screed bar during screeding. Figure 2.18 illustrates this process, and Figure 2.19 shows typical photographs.

Figure 2.18. Illustration of loading AC and performing pre-strike-off.



a) Regular loading

b) Side loading

c) Back-blading crown

d) Back-bladed pile

During AC placement, the screed was positioned near the crater with the screed set 1.5 in. above the parent slab surface so that the compacted AC surface would be flush with the parent slab. This 1.5-in. roll-down factor was found to be sufficient for a 4-in.-deep repair.[1] The CTL operator placed the first load of material near the screed, working away from the screed. Once the crater was approximately 60-70% filled with AC, screeding began. As with concrete repairs, asphalt repairs required a screed operator and a spotter. In many cases, one screed pass was sufficient; in some cases, multiple screed passes were needed. The following subsections describe any procedural details specific to each screed. Note these procedures were the initial operating procedures used or those prescribed by the manufacturer – any procedural improvements are discussed in Chapter 3 results.

Following screeding, the screed was used to push excess AC several feet away from the repair so that it could be more easily cleaned. Excess AC was cleaned up using shovels and a CTL bucket. Minor handwork was required to clean the edges of the repair and fold back AC with asphalt lutes to prepare for compaction.

Compaction began as soon as other equipment cleared the area and excess AC was removed. The roller pattern used[1] was used herein with minor modifications to accommodate the 47-in.-wide CAT CB24B roller (Figure 2.20). A small crater (8.5 ft wide) or one lane of a large crater (approximately 7.5 ft wide) was compacted in three compaction lanes. In each compaction lane, seven total passes were applied with a pass being defined as a pair of forward and backward passes. The first pass (initial) was half static and half vibratory; the next two (intermediate) were vibratory; and the final four (finish) were static. However, the initial pass was applied in all three compaction lanes before applying intermediate passes in compaction lane #1 as illustrated in Figure 2.20. Likewise, all intermediate passes were applied before any finish passes. When the CAT CB44B was used, only two compaction lanes were necessary, but compaction was otherwise identical. Figure 2.21 shows typical photos of compaction following the Figure 2.20 roller pattern.

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[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 2.19. Photos of loading AC and performing pre-strike-off.

a) Side-Loaded Bucket of AC

b) Placing 1st Bucket on Right Side

c) Back-blading 1st Bucket

d) Placing 2nd Bucket on Left Side

e) Back-blading 2nd Bucket

f) Loaded Crater Ready to Screed

Figure 2.20. AC roller pattern for CAT CB24B.

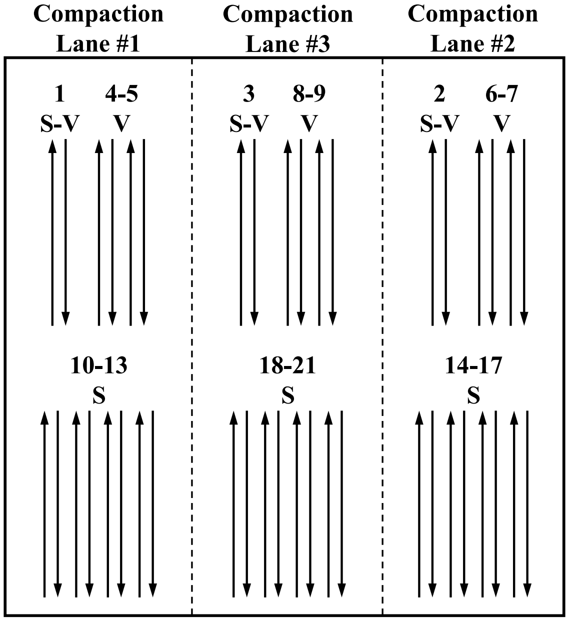


Figure 2.21. Photos of AC compaction with CAT CB24B.


a) Compaction Lane 1

b) Compaction Lane 2

c) Lane 3 to be Compacted

d) Finished Repair

2.4.2.1 Simple Strike Off

The SSO was tested with the grade control skis lowered such that the screed bar was 1.5 in. above the parent slab when the telehandler forks were level. The telehandler boom had to be angled considerably downward to place the SSO on the ground; consequently, the forks tended to dive as the boom was extended, and the operator occasionally had to raise the boom angle accordingly based on the spotter's guidance. For the large crater, as the SSO was extended into the crater, the inside grade control ski, which became unsupported inside the crater, was lowered to be in contact with the flowable fill base (i.e., the jack was set to approximately 5.5 in.). At the far side of the crater, the jack was raised back to 1.5 in. just before exiting the crater so that it would not cause the SSO to snag on the far crater edge.

2.4.2.2 Bucket Strike Off

The BSO, which did not have grade control skis, was set to the 1.5-in. grade height by laying 2x4 lumber on each side of the crater (Figure 2.22) and placing the BSO on top of the 2x4s. These 2x4s are further referred to as the grade blocks. The bucket was angled so that the blade of the bucket was parallel with the parent slab. Like the SSO, the telehandler boom had to be angled downward to place the BSO on the grade blocks, so the operator occasionally had to raise the boom angle based on the spotter's guidance. For the large crater, additional 2x4s were placed inside the crater to support the grade blocks.

Figure 2.22. Grade blocks.

2.4.2.3 Hydraulic Autoskreed

With the ASHyd, Nasby Fabrication expressed concern that screeding asphalt with a pushing motion could potentially bend the boom's hydraulic cylinders. Instead, their preference was to extend the boom beyond the repair, lower the screed bar to the 1.5-in. grade (using grade blocks), turn on the vibrators, and screed backwards with a pulling motion. The pulling motion required technicians to charge the crater with AC beginning on the side opposite the screed, which differed from normal practice. Also, instead of immediately lowering the screed bar to 1.5 in., screeding was performed in several incrementally lower passes of the screed to prevent straining the ASHyd. The ASHyd was not used to repair a large crater over concerns that it could not effectively move that much AC.

2.4.2.4 Telehandler Autoskreed

The ASTH was used in the normal pushing configuration. For AC repairs, the initial screed setup was to attach the U-blade, combination end gate and grade skis, and the roller system. The grade skis were fixed at a 1.5 in. height, and the roller system was placed on 1.5-in. starter sticks. The intended design was for the ASTH to be used in the exact same manner as when screeding concrete with the exception of the additional attachments. This approach did not work well and was eventually revised.

2.5 Screed assessments

Each screed was evaluated based on the following factors:

- Size, weight, and design simplicity and versatility
- User feedback from technicians
- Speed (i.e., number of screed passes possible)
- Finished repair quality
- Potential to be further modified to produce an integrated screed.

Finished repair quality was evaluated by visual inspection, surface profile measurements, and, in several cases with AC repairs, core samples (Figure 2.23). Key items of interest during visual inspection were extreme roughness issues, cracking for RSC repairs, evidence of segregation or tearing for AC repairs, and any other notable distress. Surface profiles were measured using a straightedge on a 2-ft grid for small craters or a 3-ft grid for large craters and were reported as deviation (in.) relative to the existing grade of the surrounding parent slab. Cores cut from AC repairs were dried in the lab for air void (V_a) determination following ASTM D6752 (ASTM 2017c) and D2041 (ASTM 2011) for bulk and maximum specific gravities, respectively. This was to verify that reasonable compaction was being achieved using the set roller pattern.

Figure 2.23. Repair evaluations.

3 Initial Screed Evaluation Results

3.1 Concrete repairs

The following sections describe evaluation results for each screed for concrete repairs. In general, concrete repairs were simpler than asphalt repairs because the material was to be screeded level with the surrounding pavement (i.e., no roll-down factor was required).

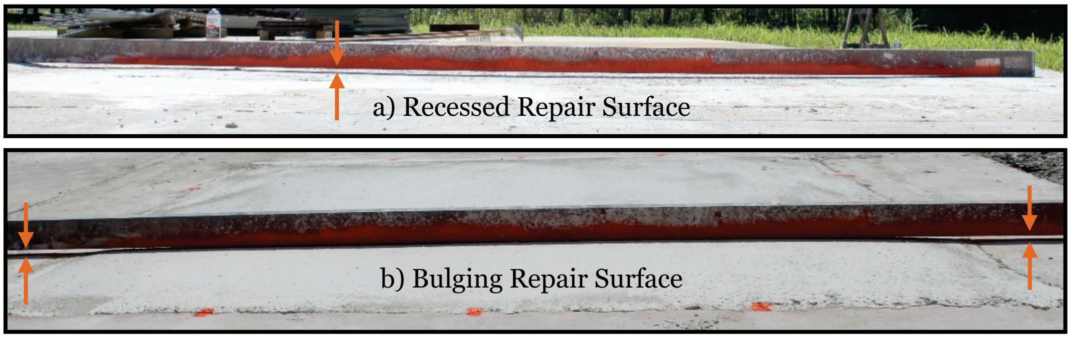
Table 3.1 provides a summary of the concrete repair surface profiles. Average elevation indicates the degree to which the repair surface was either recessed (negative values) relative to the surrounding pavement or bulging (positive values) as shown in Figure 3.1. Maximum difference (*MD*) is the elevation difference between the highest and lowest measurement points, providing an indication of repair smoothness using only the extreme measurements. Standard deviation (*SD*) provides a second indication of overall smoothness incorporating all measurements.

Table 3.1. Concrete crater repair profile data.

	SSO			BSO			ASHyd			ASTH		
Crater	Avg Elev.	Max Diff.	Std. Dev.	Avg Elev.	Max Diff.	Std. Dev.	Avg Elev.	Max Diff.	Std. Dev.	Avg Elev.	Max Diff.	Std. Dev.
C1	-0.44	0.38	0.12	-0.36	0.34	0.11	0.51	0.25	0.10	0.24	0.41	0.15
C2	-0.46	0.13	0.23	-0.34	0.38	0.14	0.28	0.69	0.23	-0.10	0.41	0.16
C3	-0.54	0.50	0.33	-0.07	1.68	0.47	-0.39	0.58	0.16	-0.24	0.70	0.26
Avg	**-0.48**	**0.34**	**0.22**	**-0.26**	**0.80**	**0.24**	**0.13**	**0.50**	**0.16**	**-0.04**	**0.50**	**0.19**

-- All units are in inches.

Figure 3.1. Illustration of recessed and bulging repair surfaces.



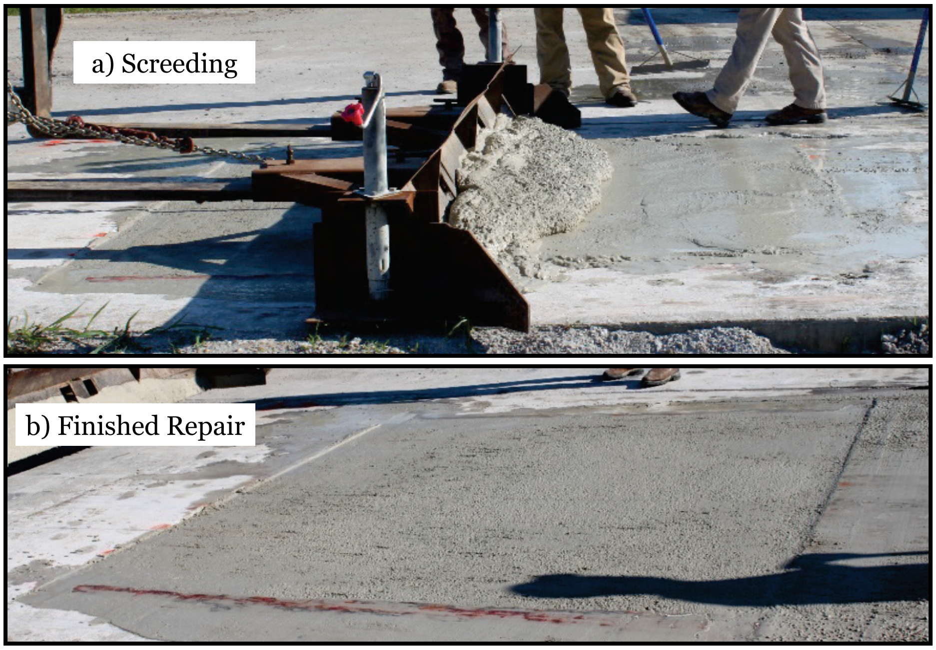
Detailed timing data was maintained throughout testing; however, screeding times were typically close and did not provide much additional insight. Small crater times were generally 0.5 to 2 min total for 1 to 3 passes. Large crater times were longer at 5 to 7 min total, but longer times were typically due mostly to other factors such as the SVM$_7$ and were not a reflection of the screed itself. Because all screeds demonstrated the ability to reasonably quickly screed repairs and the timing data did not add meaningful value, individual timing results are omitted.

3.1.1 Simple Strike Off

The SSO recorded an average elevation of -0.48 in., meaning the average surface of the three repairs was about 0.5 in. lower than the surrounding pavement. The *MD* between the extreme elevation points averaged 0.34 in., and *SD* among elevation points averaged 0.22 in. Both *MD* and *SD* were highest for crater C3.

Overall, the simplicity of the SSO made it easy to operate, and it worked very well for small repairs. Figure 3.2 shows the SSO in use on a small repair where the recessed characteristic of the finished surface is visible in Figure 3.2b. Otherwise, there were no issues of note.

Figure 3.2. Small crater RSC repair with the SSO.



For large craters, the SSO’s inability to span the width of the large crater was troublesome since the grade of the unsupported side had to be entirely controlled by the telehandler operator. It was nearly impossible to make the minute boom adjustments needed. As a result, the unsupported side of the SSO generally could not be kept level across the width of the repair, leaving a low spot in the middle of the repair (Figure 3.3a).

The RSC also begins setting before the entire crater can be filled. This meant screeding for the first pass (left-hand) was done in increments, several feet at a time, to try to screed RSC while it was workable. This was difficult at times though the most notable issue was when the right-hand pass was conducted and slightly overlapped the first. This resulted in a decent bit of tearing of the surface. Overall, the profile of the surface met RQC requirements and would most likely function adequately, but it was not a clean or visually appealing repair as seen in Figure 3.3b. Note that the SSO was the first screed tested, after which repairs were excavated to reuse the craters. In doing so, some edges of the craters were chipped.

Figure 3.3. Large crater RSC repair with the SSO.

3.1.2 Bucket Strike Off

The BSO recorded an average elevation of -0.26 in., meaning the average surface of the three repairs was about 0.25 in. lower than the surrounding pavement. The *MD* between the extreme elevation points averaged 0.80 in., and *SD* among elevation points averaged 0.24 in. Similar to before with the SSO, both *MD* and *SD* were highest for crater C3.

