STATE-OF-THE-PRACTICE: RUBBLIZATION OF AIRFIELD PAVEMENTS

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INTRODUCTION

Rubblization is the in-place process of fracturing an existing Portland Cement Concrete Pavement (PCCP) into small, interconnected pieces that can then serve as a base course for a new Hot Mix Asphalt (HMA) overlay. Because there are no hauling or disposal costs, and none of the existing pavement system is discarded, rubblization is a very cost-effective rehabilitation method. Since the rubblization process fractures the existing PCCP into small pieces, the underlying slab integrity that can cause reflective cracking is eliminated. All existing pavement layers remain to serve as critical structural support layers for the new Hot Mix Asphalt (HMA) overlay. The net effect of rubblizing is to convert a deteriorating rigid pavement system into a new and well-serving flexible one.

Since the early 1990s, the most common procedure for PCCP rehabilitation has been rubblization. From 1994-2002, highway agencies in the northeast, south and midwest United States have rubblized and placed Hot Mix Asphalt (HMA) over more than 41 million square meters (50 million square yards) of highways. The number of rubblization projects each year continues to grow.

While rubblization technology and equipment was initially developed for highway pavements, there is a tremendous need to rehabilitate aging airfield pavements as well. Airfield PCCP pavements often have significantly greater thicknesses as compared to highway PCCP. Within the FAA Integrated Airport System airfield infrastructure and the U.S. Department of Defense airfield inventory, there are more than 83 million square meters (100 million square yards) of PCCP greater than 33 cm (13 in) thick and more than 35 years old. These aging pavements will likely need major rehabilitation within the next 10 years. Traditionally, concrete pavement restoration (CPR) procedures (including sub-sealing, full-depth patching, partial-depth patching, load transfer reconstruction, diamond grinding, and joint sealing) have been employed to maintain these airfield pavements in a fair to good condition. The CPR procedures are becoming less effective today, as the pavement condition ratings reach a critical point, where major rehabilitation is required.

RUBBLIZATION PROCESS

Rubblizing PCCP means the complete destruction of any slab action before applying a HMA overlay. The concrete-to-steel bond is broken in jointed reinforced concrete pavements (JRCP) and continuously reinforced concrete pavement (CRCP). Rubblization effectively reduces the existing concrete pavement to an in-place crushed aggregate base having a high degree of particle-to-particle interlock. The rubblized base eliminates inherent distresses (such as reflective cracking, D-cracking, or alkali silica reaction) and provides a sound base for the HMA.

Rubblization saves natural resources, expedites construction, and is environmentally friendly as a rehabilitation technique. The old PCCP stays in place and becomes the base for the new HMA pavement, thereby reducing or eliminating the need for new virgin aggregates. Weather delays are minimized, since the subgrade is never opened up and exposed to the elements. Rubblization eliminates the need to remove and dispose of the old PCCP, thereby reducing air pollution (truck exhaust and fugitive dust) and saving landfill space.

The procedural steps in the rubblization technique are essentially the same for airfields as they are for highways. These steps are:

- Mill and Remove Any Existing Asphalt
- Install a Side Drain System
- Isolate Any Adjacent Sections with a Full-Depth Sawcut
- Rubblize the Concrete Pavement
- Cut Off and Remove Any Exposed Steel Reinforcement
- Remove Exposed Joint Sealing Material
- Roll the Rubblized Concrete Pavement
- Remove and Patch Any Unstable Areas
- Place Asphalt HMA Leveling Course/HMA Overlays
- Pave Transitions To Existing Pavement Surfaces
- Adjust Shoulders Grades as Necessary

There are two basic types of rubblization equipment, the resonant pavement breaker (RPB) and the multi-head breaker (MHB). These two machine types are described below.

RESONANT PAVEMENT BREAKER (RPB)

Various models of the RPB exist. All are self-contained, self-propelled units that vary in size and weight. The largest model is the RB-500 (Figure 1), which is a sixth generation machine developed to rubblize heavy load PCCP (greater than 13 inches thick). The RB-500 weighs approximately 30,000 kg (68,000 lb) and is powered by a 447kW (600HP) diesel engine. The breaking unit produces low amplitude (12.5-25 mm [0.5-1 in]), high frequency (42-46 hertz) impacts delivered through a massive steel beam. This vibrating beam is 3.8 m (12.5 ft) long and has been described as a “giant tuning fork.”