Overall, the BSO was also simple and easy to operate and performed similarly to the SSO for small repairs. Figure 3.4 shows a small repair with the BSO. In general, the BSO worked well, but the bucket retained a considerable amount of RSC (Figure 3.5) which increased cleanup efforts.

Figure 3.4. Small crater RSC repair with the BSO.


a) Screeding

b) Finished Repair

Figure 3.5. Excess RSC retained in BSO bucket requiring more cleaning.

Figure 3.6 shows the BSO screeding a large repair. As with the SSO, the large repair was difficult because the BSO did not span the entire repair width. Again, this required the operator to try to keep the BSO on a grade level with the parent slab, which was difficult and resulted in a very sloppy finished profile. Though the average elevation was suitable, *MD* exceeded the 0.75-in. RQC requirement because of the non-uniform surface. Note the uneven repair edge in Figure 3.6b; this was caused by the excavation and reuse of the crater and was not related to the BSO repair quality.

Because the large crater requires much more time to fill with RSC, screeding was done incrementally as before with the SSO. However, RSC began setting in the BSO bucket as well, which made final cleanup much more difficult. Pressure washing alone did not clean the screed adequately. Chipping hammers were needed to remove all the hardened RSC material.

Figure 3.6. Large crater RSC repair with the BSO.

3.1.3 Hydraulic Autoskreed

The ASHyd recorded an average elevation of 0.13 in., meaning the average surface of the three repairs was slightly above the surrounding pavement. The *MD* between the extreme elevation points averaged 0.50 in., and *SD* among elevation points averaged 0.16 in. Unlike the SSO and BSO, the profile of crater C3 was not discernably worse than the small repairs due to the full-width screed board.

The ASHyd worked well for small repairs. Figure 3.7 shows the ASHyd in use. The ASHyd was easy to operate as all functions could be controlled from the user's remote. For crater C2, the crater was overfilled with an excess of RSC to test the ability of the hydraulics to push a large amount of material, in which case it had no issue.

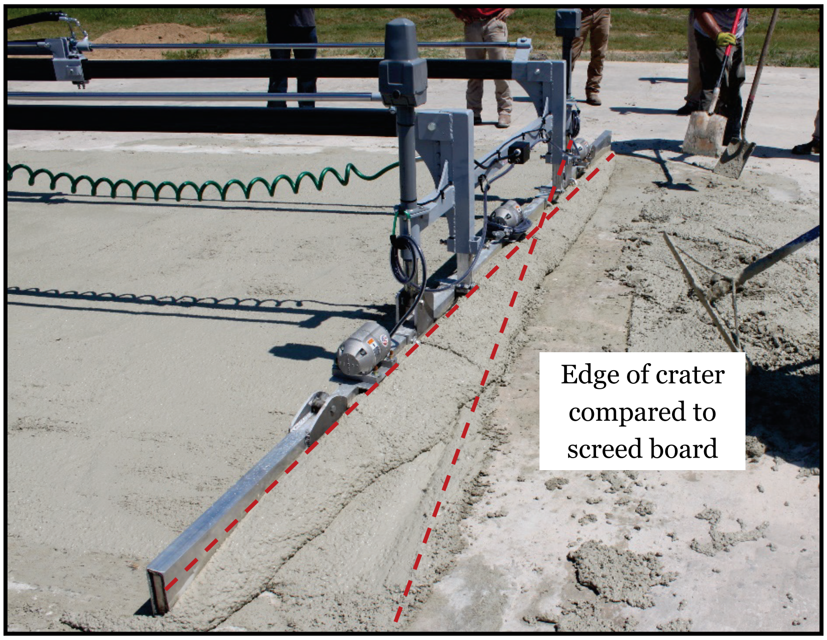
Figure 3.7. Small crater RSC repair with the ASHyd.

a) Screeding

b) Finished Repair

One detracting, though not prohibitive, aspect of the ASHyd is that the left and right hydraulic cylinders are connected via a hydraulic flow divider. As a result, if resistance on the two cylinders is unbalanced (e.g., more concrete is built up on one side of the screed than the other), flow will be diverted to the cylinder with less resistance. This causes the screed board to advance faster on one side (Figure 3.8). If it becomes too angled, the hydraulic booms can bind. The only solution once this began was to fully extend or retract the screed to realign both cylinders.

Figure 3.8. Angled ASHyd screed board.



The ASHyd worked significantly better for the large repair than the SSO and BSO due to its ability to span the entire crater width (Figure 3.9). Relative to the SSO and BSO, Table 3.1 profile measurements were noticeably improved as might be expected. In Figure 3.9b, some rough patches are noticeable in the far end of the repair. These were typically due to issues with the SVM_7, most commonly a backup in the auger that led to pockets of dry RSC. These dry areas tended to tear when screeded causing the rough appearance. Also in Figure 3.9b, the uneven crater edges caused by the excavation and reuse of the crater can be observed. This yielded unclean lines around the repair edges, but these were not related to the performance of the ASHyd.

Figure 3.9. Large crater RSC repair with the ASHyd.

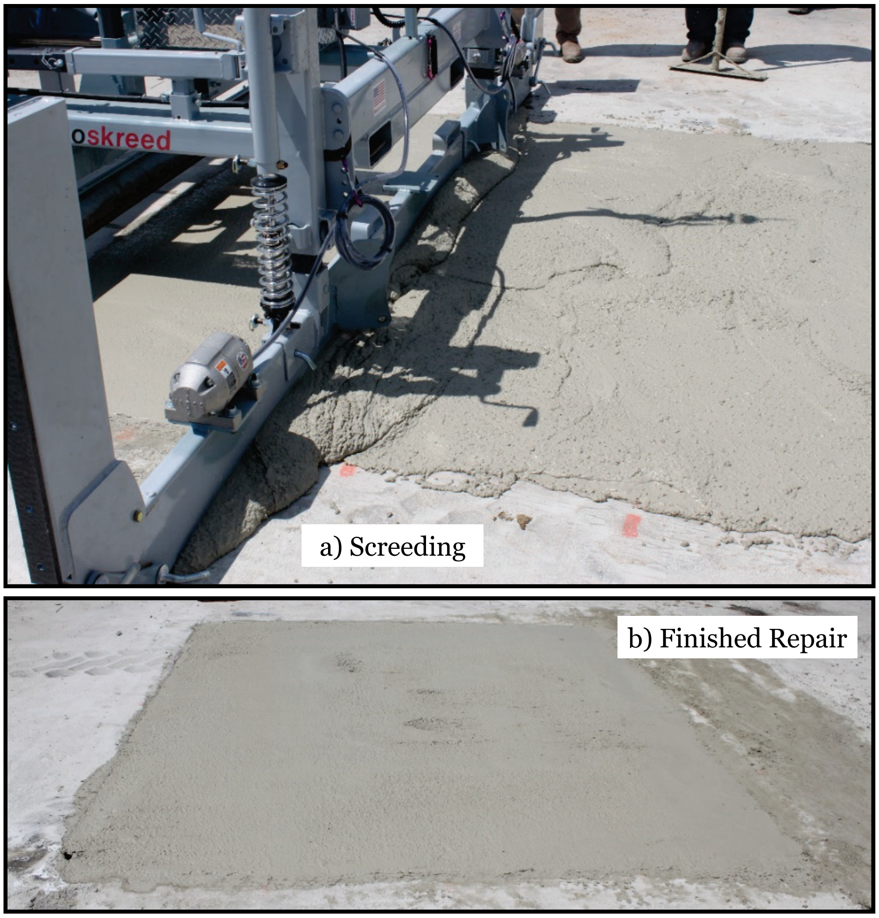
3.1.4 Telehandler Autoskreed

The ASTH recorded an average elevation of -0.04 in., meaning the average surface of the three repairs was slightly below the surrounding pavement. The *MD* between the extreme elevation points averaged 0.50 in., and *SD* among elevation points averaged 0.19 in. As with the ASHyd, the measurements for crater C3 were reasonably similar to those of the small repairs.

The ASTH performed well for small repairs. Figure 3.10 shows a small repair with the ASTH. No issues were encountered using the ASTH for small repairs.

Like the ASHyd, the ASTH worked well for the large repair because it could span the entire crater width. As with all large repairs in this project, the production rate of the SVM$_7$ was slow for the quick set time of the RSC, which was being placed without citric acid to retard the set time. Therefore, screeding was begun before the crater was filled to try to screed the first bit of RSC before it set. Four incremental, overlapping passes were made; this worked for the most part but did leave indentations in the surface where the ASTH screed was set back down as shown in Figure 3.11. This occurred because RSC would flow somewhat under the screed board, likely aided by the vibrators, and was also occurring with the small repairs. The difference between the small and large repairs was that the small repairs could be completely re-screeded with subsequent passes; whereas, screed passes on the large repair could only be partially overlapped to avoid potential tearing of the previously screeded RSC. These indentations resulted in slightly worse profile measurements in Table 3.1; however, RQC requirements were still easily met. The recommendation for future large repair screeding would be to screed continuously but slowly to prevent indentations caused by picking up and resetting the screed.

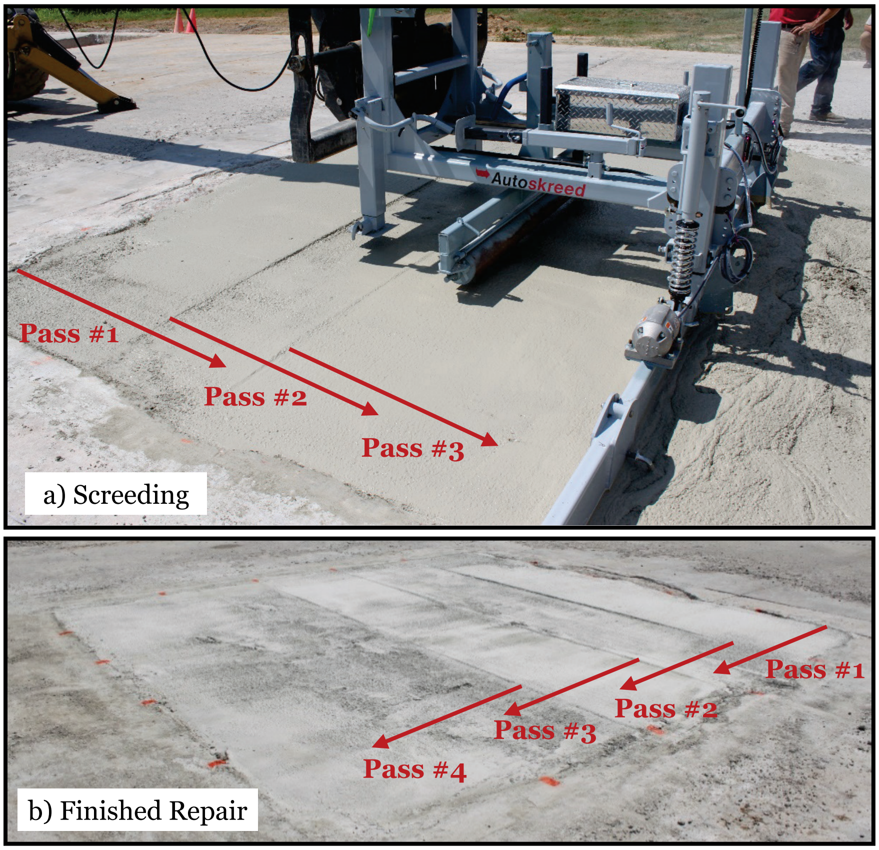
Figure 3.10. Small crater RSC repair with the ASTH.



a) Screeding

b) Finished Repair

Figure 3.11. Large crater RSC repair with the ASTH.



One of the only issues related to the ASTH itself was the difficulty in leveling it prior to screeding a repair. On some occasions, it was an iterative process that could take several minutes of adjusting the telehandler outriggers, boom angle, and fork angle. With the CAT TL1055C, it was also not possible to level the boom as Nasby Fabrication intended, which led to the practice of preloading the travel springs about 3 in. to ensure the ASTH remained in contact with the parent slab while screeding. Telehandler forks are designed to lift items and not to apply downward pressure, in which case they are free to rotate upwards. Therefore, applying downward pressure to preload the travel springs located at the end of the forks simply rolled the entire ASTH backward, which can be seen in Figure 3.11a. This could be avoided but required even greater effort by the operator to find the delicate balance in which the springs were compressed while also keeping the ASTH level. However, even when the ASTH was not level, its screeding ability did not seem to be negatively affected. For this reason, the pre-screeding leveling steps were essentially abandoned other than a quick effort to nominally level the screed by adjusting the fork tilt.

3.2 Asphalt repairs

The following sections describe the screed evaluation results for each of the screeds when placing asphalt in the three test craters. Table 3.2 provides a summary of the asphalt repair surface profiles. The same three metrics (average elevation, *MD*, and *SD*) described in Section 3.1 were used to evaluate the asphalt repairs.

Table 3.2. Asphalt crater repair profile data.

	SSO			BSO			ASHyd			ASTH		
Crater	Avg Elev.	Max Diff.	Std. Dev.	Avg Elev.	Max Diff.	Std. Dev.	Avg Elev.	Max Diff.	Std. Dev.	Avg Elev.	Max Diff.	Std. Dev.
C1	-0.24	0.38	0.38	-0.29	0.38	0.13	0.12	0.53	0.17	-0.46	0.75	0.23
C2	-0.07	0.75	0.13	-0.20	0.47	0.15	0.22	0.66	0.21	0.57	0.72	0.23
C3	-0.22	1.15	0.50	-0.28	1.30	0.33	-	-	-	0.64	0.90	0.25
Avg	**-0.18**	**0.76**	**0.34**	**-0.26**	**0.72**	**0.20**	**0.17**	**0.59**	**0.19**	**0.25**	**0.79**	**0.23**

-- All units are in inches.

Table 3.3 provides in-place density data for SSO and ASHyd repairs to assess whether adequate compaction was achieved with the selected roller pattern. Typical airfield V_a requirements for new construction range from 4 to 6% for full pay. The crater repairs exhibited sufficient compaction for RADR operations and even for normal construction, supporting the roller pattern as well as the roll-down factor of 1.5 in. per 4 in.

Table 3.3. Asphalt crater repair compacted density data.

	SSO		BSO		ASHyd		ASTH	
Crater	Avg V_a (%)	No. Cores	Avg V_a (%)	No. Cores	Avg V_a (%)	No. Cores	Avg V_a (%)	No. Cores
C1	5.8	3	—	—	6.1	3	—	—
C2	5.8	3	—	—	5.7	3	—	—
C3	6.1	5	—	—	—	—	4.9	6
Avg	**5.9**	—	—	—	**5.9**	—	**4.9**	—

– A minimum of one core was taken from each compaction lane in each repair.

– Asphalt repairs for the BSO and ASTH C1 and C2 were immediately followed by excavation and additional testing in which case the asphalt had not cooled sufficiently to be cored.

Detailed timing data was maintained throughout testing; however, screeding times were typically close and did not provide much additional insight. Small crater times were generally 0.5 to 2.5 min total for 1 to 2 passes but were as high as 5 min for the ASTH, which encountered issues as discussed in Section 3.2.4. Large crater times were longer at 4 to 7 min total. Because all screeds demonstrated the ability to reasonably quickly screed repairs and the timing data did not add meaningful value, individual timing results are omitted.

3.2.1 Simple Strike Off

The SSO recorded an average elevation of -0.18 in. for the three test crater repairs. The average *MD* was 0.76 in., and the *SD* averaged 0.34 in. The measures of overall smoothness (*MD* and *SD*) were worst for crater C3.

The SSO worked well overall for small repairs, providing a well-screeded surface. Figure 3.12 shows the SSO in use. Because the end gates are incorporated into the grade control skis and cannot be relocated to match the width of the crater, excess AC spilled to the outside of the repair during screeding as shown in Figure 3.13 and had to be removed with shovels and rakes before compaction. This could have been alleviated by decoupling the end gates and grade skis so that the end gates were adjustable. However, if the end gates were set at the edges of the crater, the telehandler would have to be perfectly aligned with the crater. Otherwise, the end gates would drift into or away from the crater edges as the screed was advanced. This scenario was also discussed in Pullen et al. (2016) where an emphasis was placed on aligning the telehandler with the crater.[1] For the 30-ft repairs in particular, this was not necessarily easy because a slight misalignment, that may not be visually apparent at first, would be magnified as the screed was extended. While it required more handwork to clean up the edges between screeding and rolling, it was felt in this project that this method may be an overall better solution than trying to exactly trim AC along the crater edges with end gates.

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[1] Pullen, A. B., C. L. Wilbur, C. Ishee, and J. Hall. 2016. Draft Report. *Rapid airfield damage repair asphalt concrete placement: Development of prototype asphalt concrete screeds*. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 3.12. Screeding small crater AC repair with the SSO.

Figure 3.14 shows a completed small crater repair. All repairs were very close in elevation to the surrounding pavement and were relatively smooth; however, after compaction, some dips and waviness were noticeable. Because the uncompacted repair surface (i.e., Figure 3.13b) was smooth, it was determined this waviness was a function of loading the AC into the crater. AC was more heavily consolidated in the areas where it was dropped from the CTL bucket and less consolidated in areas to which it was pushed either during back-blading or screeding. This was a recurring issue with all screeds and could be minimized by keeping the CTL bucket low and rolling the AC out rather than dropping it from height.

For the large crater repair, the SSO worked much better for asphalt than it did concrete because asphalt was placed in multiple lanes allowing the grade control jacks to be used. During the transitions into and out of the crater when the inside jack was lowered or raised, the SSO would sag and leave imperfections in the screeded surface as can be seen in Figure 3.15. For the most part, these dips rolled out during compaction and resulted in minor waviness relative to the AC loading issues mentioned previously.

Figure 3.13. Excess AC being removed around small crater edges.

a) Initial Shoveling

b) Final Raking

Figure 3.14. Completed small crater AC repair with the SSO.

Figure 3.15. Large crater imperfections from adjusting the SSO grade control skis.

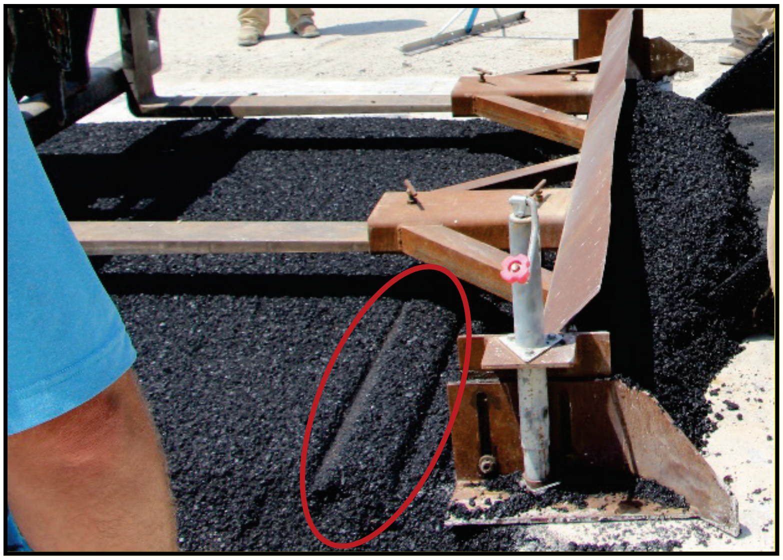


Figure 3.16 shows the inside edge of the first paving lane in the large repair. The SSO's inside end gate helped to form a clean, nearly vertical face, which greatly improved compaction. Some AC was wider than the end gate and was not redirected into the repair width as can be seen in Figure 3.16, but this was easily removed by shovel.

Figure 3.16. Inside face of first paving lane of large SSO repair.

Figure 3.17a shows the second large repair paving lane between screeding and compaction. Figure 3.17b shows the same lane after the first roller pass where waviness from improper loading with the CTL is noticeable. This waviness was not rolled out during compaction and likely led to the worsened profile measurements in Table 3.2.

Figure 3.17. Second paving lane of large SSO repair.

a) Uncompacted Second Lane

b) Waviness

Figure 3.18 shows the final large crater repair. Other than the waviness, there was a portion of the longitudinal joint between the two paving lanes that did not appear to be well-compacted. This was due mainly to a slight dip in the first paving lane such that the first paving lane was lower than the second. Overall, the large SSO repair did not satisfy RQC requirements based on *MD* (i.e. within-repair roughness). As noted before, the jagged repair edge was a result of the large crater being reused and chipped; it was not related to the SSO.

Figure 3.18. Completed large crater AC repair with the SSO.

3.2.2 Bucket Strike Off

The BSO recorded an average elevation of -0.26 in. for the three test crater repairs. The average *MD* was 0.72 in., and the *SD* averaged 0.20 in. As with the SSO, the measures of overall smoothness (*MD* and *SD*) were worst for crater C3.

The BSO worked well overall for small repairs, providing a well-screeded surface. Figure 3.19 shows the BSO in use. The biggest issue with the BSO was its lack of a grade control system, requiring the use of 2x4s to provide the roll-down factor. If placed directly at the crater edges, the 2x4s helped to some extent in the amount of AC cleanup required between screeding and compaction. It did not completely eliminate cleanup though. Another notable difference with the BSO is that it requires more AC be loaded into the crater to accommodate the amount that will fill the bucket. Cleanup of excess AC was required using shovels and rakes as with the SSO in Figure 3.13. Figure 3.20 shows a completed small crater AC repair.

Figure 3.19. Screeding small crater AC repair with the BSO.

Figure 3.20. Completed small crater AC repair with the BSO.

For the large repair, the BSO provided a final surface almost equivalent to the SSO; however, the entire screeding process was much clumsier as multiple 2x4 grade blocks were required (Figure 3.21). Also, excess AC remained in the bucket, meaning the BSO did not fill in low spots as well as other screeds. Overall, the large BSO repair did not satisfy RQC requirements based on *MD* (i.e., within-repair roughness).

Figure 3.21. Large crater AC repair with the BSO.

a) Screeding

b) Finished Repair

3.2.3 Hydraulic Autoskreed

The ASHyd recorded an average elevation of 0.17 in. for the two small crater repairs. The average *MD* was 0.59 in., and the *SD* averaged 0.19 in. Recall that the large repair was not attempted with the ASHyd for concern that it was not robust enough to handle the increased load of a larger amount of AC.

Figure 3.22 shows the ASHyd screeding a small repair. Once positioned, the screed worked quickly but struggled to move large amounts of AC. Instead, the ASHyd would begin riding up on the AC. To work around this issue, the repairs were screeded in multiple passes, incrementally lowering the screed board to the 1.5 in. height. As with the BSO, 2x4 grade blocks were used to provide the 1.5 in. reference. The incremental passes caused some waviness in the screeded surface as shown in Figure 3.23, but this was mostly rolled out during compaction. In contrast to all other screed testing in this project that pushed material away from the telehandler or ASHyd, AC was pulled towards the ASHyd as a precaution to prevent any potential bending of the hydraulic cylinders. Figure 3.24 shows a completed small crater repair.

Figure 3.22. Small crater AC repair with the ASHyd.

Figure 3.23. Waviness in screeded surface of ASHyd small crater AC repair.

Figure 3.24. Completed small crater AC repair with the ASHyd.

3.2.4 Telehandler Autoskreed

The ASTH recorded an average elevation of 0.25 in. for the two small crater repairs. The average *MD* was 0.79 in., and the *SD* averaged 0.23 in. The ASTH was used with the asphalt attachments supplied by Nasby Fabrication.

For small crater C1, the ASTH used the pin-on U-blade and end gates that doubled as grade control skis. Figure 3.25a shows the screed in position with the end gates set to match the crater width. Because of the inward angle of the end gates, they both drifted into the crater while screeding as shown in Figure 3.25b. This cut off part of the asphalt material but also caused the ASTH to snag and begin chattering across the repair. Ultimately, the end gates were widened as shown in Figure 3.25c, acting solely as grade control skis. Because the U-blade was pinned to the ASTH at its center section and the grade control skis were located on the outer sections, the middle of the U-blade sagged when any downward force was put on the ASTH. Thus, while there was about 1.5 in. of roll-down at the outside edges of the repair, the middle of the repair had essentially no roll-down factor. This is evidenced by the Table 3.2 average elevation of approximately 0.5 in. below the surrounding pavement, the lowest elevation of all asphalt repairs.

Figure 3.25. Small crater C1 AC repair with the ASTH.

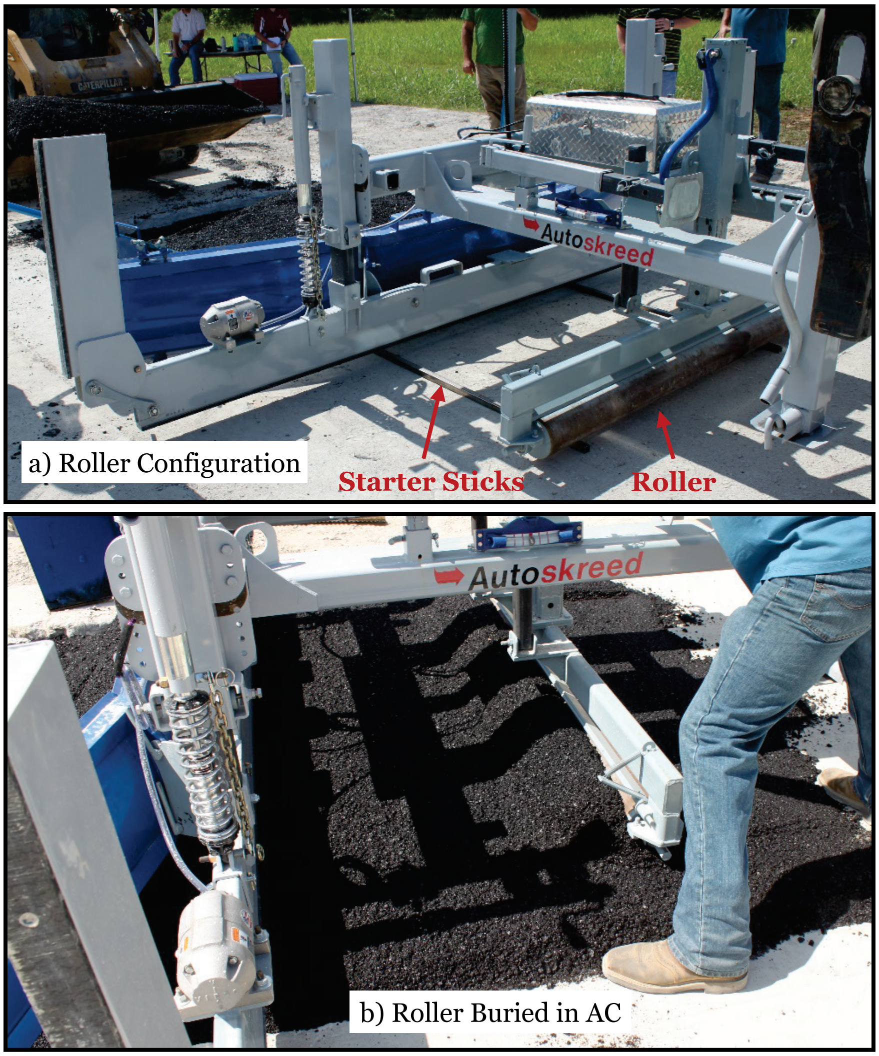

a) Initial Configuration

b) End Gate Riding into Crater

c) End Gate Widened

For small crater C2, a slightly different approach was tried since crater C1 was not fully successful. The end gates were set wide and used essentially for grade control only. To prevent the middle of the U-blade from sagging again, the roller system designed for use with large repairs was also used. Figure 3.26a shows the roller system resting on the 1.5-in. square starter sticks with the idea being that the roller would transition seamlessly from the starter sticks to the AC and simply roll across it at a consistent grade. Figure 3.26b shows that the roller plowed through the AC rather than rolling across it. Screeding was finished with handwork.

Figure 3.26. Small crater C2 AC repair with the ASTH.



For the large crater repair, neither the roller nor the end gates were used to any meaningful degree. For the first paving lane, the telehandler boom was constantly adjusted to try to, first, keep the outside end gate in contact with the parent slab and, second, keep the U-blade level from left to right as the inside end gate was unsupported (Figure 3.27a). For the second paving lane, small steel brackets designed as stands for the screed board were placed under the screed board to ride on 2x4 grade blocks as shown in Figure 3.27b. Overall, this process was one that would not be easily repeatable because it relied too much on the operator. Ultimately, the large ASTH repair did not satisfy RQC requirements based on *MD* (i.e., within-repair roughness).

Figure 3.27. Large crater AC repair with the ASTH.

a) Paving Lane #1

b) Paving Lane #2

3.3 Screed assessment and discussion

From an engineering judgment perspective, the repair profile measurements and timing data were not greatly informative as all screeds, based on those results, were generally adequate. The data did not greatly differentiate a “good” screed from a “bad” one. The differentiation of screeds is hidden behind the measured results and lies with other more subjective factors. For example, with large crater concrete repairs, the SSO and BSO could be operated accurately enough to obtain profile measurements reasonably comparable to that of the ASTH and ASHyd; however, because the SSO and BSO could not span the entire repair width, they required significantly greater effort as well as operator experience to produce those comparable results. This is a notable issue for the SSO and BSO even though the profile measurements may not indicate it.

In comparing the screeds subjectively, it is first important to isolate issues observed during screed testing that were not actually a result of the screeds themselves (e.g., materials issues) as these, for the most part, should not be counted against the screeds. For concrete repairs, the fast set time of RSC was a factor for all large crater repairs. For small repairs, the crater could be completely filled before screeding with no concerns for set time. For the large crater, screeding must begin before the crater is filled; even so, it was not always possible to screed the repair before encountering some areas of partially set RSC, causing tears. The exception to this materials issue was that the ASHyd and ASTH experienced fewer issues than the SSO and BSO because the ASHyd and ASTH could screed the entire crater width, whereas the SSO and BSO required two side-by-side passes.

The second materials issue with concrete repairs was related to the flowability of RSC. For example, the large repair with the ASTH appeared poor visually because of the four incremental passes shown in Figure 3.11. This was more of a practice and procedure issue than a screed issue as the same thing would have happened with any screed. This was simply a lesson learned in how to screed a large crater. Rather than making incremental overlapping passes, the screed should never be lifted, and one continuous pass should be made. Multiple passes should be made only by covering the entire repair again, if the material is still workable enough to allow that.

The final materials issue was related to asphalt repairs of all sizes, though the issue was typically more severe for large repairs. When loading AC into the crater with a CTL, the way in which the CTL operator discharges the load had noticeable effects. If the bucket was dropped from several feet high, the pile would consolidate to a greater degree than AC that was pushed off the pile by the screed. This produced low spots or waviness once compacted, with the high spots corresponding to the CTL drop locations. It was found that the better practice was to keep the CTL bucket low when dumping AC so that it rolled out of the bucket more so than dropped. This AC loading issue occurred to some extent with all screeds; however, not all dips and waviness were related to improper AC loading.

Some dips and waviness were actually caused by the screeds, and this discussion serves to point out issues that were screed-related.

With regard to large crater concrete repairs, the screed must be able to span the entire repair width like the ASHyd and ASTH. Practically speaking, the SSO and BSO failed in this area and largely have to be removed from consideration for an integrated screed in their current form. While they could be modified, there are no simple solutions to lengthen either of these screeds to span the width of large repairs.

With regard to screed board geometry, the BSO bucket was deemed least ideal. There were no notable issues with the angled blade shape of the SSO or the straight board shape of the ASHyd and ASTH other than it was sometimes overtopped with AC. The BSO bucket retained a considerable amount of material that had to be emptied and cleaned up after screeding. The concept behind the BSO bucket was that it would provide a buffer of material to fill in low spots while screeding. Instead, the bucket retained this excess material, which was wasted.

Remaining points of discussion are grouped into categories of size and weight, simplicity, versatility, speed, repair quality, and modification potential. Screeds were ranked in each category from 1 to 4 (1 being the best), as shown in Table 3.4, to provide some quantitative assessment of the subjective attributes of the four screeds.

Table 3.4. Screed performance rankings.

Factor	SSO	BSO	ASHyd	ASTH
Size/Weight	1	2	4	3
Simplicity	1	2	4	3
Versatility	2	4	3	1
Speed	3	4	2	1
Repair Quality	2	4	3	1
Mod. Potential	3	4	2	1
Average	**2.0**	**3.3**	**3.0**	**1.7**

Regarding size and weight, the SSO was the smallest, followed by the BSO, ASTH, and ASHyd. Note that there is a fairly large jump in size from the ASTH to the ASHyd. The SSO and BSO were significantly smaller than the other two screeds; however, it did not make much practical difference since all the screeds were moved with a telehandler. Even so, the larger screeds have more potential to be damaged during transportation and storage because they are bulkier and have more small or sensitive parts. Therefore, the SSO, BSO, ASTH, and ASHyd receive rankings of 1, 2, 3, and 4, respectively.

Regarding simplicity, the SSO was very basic in design featuring only an angled blade with integrated fork pockets and adjustable grade control skis that doubled as end gates. The fork pockets made it very quick for any telehandler to use, and the skis were manual jacks making adjustments quick and easy. For these reasons, the SSO ranked 1st. The BSO was very similar to the SSO in design. It featured a bucket with a standard carriage connection to a telehandler. This connection required the forks to be disconnected from the telehandler to use, requiring a longer setup time if the telehandler is to be used for multiple tasks. Therefore, the BSO ranked 2nd. The ASTH and ASHyd featured much more technology than the other two screeds, but the ASTH was by far the simpler of the two since the ASHyd had an onboard motor and hydraulics system. The ASTH and ASHyd received rankings of 3 and 4, respectively.

Regarding versatility, the ASTH was believed to be the most versatile. With the exception of a permanent grade control system (something that could be added with relative ease to the ASTH configuration), the ASTH performed relatively well for both repair types and sizes and was ranked 1st. The SSO handled all repairs relatively well with the exception of large crater concrete repairs. Even so, the final repair was manageable, earning the SSO a ranking of 2. The BSO, ranked 3rd, was close behind the SSO as it also struggled with the large crater concrete repair and was not as efficient at the large crater asphalt repair. The ASHyd was ranked last because, while it worked very well for concrete repairs, it was unable to perform large asphalt repairs and struggled with small asphalt repairs.

For speed, or repair time, all screeds were relatively comparable. There was no real difference in screeding times since three of the four were powered by a telehandler and could move as fast as the telehandler boom extended. The ASHyd's built-in hydraulics were about the same speed as a telehandler's. If rankings were to be assigned, the ASTH and ASHyd should be considered the fastest simply due to their ability to screed large concrete repairs faster than the SSO and BSO. Of those two, the SSO was faster for large asphalt repairs because of its grade control skis and because less material was required (the BSO retained material in the bucket, requiring additional CTL loads to fill the crater).

For repair quality, the ASTH was ranked first. For the asphalt repairs, the attachments provided by Nasby Fabrication were very clumsy and did not work. Those are largely ignored in this assessment. Otherwise, it was difficult to differentiate screeds based on repair quality as the quality of repairs was really quite similar in most cases. There were minute differences between the SSO and ASHyd. For example, the SSO large concrete repair was of lower quality than that of the ASHyd; however, the ASHyd was completely unable to conduct a large asphalt repair, and the SSO was. The BSO seemed to provide the worst repairs when all repair types and sizes were considered.

For modification potential, the ASTH seemed most promising. Better asphalt attachments than those provided by Nasby Fabrication could be fabricated and could very easily attach to the ends of the main 12-ft screed board via brackets similar to those that attach the 2.5-ft extension wings. Thus, it was felt the ASTH could relatively easily be converted into an integrated screed that could also screed asphalt. Any attachments made for the ASTH would, in theory, be compatible with the ASHyd since the configuration was similar. While the ASHyd would still not be well-suited for asphalt repairs for other reasons, it does exhibit reasonable modification potential. The SSO and, to a greater extent, the BSO stand to benefit from improvement for asphalt repairs (even though that was their primary purpose). An even larger gap exists to modify them for full-width large crater repairs.

Overall, the ASTH was believed to be the most promising screed in terms of potential to be modified into an integrated screed for both AC and RSC. There were no issues to speak of regarding concrete repairs, large or small. With redesigned asphalt attachments based on lessons learned from the initial evaluation, the ASTH demonstrated potential to be a good asphalt screed. The ASTH and ASHyd were by far the most developed screeds in terms of product and design maturity, but the ASTH was considerably simpler without the mechanical components of the ASHyd. Ultimately, the ASTH was selected as the screed of choice for screed integration efforts described in Chapter 4.

4 Screed Integration Efforts

4.1 Overview

Based on the initial screed evaluation results presented in Chapter 3, the ASTH appeared to be the most promising screed for further developing into an integrated solution. Overall, the ASTH worked relatively well for concrete repairs of both small and large craters. This was not an unreasonable finding considering concrete repairs were the primary purpose for which it was developed.

The asphalt attachments provided by Nasby Fabrication did not work well for asphalt repairs. This chapter describes efforts undertaken by ERDC to develop improved asphalt attachments, primarily relating to grade control, that could transform the ASTH into a more integrated screed. The approach was to use lessons learned from grade control and end gate attachments from all screeds tested in Chapter 3 to develop the improved attachments but to develop them for the ASTH given its perceived potential.

4.2 ASTH asphalt attachment development

4.2.1 Grade control systems

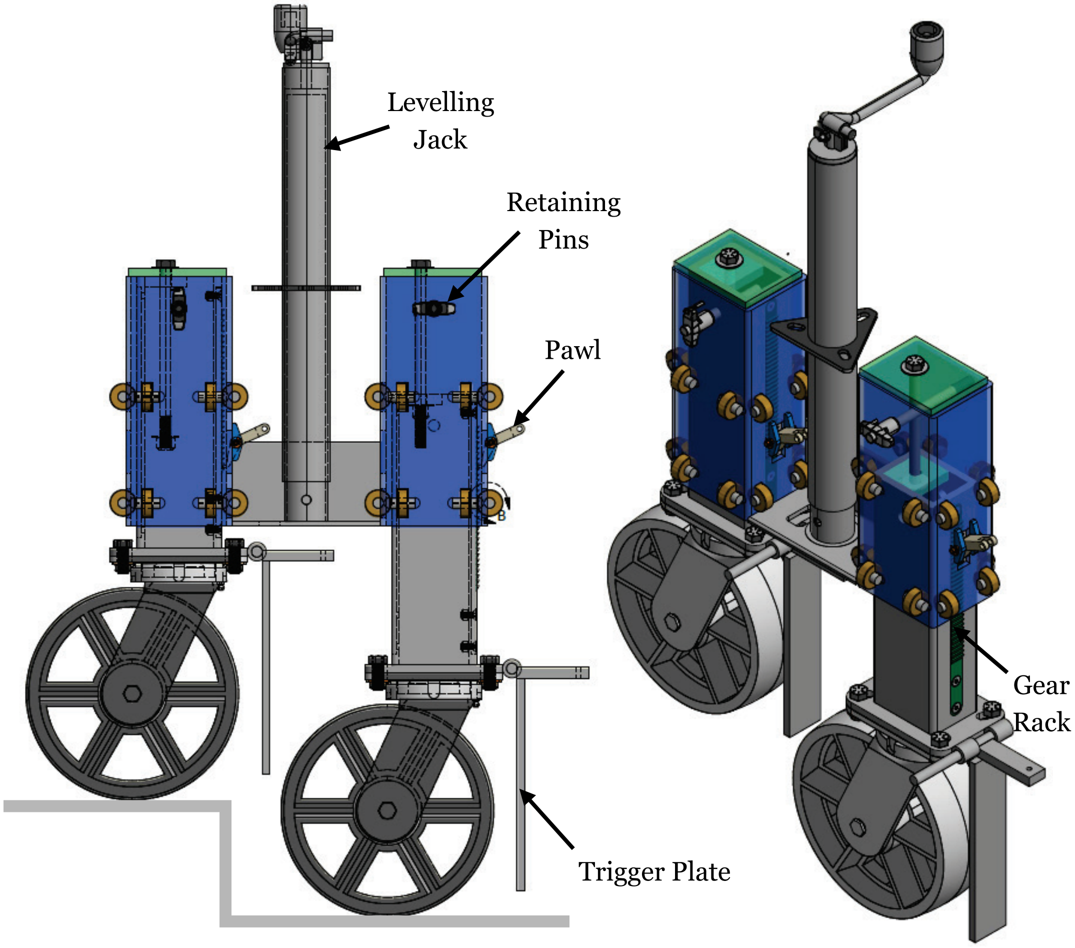
The ideal scenario for controlling grade would be a system that would not require the operator to make adjustments during screeding. The operator would set the initial screed bar height but would not need to make adjustments during screeding, particularly to the grade control components on the unsupported edge inside the crater. This ideal scenario presented a design challenge that had not yet been addressed by any of the grade control systems considered for the ASTH or any of the other screeds.

Given the complexity of the grade control issue on the unsupported edge inside the crater, this system is discussed first, and most discussion focuses on it rather than the outside-edge grade control system.

4.2.1.1 Grade control on the inside/unsupported edge

The initial design concept was to develop a two-stage assembly that allowed the ASTH screed board to remain fixed at a consistent elevation during the transition period into and out of the crater. This was accomplished using two steel wheels mounted on independent telescoping tubes. A ratcheting gear rack on the inner tube and a pawl on the outer tube allowed the inner tube to extend but not retract until the pawl was released via a hinged trigger plate. Figure 4.1 provides conceptual design drawings for the automatic grade control system (AGCS)

Figure 4.1. ASTH inside-edge automatic grade control system concept.

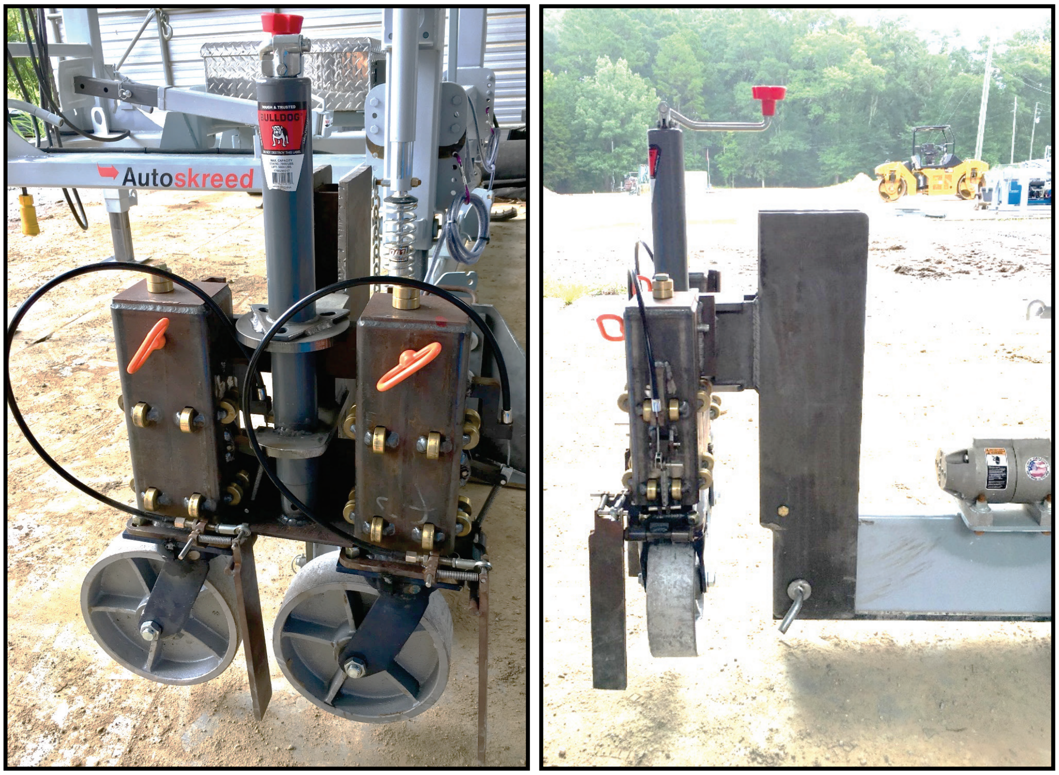


The intended procedure for operation would be to set the screed on the pavement (both AGCS wheels would be retracted and held in the retracted position with pins) and adjust the initial screed board height to account for roll-down (e.g., 1.5 in.) using the leveling jack. Once the height is set, the retaining pins are removed. As the screed is extended over the repair, the leading wheel is free to drop into the repair while the trailing wheel supports the screed and maintains consistent grade. Because of the gear rack and pawl, the leading wheel locks in place and supports the screed as the trailing wheel transitions into the repair and also locks in place.

The process is performed in reverse at the far end of the repair when the wheels transition out of the repair and back to the pavement surface. As the trigger plate on the leading wheel contacts the lip of the crater repair, it releases the pawl and allows the leading wheel to retract and ride out of the repair while the trailing wheel supports the screed. Once the leading wheel is fully retracted and again supporting the screed, the trailing wheel is released by its own trigger plate and rides out of the repair.

Figure 4.2 shows the final AGCS fabricated by a local machine shop and attached to the ASTH by the ERDC welding shop. The welding shop fabricated a bracket to allow the AGCS to pin onto the ASTH screed board in place of the folding wing extensions, meaning it could be quickly attached. Note that control cables linking the trigger plates to the pawls were not shown in Figure 4.1 but can be seen in Figure 4.2.

Figure 4.2. ASTH inside-edge automatic grade control system.

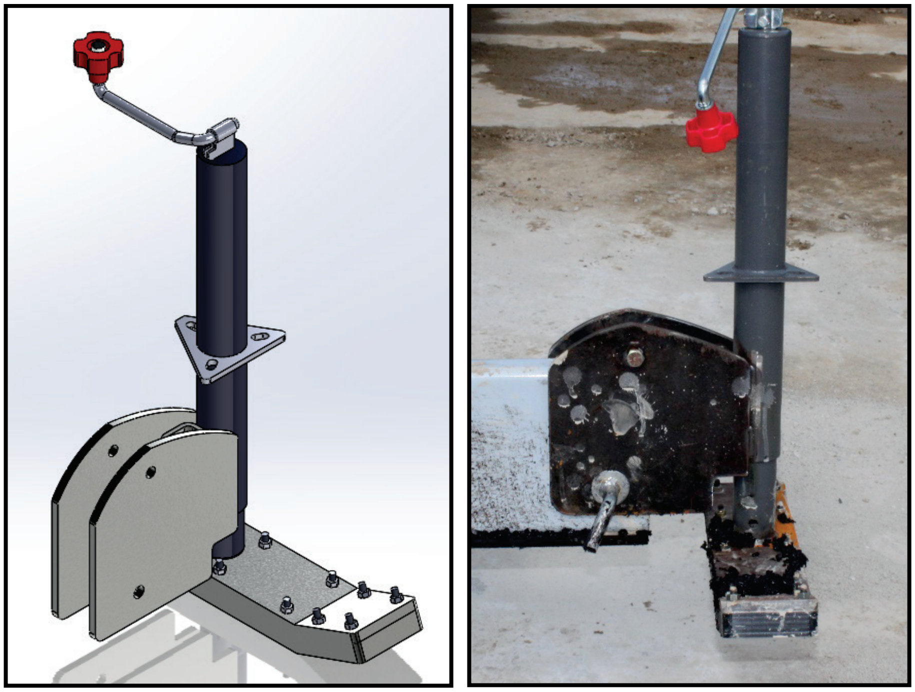


4.2.1.2 Grade control on the outside/supported edge

On the outside edge of the crater repair, the grade control support would ride on the existing pavement surface through the entire screeding process, considerably simplifying the design relative to the AGCS. The outside grade control system illustrated in Figure 4.3 consisted of an 18-in.-long ski with an angled nose.

Similarly to the AGCS, a jack was used to set the initial screed bar height. The design was largely based off the SSO grade control skis that worked relatively well. Similar to the ASTH screed board, the Figure 4.3 grade control ski had a 1-in.-thick sacrificial Nylatron® wearing surface. It utilized the same mounting bracket style as the ASTH folding wing extensions in order to be quickly pinned onto the screed board.

Figure 4.3. ASTH outside-edge grade control system.

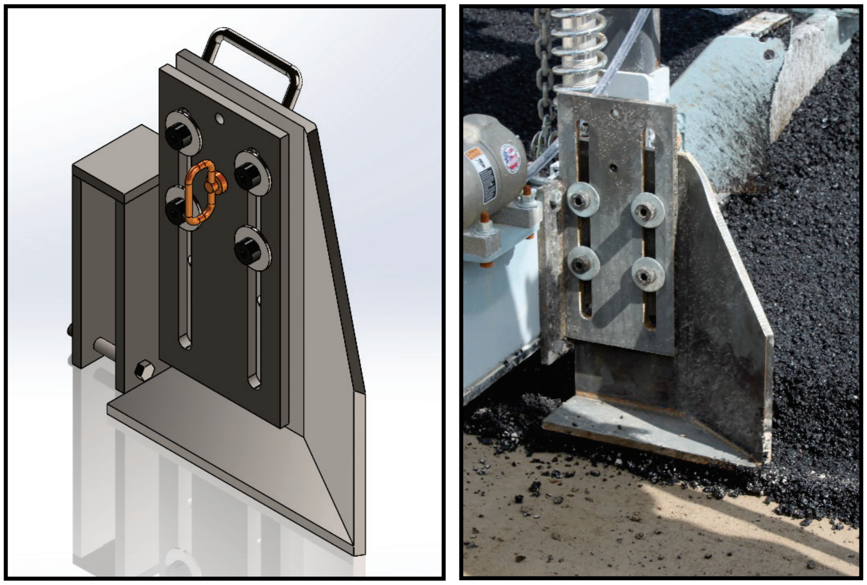


4.2.2 End gate system

Of the screeds that included end gate attachments, the SSO's end gate attachment was the most effective. However, it was also incorporated into the grade control skis and could not be adjusted. Figure 4.4 shows an end gate attachment similar in concept to that of the SSO but detached from the grade control systems. Further, it was designed to be free floating to naturally fall into the crater repair when screeding. At the far end of the repair, the floating portion of the end gate must be manually lifted to allow the screed to pass over the repair.

The Figure 4.4 end gate was mounted on the ASTH screed board via a U-shaped bracket that was secured with a pin. This allowed the end gate to be positioned at multiple points along the screed board. Only one end gate was fabricated in the screed integration phase of this project. It was intended primarily for large craters in an effort to better maintain the free edge inside the crater, which was a more critical location than the outside of the crater that was easily corrected with shovels prior to compaction.

Figure 4.4. ASTH end gate assembly.



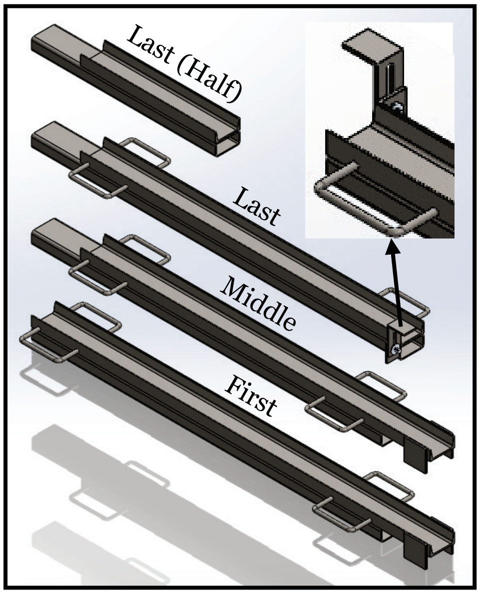
4.2.3 Ride track

A ride track (Figure 4.5) was designed to be placed in the crater repair during screeding. This was intended primarily to bridge over any surface deviations in the flowable fill base. This would provide a smoother surface for the AGCS wheels to ride on, ultimately yielding a more consistently smooth HMA placement. The track sections were made of 2-in. by 4-in. hollow tubing and channels. This 2-in. thickness also assisted the AGCS when it was exiting the crater; the 10-in.-diameter AGCS wheels had only to ride out of what was effectively a 2-in.-deep repair (4-in. repair depth minus 2-in. track thickness), which was considerably easier for the AGCS to do than riding out of the full 4-in. repair depth.

The track pieces were configured so that each piece overlapped the next as shown in Figure 4.6a, creating a continuously linked track. The pieces were designed to overlap 2 to 8 in. depending on the size of the crater and the total length of track needed. By fully nesting six 65-in. track pieces (overlapped 8 in.), a 30-ft track could be produced. By overlapping each track piece the minimum 2 in., the total track length could be extended to

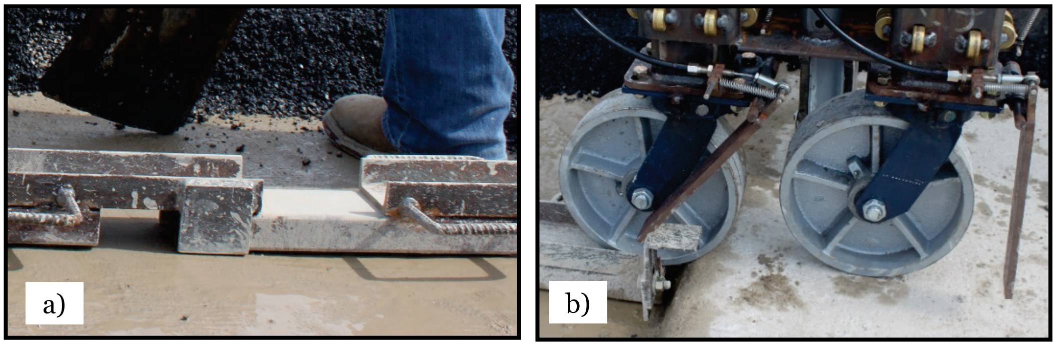
32 ft 6 in. Using the 2-ft 6-in. half-track piece, any combination of total track lengths could be created. The 15-ft crater used in this project required only three track pieces (first, middle, and last).

Figure 4.5. Ride track pieces for ASTH automatic grade control system.



An adjustable tab was welded to the last track piece as shown in the expanded view in Figure 4.5 and Figure 4.6b. It served to engage the trigger plates on the AGCS. The tab included a 2-in.-long shelf that effectively held the trigger plate back and the pawl released for a longer period of time, providing ample time for the AGCS wheels to fully retract when riding out of the crater repair.

Figure 4.6. Detail photographs of ASTH ride track.



4.3 Asphalt repairs with modified ASTH

As detailed in Table 2.8, the modified ASTH including all the attachments described in Section 4.2 was used to perform asphalt repairs on one large and one small crater. The purpose of these two repairs was to evaluate the asphalt attachments, with the primary focus being on the large crater since it presented the more challenging scenario.

4.3.1 ASTH-Mod operating procedures

The procedures for placing and compacting AC were the same as previous tests. Operation of the screed was generally similar to operating the ASTH previously with the exception of the new attachments. Once the screed was in position at the edge of a crater, it was set on the ground, and the grade control jacks on both the AGCS and the grade control ski were used to raise the screed board to the desired roll-down height (1.5 in. for a 4-in. repair in this project), similar in function to the SSO grade control jacks.

Setting initial grade height was all that was required for a small crater since the grade control ski and AGCS both remained outside the repair on existing pavement. For a large crater, the track and end gate were needed, and the AGCS was utilized to maintain grade.

During setup, the track was laid in the repair in line with the travel path of the AGCS wheels. It was helpful to boom the ASTH-Mod over the repair to ensure the track and telehandler boom were aligned for the full length of the repair. The fork tilt was then adjusted to level the ASTH-Mod, which was necessary to approximately balance the load on the two AGCS wheels (in addition to the other reasons previously listed for leveling the ASTH). The ASTH-Mod springs were also preloaded slightly as before. Prior to screeding, the retaining pins were removed from the AGCS and the free-floating end gate.

When screeding of a large crater began, the AGCS design allowed the telehandler operator to boom out like normal as if screeding a small crater, requiring no adjustments to the grade control as a result of the large crater. As with all of the screeds and crater sizes, the boom angle required occasional adjustment to keep the screed firmly in contact with the pavement.

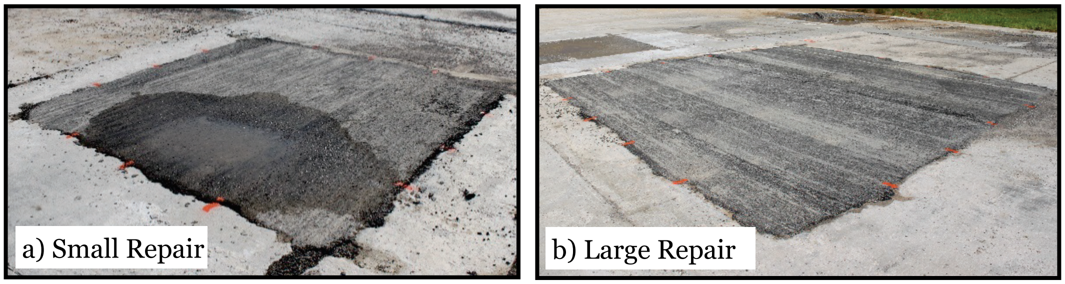
4.3.2 ASTH-Mod repair results

Table 4.1 provides data from the post-repair surface evaluation. The average elevation of each repair relative to the existing grade was -0.01 in., while the average *MD* within each repair was 0.72 in. The average *SD* between within-repair elevation measurements was 0.20 in. Relative to the original profile data in Table 3.2, there was less of a difference between the small and large repairs. Figure 4.7 shows images of both repairs.

Table 4.1. Asphalt crater repair profile data with the ASTH-Mod.

Crater	Avg Elev. (in.)	Max Diff. (in.)	Std. Dev. (in.)
C1	—	—	—
C2	-0.22	0.66	0.21
C3	0.20	0.78	0.18
Avg	**-0.01**	**0.72**	**0.20**

Figure 4.7. Small and large AC repairs using ASTH-Mod.



a) Small Repair

b) Large Repair

The ASTH-Mod performed relatively well for the small crater, which was largely expected based on prior experience with the ASTH and other simple jack-operated grade control systems. With both left and right grade control systems always riding on existing pavement, there are few challenges to obtaining a well-screeded surface for a small crater.

Testing the ASTH-Mod on the small crater revealed two issues. First, AC easily overtopped the 8-in.-tall screed board if the AC in the crater was not sufficiently leveled during pre-strikeoff or if, though leveled, there was too much AC in the crater. Figure 4.8 illustrates this problem. This problem was already anticipated based on Chapter 3 testing; however, no effort was made to address this during the screed integration work because the resources required to build a new screed board were not justified given the simplicity of the issue. The problem could be relatively easily addressed if a final screed design is ever to be fabricated. Possible solutions include using a taller screed board or adding an angled flange piece to the top of the current screed board similar to the SSO design.

Second, when the vibrators were switched on and a slight downward load was applied to the ASTH-Mod for screeding, the handles on the grade control jacks, particularly on the left-hand grade ski side, would slowly rotate, retracting the jack. Ultimately, jacks with handles that can be locked at their set point would be desired to alleviate this issue; as a temporary solution in the midst of field testing, jack handles were simply secured in place with duct tape.

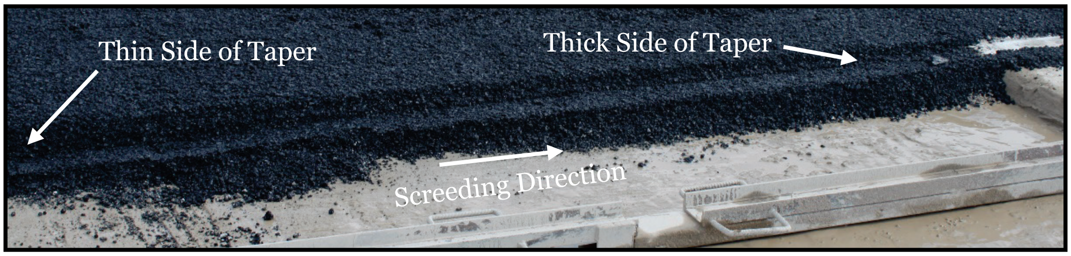
Figure 4.8. AC overtopping ASTH-Mod screed board.

On the large crater, the AGCS and floating end gate demonstrated the potential to work; however, preloading the travel springs on the ASTH caused minor issues. Recall that the travel spring stiffnesses were 140 lb/in. Typically, the springs were preloaded 3 in. to the midpoint of their total 6 in. travel distance. This would result in 840 lb of downward force being applied to the screed. Because the screed board was located at the end of the telehandler forks, creating a 6-ft moment arm, it was difficult to apply this preload while keeping the ASTH-Mod level. Instead, the ASTH-Mod tended to roll backwards as illustrated in Figure 4.9.

Figure 4.9. Unleveled ASTH-Mod due to preload.

With the ASTH-Mod angled, the floating end gate also sat at an angle with the nose up as can be seen in Figure 4.9. This allowed the end gate to ride on top of any AC in its path rather than directing it into the width of the placement and creating a clean vertical face. As the screed extended across the repair, the end gate gradually climbed creating a tapered edge as shown in Figure 4.10.

Figure 4.10. Tapered AC edge due to upward angle of end gate nose.



Preloading the relatively stiff travel springs to the midpoint of travel created two other issues related to the operation of the AGCS. First, the applied 840-lb preload force caused twisting to occur between the ASTH and the AGCS when entering the crater and the lead AGCS wheel was unsupported. As designed, the lead wheel should have lowered until the pawl engaged the teeth on the gear rack and locked the wheel in place so that it could then support the AGCS while the trailing wheel transitioned. Instead, the lack of torsional stiffness in the connection between the ASTH and AGCS allowed the entire AGCS to rotate forward under the preload as the leading wheel entered the crater. As a result, the leading wheel would not fall far enough to lock in place and support the AGCS. Ultimately, the grade of the AGCS side of the screed would fall the distance from the existing pavement surface to the ride track.

This issue was partly due to the large force required to preload the travel springs to their midpoint and partly due to the lack of torsional stiffness within the AGCS attachment design. Both can be addressed in future designs. The lack of torsional stiffness was not entirely unexpected based on the bracket design shown in Figure 4.2. The bracket was meant to fit the AGCS onto the existing screed board without requiring an entirely new screed board to be designed and fabricated; the means of connecting the AGCS to the screed board has room for improvement and can be optimized. The travel springs could also be replaced with lighter springs so that less downward force is applied when the springs are preloaded. For example, a 32-lb/in. spring would result in approximately 160 lb of downward force in comparison to the current 840 lb, reducing the force by a factor of slightly more than five.

In the field testing, this issue was resolved by barely preloading the springs so that there was minimal load on the AGCS. While this method works, it requires careful attention by the operator to make sure the telehandler boom is frequently adjusted to keep the ASTH-Mod in contact with the pavement. This is not a good long-term solution since it is less forgiving and less robust.

Another issue with the AGCS was that the large force applied by the travel springs made it difficult for the trigger plate to release the pawl when the AGCS was transitioning out of the crater. When the AGCS is inside the crater (i.e., the AGCS wheels are extended), any downward force from the ASTH, whether self-weight or preload force, is effectively carried on a single tooth of the AGCS's internal gear rack. This translates to a fairly large force on the trigger plate that would be needed to release the pawl. Several attempts to engage the trigger plate while the ASTH-Mod was preloaded were stopped for concern that the control cable linking the trigger plate and pawl may not withstand the full force needed to release the pawl.

This issue appeared largely due to the stiff travel springs and the large force applied when preloading them. As previously discussed, this was addressed in the field testing simply by barely preloading the springs, which is not an adequate long-term solution. Lighter springs would still provide the vertical travel tolerance for the operator but would not impart as much force on the AGCS.

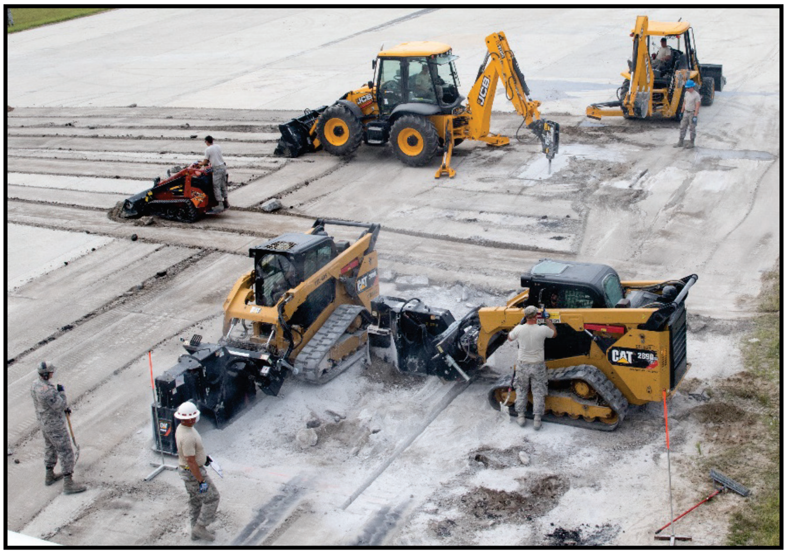
Overall, the ASTH asphalt attachments worked relatively well with the exception of the issues discussed. Several of these issues could be addressed by modifying the ASTH design slightly and were taken into consideration in developing the final integrated screed design in Chapter 6. The only remaining potential concern is with the AGCS. Given its moving parts, it could require more careful handling and maintenance, which may not be ideal for troop use. However, the AGCS as tested in this project was an initial design and could perhaps be refined to be more robust and user friendly.

5 RADR Demonstration Findings

5.1 Overview of demonstration

The RADR demonstration was conducted over four days at the Silver Flag Exercise Site. A different series of five craters was repaired each day for four total series. The craters were blasted prior to the demo and varied in size, but all were approximately 8-10-ft craters. Figure 5.1 shows a typical photograph of crater repair operations during the demonstration.

Figure 5.1. Crater repair operations during the RADR demonstration.



Each series of repairs (Experiments 1 to 4) utilized a different backfill material: 1) traditional rapid-setting flowable fill, 2) polyurethane foam, 3) cement-stabilized soil, and 4) sand-filled geocells. All repairs were surfaced with 10 in. of rapid-setting concrete. No asphalt repairs were conducted as a part of this demonstration.

Two different sets of equipment were used to conduct repairs. The primary equipment set for the demonstration was termed the lighter and leaner equipment set, in contrast to traditional crater repair equipment pieces that are large, expensive, and logistically burdensome. Traditional crater repair equipment utilizes such items as front end loaders, wheeled excavators, large telehandlers, and the SVM7. Lighter and leaner equipment relied on backhoes, CTLs, smaller telehandlers, and the SVM2, among other items. Lighter and leaner equipment was used for

Experiments 1 to 3 while the traditional equipment was used for Experiment 4 as a control.

Based on findings from Chapter 3, the ASTH was selected for inclusion in the demonstration as the alternate screed to the traditional magnesium bar screed and Screed King. The ASTH was used for repair series where the lighter and leaner equipment was used. The magnesium bar screed and Screed King were used with the traditional equipment set. The only exception to this was for Experiment 3 where a piece of the sacrificial Nylatron® strip broke off the ASTH screed board on the first crater; the magnesium bar screed and Screed King were used for the remaining Experiment 3 craters.

5.2 Demonstration repair results

Results from the RADR demonstration repairs are discussed in three parts: survey results, timing results, and visual observations. Figure 5.2 shows the ASTH in use at the demonstration, while Figure 5.3 shows typical usage of the magnesium bar screed and Screed King. Figure 5.4 shows typical finished surfaces for the ASTH and Screed King.

Figure 5.2. ASTH in use at the RADR demonstration.

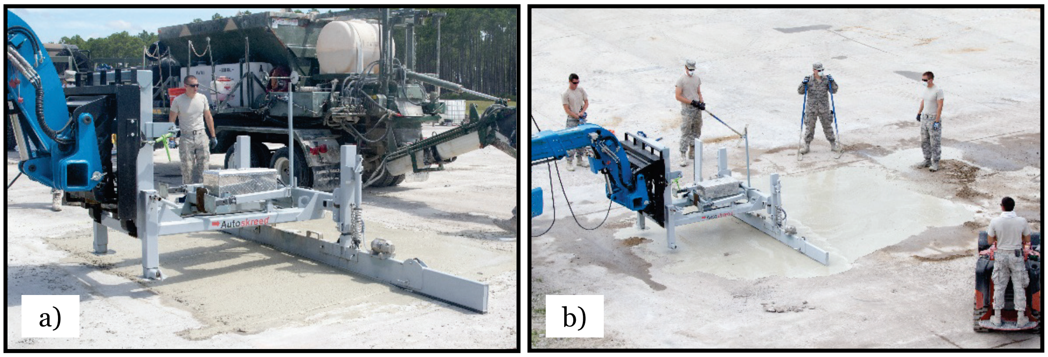
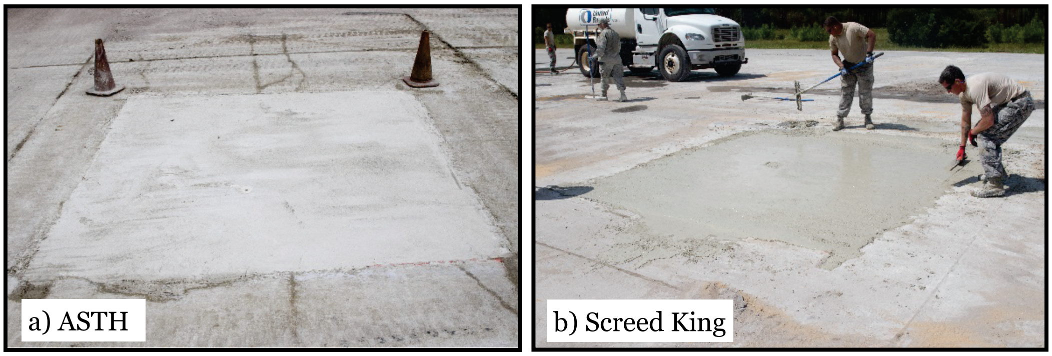


Figure 5.3. Bar screed and Screed King in use at the RADR demonstration.

a) Magnesium Bar Screed

b) Screed King

Figure 5.4. Finished concrete repairs at the RADR demonstration.



a) ASTH

b) Screed King

5.2.1 Survey results

Table 5.1 summarizes repair profile data from the RADR demonstration by experiment. In all, 11 repairs were performed with the ASTH, which includes Experiment 1 Crater 1 and three training craters for which no profile data was measured. Similarly, nine repairs were performed using the magnesium bar screed and/or Screed King. The troops did not use the bar screed and Screed King consistently. In some cases, the bar screed was used as a pre-strike-off for the Screed King; in others, only one of the two devices was used.

Table 5.1. Crater repair profile results from the RADR demonstration.

	Crater	ASTH					Crater	Mag. Bar & Screed King		
		Avg Elev. (in.)	Max Diff. (in.)	Std. Dev. (in.)				Avg Elev. (in.)	Max Diff. (in.)	Std. Dev. (in.)
2	1	-0.14	0.77	0.20		3	2	-0.28	0.67	0.14
	2	-0.58	1.38	0.35			3	-0.44	0.85	0.20
	3	-0.16	0.73	0.18			4	-0.03	0.49	0.13
	4	-0.24	0.64	0.16			5	0.02	1.19	0.19
	5	0.08	0.60	0.12		4	1	-0.13	0.58	0.12
3	1	-0.26	0.75	0.18			2	-0.05	0.60	0.15
—	—	—	—	—			3	-0.42	0.49	0.13
—	—	—	—	—			4	-0.29	0.72	0.21
—	—	—	—	—			5	-0.33	0.59	0.13
Avg		**-0.21**	**0.81**	**0.20**		Avg		**-0.21**	**0.69**	**0.15**

— No valid profile data was recorded from Experiment 1. The SVM$_2$ was damaged during Experiment 1 after Crater 2, and no additional craters were repaired. Survey equipment was unavailable to collect profile data on Craters 1 and 2.

— During Experiment 3, a portion of the sacrificial Nylatron® strip broke off the ASTH at the end of screeding Crater 1. The magnesium screed bar was used for Craters 2 and 3, both the magnesium bar screed and Screed King were used for Crater 4, and only the magnesium bar screed was used for Crater 5 because the repair was wider than the Screed King.

It should be noted that profile measurements in Table 5.1 were obtained using rod-and-level surveys, which differs from the method in Chapters 3 and 4 where measurements were obtained using a straightedge. The measurement layout also differed. In Chapters 3 and 4, profile measurements were recorded on a 2-ft (small crater) or 3-ft (large crater) grid pattern. During the RADR demonstration, measurements were taken differently since the repairs were to be trafficked with an F-15E load cart. A transverse cross section was obtained as well as three longitudinal profiles near the center of the repair in the trafficked area. These differences mean Table 5.1 results should be loosely compared to those in Chapters 3 or 4.

For the ASTH, the average repair surface elevation was 0.21 in. lower than the surrounding pavement. The average *MD* and *SD* were 0.81 in. and 0.20 in., respectively. These results were not meaningfully different from the initial ASTH evaluation results presented in Table 3.1.

For the bar screed and Screed King, survey results were very similar to that of the ASTH, implying both provide an equally level and smooth repair surface. While this did appear to be the case, it should be noted that obtaining level and smooth results with the bar screed or Screed King does depend, to some degree, on the consistency of the concrete being placed. During the RADR demonstration, all concrete produced tended to be on the wet, flowable side rather than the dry, stiff side. This is observable in Figure 5.2b, for example, and makes controlling the bar screed and Screed King noticeably easier, producing better results. For stiffer concrete, it becomes significantly more difficult to manually drag excess concrete away, and the concrete typically sets faster, compounding the issue.

5.2.2 Timing results

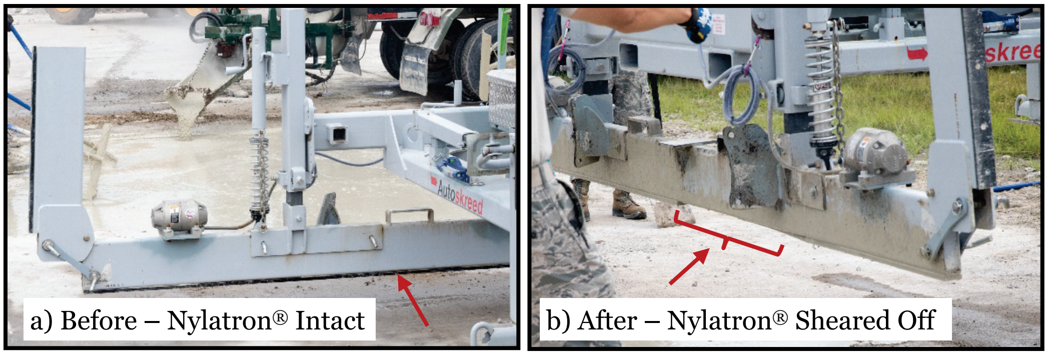
Timing data was recorded for Experiments 1 to 4 as well as three crater repairs that were conducted for practice at the beginning of the demonstration. In all, 11 repairs were performed with the ASTH at an average time of 3.4 min of screeding time per repair, including up to 4 passes although 2 were typical. In contrast, the nine repairs performed with the magnesium bar screed and/or Screed King averaged 4.2 min of screeding time. One or two passes were typically all that was feasible before the concrete had nearly reached initial set and was too stiff to work any further.

5.2.3 Visual observations

From observing screeding operations, it appeared the ASTH was relatively straightforward and simple to use. As discussed in previous chapters, leveling of the ASTH can be somewhat tedious but also unnecessary. If anything, the troop repairs demonstrated this. The airmen received training on how to set up the ASTH; however, in practice, they rarely leveled the ASTH before use. At most, the spotter would instruct the operator to tilt the forks up or down slightly until he felt the ASTH looked nominally level. When the operator lowered the ASTH to preload the springs, the ASTH almost always rolled backwards as discussed in previous chapters. The airmen continued on regardless of whether or not the ASTH was level after preloading. Nonetheless, repairs were generally satisfactory, demonstrating the ASTH has a decent level of operator forgiveness, which is a desirable attribute.

During the screeding of Crater 1 in Experiment 3, the ASTH screed bar snagged on the far crater edge as it was exiting the crater. When this happened, a short piece of the sacrificial Nylatron® strip was sheared off the screed bar. Upon further inspection, the Nylatron® was attached to the steel screed bar by Tapcon® masonry screws that had sheared. This could be prevented in the future by modifying the screed bar to allow the Nylatron® to be inset slightly into the screed bar to provide much greater shear resistance.

Figure 5.5. ASTH before and after Nylatron® strip was damaged.



a) Before – Nylatron® Intact

b) After – Nylatron® Sheared Off

With respect to manpower, the ASTH required one operator and one spotter, while the bar screed or Screed King required at least three airmen or more in some cases. For example, Figure 5.3a shows a case where six men (one ERDC technician had to assist the airmen) were required to drag the bar screed. This was at least partly because of the width of the repair and the amount of excess concrete, creating a significant weight of concrete that must be moved. Figure 5.3b also shows that one person must wade through the fresh concrete when using the Screed King, which can be cumbersome. In addition to requiring one less airman, the physical effort involved with use of the ASTH was significantly less than that of the bar screed or Screed King, which has some benefit. Note that final finishing and cleanup of excess concrete still required more than two airmen in most cases, regardless of which screed was used.

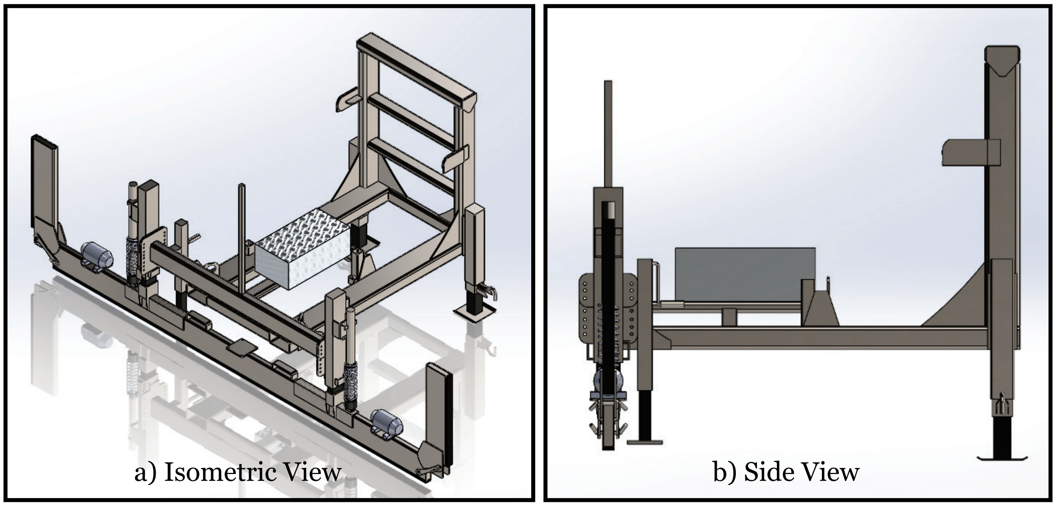
6 Conceptual Integrated Screed Design

Lessons learned during the testing of the original screeds and the modified ASTH both at ERDC and during the RADR demonstration were used to draft a conceptual integrated screed design to be considered for future fabrication and testing. This chapter discusses recommendations for an integrated screed based on the ASTH and presents conceptual drawings. Discussion of modifications is broken into four sections: screed frame modifications, configurations for storage and use, screed board modifications, and attachment design considerations.

6.1 ASTH screed frame modifications

After conducting tests with the original and modified ASTH, a number of properties and features of the base ASTH frame shown in Figure 6.1 were found to have room for improvement. Four key aspects are discussed in this section.

Figure 6.1. Original ASTH frame.

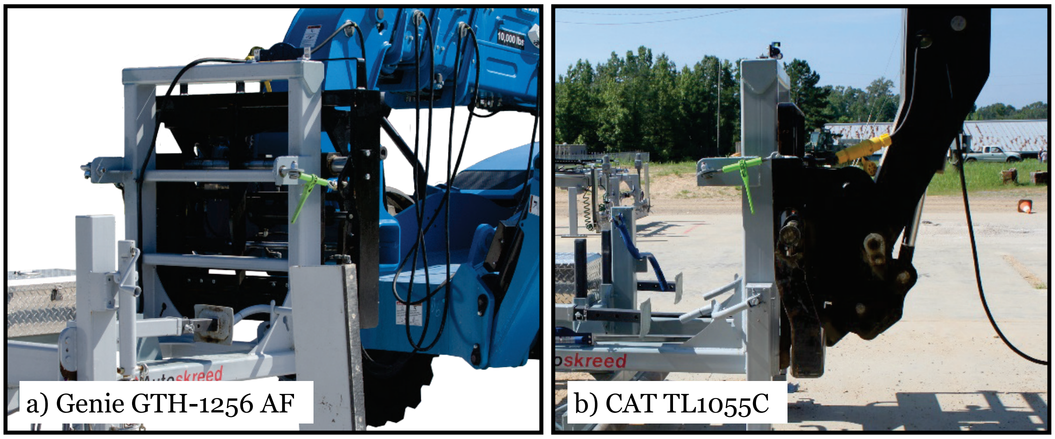


a) Isometric View

b) Side View

The first aspect was its height. When forklifted, the ASTH frame was slightly taller than the Genie GTH-1256 AF fork carriage for which it was designed. For the CAT TL1055C and other telehandlers that were measured, the ASTH frame was also taller than the fork carriage. Figure 6.2 illustrates these height differences. While the ASTH's height had no negative impact on its performance, it also served no beneficial purpose and made the ASTH unnecessarily tall, which could become important for shipping logistics.

Figure 6.2. Photos comparing ASTH frame height to fork carriages.



a) Genie GTH-1256 AF

b) CAT TL1055C

The second aspect was its 6-ft length, which served no meaningful purpose other than to fully conceal the telehandler forks. While that is convenient, it makes the ASTH quite long with unused space as seen in Figure 6.1b. This length can also make the ASTH more awkward to maneuver. When driving the telehandler with the ASTH, the 12-ft-wide screed board (or 17-ft wide if the extension wings are folded down) being carried 6 ft beyond the fork carriage significantly impacts maneuverability due to the much greater turning radius and clearance needed. As with the ASTH height, its length leads to a larger-than-necessary logistical footprint.

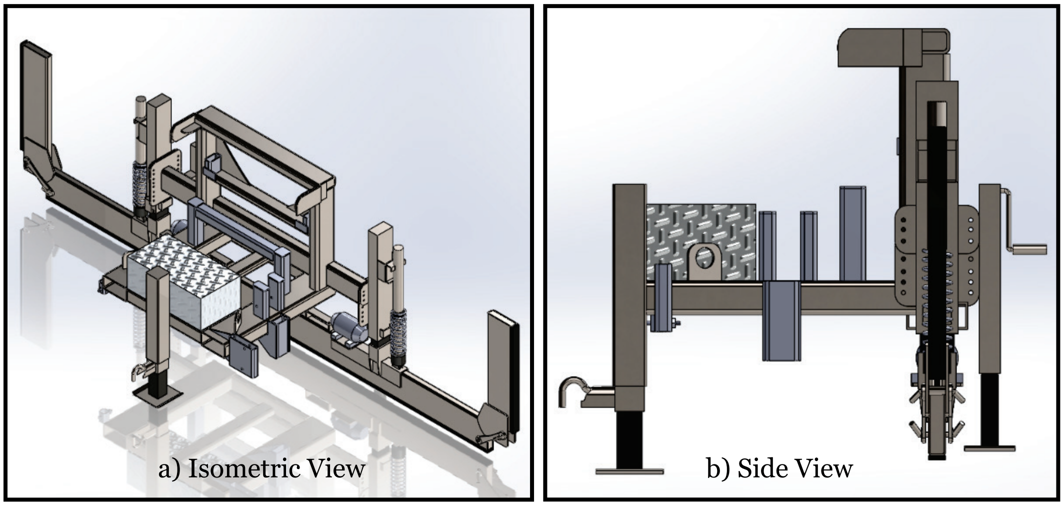
The third aspect was the screed board location on the ASTH frame. As discussed in Chapter 4, it was difficult to keep the ASTH level when preloading the springs; instead, the ASTH tended to roll backward due to the 6-ft moment arm created by the screed board's position on the ASTH.

The fourth aspect dealt with the travel springs that were too stiff as discussed in previous chapters. The concept of the travel springs is sound in that it provides vertical travel and makes it easier for the operator to keep the ASTH in contact with the pavement when screeding. The stiffness of the springs, however, caused several issues such as with the AGCS.

The fifth aspect was the camera-mount pole at the front of the ASTH. The camera itself did not prove to be useful to the point that it could replace a spotter observing the screed. Ultimately, the camera's value was minimal, and it is recommended that the mounting pole for the camera be removed.

Figure 6.3 illustrates a screed frame that has been redesigned to address the aforementioned issues. The topmost section of the ASTH frame would be removed to reduce its height while still providing sufficient structure for the forklift carriage to push against. The length would be reduced from 6 ft to 3 ft. This would mean the telehandler forks would protrude through the ASTH during use, but it would reduce the overall footprint for maneuvering, transportation, and shipping. The screed board would be relocated to the rear of the ASTH to eliminate the moment arm created by locating it at the front. By relocating it, downward force applied from the telehandler is directly imparted to the travel springs in the same line of force. The preload springs would be replaced with lighter springs in the 32-lb/in. range, and the camera-mount pole would also be removed.

Figure 6.3. Conceptual ASTH frame.

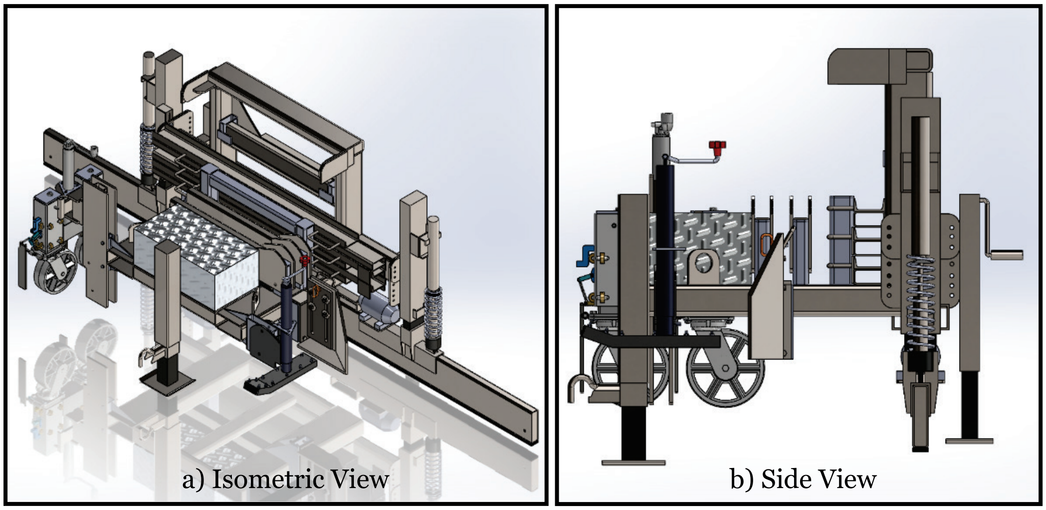

a) Isometric View
b) Side View

Lastly, the original ASTH included four jacks as shown in Figure 6.1 to be used as support legs. The two jacks located directly behind the screed board did not add meaningful value as the screed was typically left resting on the screed board and the two rear jacks when not on a forklift. These two front jacks were intended to hold the ASTH when attaching or removing the screed board, but this was not done frequently and could be done by forklifting the ASTH instead. The two rear jacks were useful on the original screed; however, on the redesigned screed, it is believed one jack would be sufficient and eliminate having to adjust two jacks.

6.2 ASTH storage, asphalt repair, and concrete repair configurations

In redesigning the ASTH, one goal was to provide locations on the frame to store all attachments for both types of repairs, asphalt or concrete. This would allow concrete attachments (the two fold-down extension wings) to be stowed during asphalt repairs or asphalt attachments (both grade control devices, end gate, and ride track) to be stowed during concrete repairs. Additionally, all attachments could be stowed on the ASTH frame for convenience when it is stored or shipped. Figure 6.4 illustrates the storage configuration with all attachments stowed on the ASTH.

Figure 6.4. Storage configuration of conceptual ASTH.

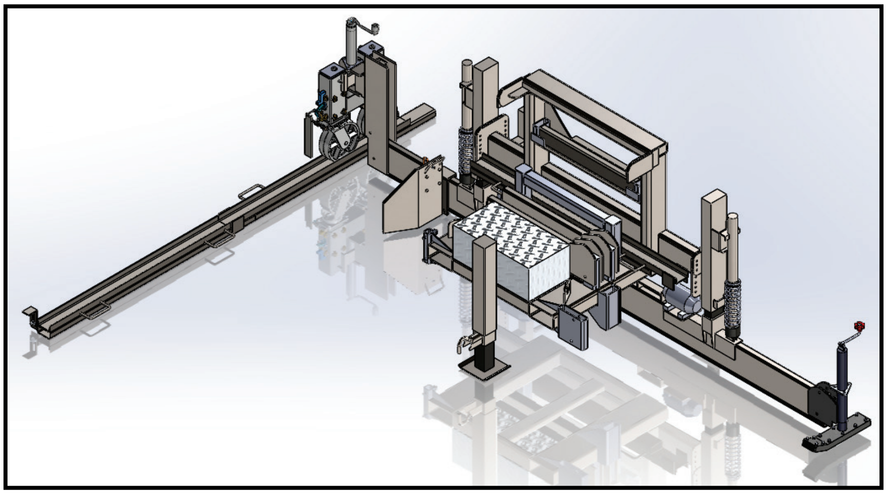


a) Isometric View

b) Side View

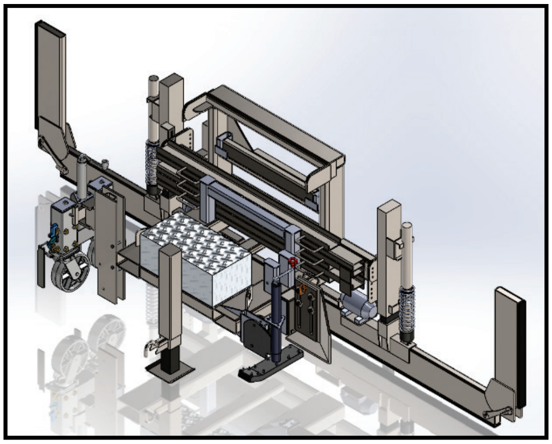
Figure 6.5 shows the asphalt configuration. The grade control ski and AGCS are mounted at either end of the screed board, with the ride track laid out for the AGCS to follow. The end gate attachment is positioned where needed along the screed board. It should also be noted the screed board was simplified to increase its useable length with respect to end gate positioning. For example, the vibrator motors were repositioned onto the screed board brackets rather than the screed board itself.

Figure 6.5. Asphalt configuration of conceptual ASTH.



In a similar manner, Figure 6.6 shows the concrete configuration. The extension wings are mounted at the screed board ends to facilitate small or large crater sizes. All asphalt attachments are stored on the ASTH frame.

Figure 6.6. Concrete configuration of conceptual ASTH.



6.3 ASTH screed board modifications

The existing ASTH screed board is simply a section of 2-in. by 8-in. steel tubing that functioned, for the most part, quite well. However, there are some instances in which it did not work all that well and could potentially be improved. These considerations are not shown in any of the conceptual drawings presented in the previous two sections but are simply discussed and should be further deliberated in future efforts.

First, the sacrificial Nylatron® strip along the bottom edge of the screed board served a good purpose. It is a durable material that withstands abrasion against concrete relatively well and protects the steel screed board itself. However, its attachment to the screed board proved to be a point of weakness during the RADR demonstration. This interface could be strengthened by providing a channel along the bottom edge of the screed board into which the Nylatron® could be partially recessed. This would provide reinforcement against lateral forces that would act to shear the bolts attaching the Nylatron® to the screed board.

Second, several issues were encountered with the existing screed board geometry during asphalt repairs. These issues were not a factor for concrete repairs because the ASTH was built primarily for screeding concrete. For asphalt, however, the 8-in.-tall screed board was overtopped with ease, and the rectangular tubing composing the screed board had little torsional resistance, making AGCS operation more difficult.

Both issues could likely be improved to some degree by increasing the screed board's height (e.g., 2-in. by 12-in. steel tubing). However, the best results would most likely be achieved by investigating an altogether different screed board geometry. For example, the SSO's geometry makes for a stiffer screed with greater torsional resistance. Because steel properties are well-characterized and the loading state can be adequately represented by a simple static torsional load, finite element modeling could be a useful tool in quickly considering other screed board geometries. Modeling efforts were beyond the means of this project, but if future efforts are taken to build and test an integrated screed, it is recommended modeling be used to design a stiffer screed board. This should be a relatively straightforward, but effective, use of finite element modeling as it would eliminate the need for fabricating and testing multiple full-scale screed board options.

6.4 ASTH attachment design considerations

In all, there are five attachments (one for concrete, four for asphalt) recommended for the ASTH. They are as follows:

1. 2.5-ft screed board extension wings (2)
2. Grade control ski for outside edge
3. Automatic grade control system (AGCS) for inside edge
4. Ride track for AGCS (6 full pieces and 1 half piece)
5. End gate.

The extension wings worked well for concrete repairs during this project. The only recommendation is to redesign the Nylatron® point of attachment to match that of the main screed board to minimize the chance of shearing off the Nylatron®.

The grade control ski mounted on the outside edge of the screed board worked well except for the jack's tendency to unwind when the vibrators were on. This should be addressed by adding a mechanism to lock the jack's handle in place once set.

The AGCS mounted on the inside edge of the screed board is by far the most sophisticated of the five ASTH attachments, meaning it has the most potential for failure. Future designs should focus primarily on making the weakest components, such as the latch release cable assembly, more robust as well as concealing or moving sensitive components behind a protective shroud. This cover could be removed for adjustments or servicing but would normally be in place to keep the AGCS's mechanical components out of the way.

The ride track performed as intended. The only issue that could be improved upon is its weight, which is about 80 lb per full track piece. The track pieces were built from materials on hand at the time, which happened to have thick walls. Thinner-walled steel should work just as well but could reduce the weight meaningfully so that each track piece could be more safely carried.

The end gate worked relatively well. The only issues with its operation were not so much with the end gate itself as they were with the pitched angle of the ASTH as discussed in Section 4.3.2.

7 Conclusions and Recommendations

The objective of this report was to evaluate two screeds designed for concrete repairs and two designed for asphalt repairs and make recommendations toward an integrated screed capable of both concrete and asphalt repairs. Key goals for the integrated screed were that it would reduce the manpower required to 2 persons, could be capable of screeding small or large crater sizes in less than 6 min, and was overall less cumbersome to use than current screeds. A telehandler is the projected preferred prime mover for any screed attachments within the RADR base recovery process, so screed designs were preferred to be compatible with this piece of equipment.

Two asphalt screeds, the simple strike-off (SSO) and bucket strike-off (BSO), developed and tested by ARA, were obtained and tested in this project. Two prototype concrete screeds, the hydraulic and telehandler versions of the Autoskreed (ASHyd and ASTH, respectively), were also tested. All screeds were tested at ERDC for their ability to screed both asphalt and concrete repairs of both small and large craters.

Following the initial evaluation, one screed was selected as the most promising for integrating asphalt and concrete screeding capabilities into one device. During the screed integration effort, additional work was conducted to design, fabricate, and evaluate various prototype attachments. This screed was also demonstrated during the RADR demonstration at Tyndall AFB in September 2017.

7.1 Conclusions

The initial evaluation of the four existing screeds indicated the following:

1. The SSO worked relatively well for all repairs except large concrete repairs. The SSO blade was not wide enough to span the 15-ft repair, making it very difficult to control grade. The SSO's greatest attribute relative to other screeds was its grade control end gates. These worked well for small repairs and reasonably well, though not perfectly, for large asphalt repairs.
2. The BSO worked relatively well for small repairs but did not work well for large repairs for much the same reason as the SSO (i.e., it was not wide enough to span the 15-ft repair). However, it had no grade control

system whatsoever, making any repairs beyond small ones quite difficult. In the asphalt cases requiring a roll-down factor, wooden blocks were required to control grade. Excess material waste was also observed due to material entering the bucket during screeding. The bucket design of the BSO's screed blade/board was the least ideal of all the screeds tested.

3. The ASHyd worked well for both small and large concrete repairs but did not work as well for small asphalt repairs. Large asphalt repairs were not attempted to avoid potential damage to the hydraulics. The ASHyd was not designed to push large masses of material such as a large head of asphalt. Having an onboard motor and hydraulics system, the ASHyd has parts that could present a greater maintenance and operation burden.
4. The ASTH worked well for both small and large concrete repairs. The asphalt repair attachments supplied by Nasby did not work well. Despite this, the ASTH exhibited the most potential of all screeds tested as long as better attachments were designed. The most appealing attributes of the ASTH were as follows: it was relatively simple with no major mechanical parts (e.g., no hydraulics), it was wide enough to span 15-ft repairs, and it exhibited potential for straightforward modifications to adapt to handle asphalt repairs.

Based on the initial evaluation, the ASTH was selected for screed integration efforts. Key conclusions from this effort are as follows:

1. The largest shortcoming of all screeds in the initial evaluation was the ability to control grade; consequently, it was the primary focus during the screed integration effort. A device termed the automatic grade control system (AGCS) was developed to provide grade control during asphalt repairs and also to eliminate the need to manually adjust jacks during screeding. A track was designed to be placed inside the crater repair for the AGCS to ride on. Together, these components worked well aside from a few issues that related to the ASTH's travel springs and lack of torsional stiffness in the screed board.
2. The ASTH also lacked a grade control ski for the outside screed edge that rode on the parent slab. The one developed worked well unless the vibrators were switched on, in which case the grade control jack would unwind itself, lowering the grade of the screed.

3. An end gate was designed to control the width of asphalt repairs. It demonstrated the ability to work well aside from issues with the ASTH's travel springs that often caused the ASTH to not ride level.
4. Attributes of the ASTH such as the stiff travel springs and the location of the screed board along the ASTH frame presented issues, namely in making it difficult to set and maintain the ASTH at a level position. These issues could be resolved in a redesigned ASTH prototype with relative ease.

During the RADR demonstration, the ASTH and current screeds (magnesium screed bar and Screed King) were directly compared in a troop exercise. The ASTH was reviewed favorably in comparison to the current screed devices. The ASTH was about 1 min faster on average and required only an operator and spotter compared to the 3 or more airmen required to operate the current screeds.

7.2 Recommendations

Based on the testing conducted in this project, the overall recommendation is to consider the integrated screed design presented in Chapter 6 for future testing and, potentially, implementation. The design is based on the ASTH as it demonstrated good versatility and potential for modifying with quick-connect types of attachments. Chapter 6 discusses recommendations for the redesigned ASTH in depth, but key points are as follows:

1. The screed frame should be reconfigured to a more compact state as the current ASTH frame is unnecessarily large. The screed board should be relocated from the front of the ASTH frame to the back so that downward forces applied by the telehandler are transmitted directly into the screed board rather than converted into a rotation of the entire ASTH. The travel springs should be replaced with lighter springs that do not require as much force per inch of compression. Relocating the screed board and replacing the travel springs should greatly improve the ease with which the ASTH can be set and maintained in a level position during screeding.
2. The redesigned screed includes multiple attachments. Space along the screed frame should be taken advantage of by providing locations in which the attachments can be stored when not in use. This prevents the need to keep track of loose attachments.
3. The ASTH screed board should be redesigned to provide a taller and stiffer screed board. The added height would prevent asphalt from

overtopping the board. The increased torsional stiffness would improve the function of grade control attachments. As it would likely be a truss configuration, finite element modeling could be an ideal solution for economically designing an improved screed board. The sacrificial Nylatron® strip should be included, but its attachment to the screed board should be redesigned to minimize the chance of shear failure.

4. The ASTH attachments should be slightly refined in future iterations. For example, a locking mechanism could be added to the grade control jacks so that they would not be affected by the vibrators. The AGCS could be simplified or refined to the extent possible to increase its robustness and resistance to damage.

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14. ABSTRACT

An important task in the rapid airfield damage recovery (RADR) crater repair process is screeding the capping material, which may be either hot mix asphalt or rapid-setting concrete. The repaired surface must meet roughness quality check (RQC) requirements of ±0.75 in. to prevent fighter aircraft damage. Currently, the screeds recommended to meet RQC criteria for concrete repairs are cumbersome, slow, and require three or more personnel. Additionally, no screed has been identified to enable proper asphalt repairs. This project's objective was to evaluate prototype screeds (two asphalt, two concrete) and propose a single integrated screed for screeding either material to assist the RADR program in its efforts to develop lighter, leaner equipment. The new screed must also reduce manpower requirements, be less cumbersome to operate, and be able to perform small and large crater repairs.

All four prototype screeds evaluated within the scope of this study reduced manpower and created a satisfactory surface finish when properly employed. Key differences affecting results were screed board shape and the ability to control the grade of the screed. Ultimately, the telehandler-powered Autoskreed was selected as the most promising system because both asphalt and concrete screeding activities could be integrated into a single device. Additional attachments were designed and tested, and a final integrated screed design is presented in this report that satisfies the project's objectives.

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