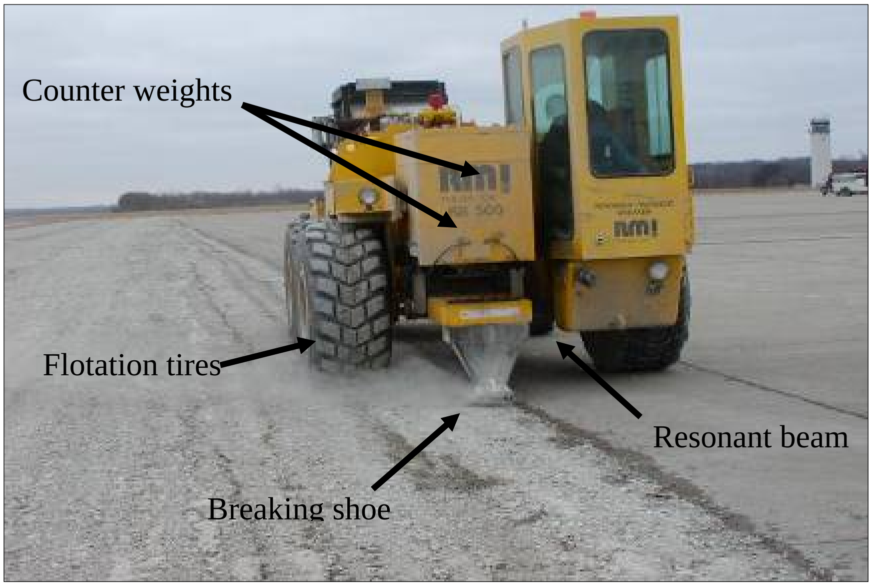

Figure 1. Resonant Concrete Pavement Breaker

The vibrating foot rubblizes the concrete pavement in narrow strips as the machine moves forward along the free edge or unfractured edge of the existing pavement. The forward speed of the machine depends on the size of the machine, slab thickness, the stiffness of the PCC, and the support provided by the subgrade. Generally, one machine can be expected to rubblize from 5,000 to 7,000 m^2 (6,000-8,000 yd^2) per workday shift, with thick airfield pavement work being on the low end of this range. For critical projects, multiple machines can be employed to expedite the process.

Light load airfield PCCP, typically found on general aviation (GA) airfields and on some USAF Auxiliary Fields, can be as thin as six inches. It is important to protect the freshly rubblized material from being overloaded by the repetitive operations of the RPB. For light load PCCP with soft subgrades or high water tables, special flotation tires (lower tire pressures) may be required to avoid damaging the rubblized and underlying layers.

Rubblization of airfield pavements using a RPB must start at a free or unfractured edge and continue with successive passes until it has moved transversely across the width of the pavement (Figure 2). This makes the process self-regulating. Any attempt by the operator to move too far into the pavement transversely, and away from the free edge, results in less and less fracturing of the pavement, until finally the machine can no longer fracture the pavement. When this happens, breaking energy is no longer absorbed by the pavement, but is reflected back into the machine itself, producing a noticeable “hammer and anvil” effect where the hammer merely bounces off the pavement surface and very little breaking is accomplished.

Figure 2. Starting from Free Edge

Relief Trenches: As RPBs work along the unfractured edge of an existing PCC pavement, a small amount of horizontal and vertical expansion takes place (Figure 3). Early airfield rubblization projects required relief joints (Figure 4) to be cut full-depth through the pavement, at fixed intervals, to take up the horizon expansion which accumulates as large areas are rubblized. Recent advancements in RPB design and technology, including significant horsepower increases, have all but eliminated the need for cutting relief trenches in the pavement prior to rubblization. However, certain combinations of older and smaller breakers, and thicker pavement sections, can result in situations where relief trenches are still necessary. The need for relief trenches will show up in the form of the “hammer and anvil” effect as described above and reduced breaking effectiveness.

Figure 3. Vertical Displacement Prior to Rolling

Figure 4. Relief Trench Cut with a Wheel Saw

MULTIPLE-HEAD PAVEMENT BREAKER (MHB)

The MHB is a rubber-tired, self-contained, self-propelled unit (Figure 5). It consists of six pairs of 544 kg (1,200 lbs.), 20 cm (8 in) wide hammers mounted laterally in pairs, with half the hammers in a forward row and the remainder diagonally offset in a rear row, so that there is continuous breakage from side to side. Wing units, carrying two 680 kg (1,500 lb) hammers, can be added to each side for a total breaking width of up to 4.0 m (13 ft). In the 16-hammer configuration, the MHB weighs 25,855 kg (57,000 lb). Each pair of hammers is attached to a separate hydraulic lift cylinder, with an adjustable drop height from 0-1.5 m (0-60 in). Each pair operates as an independent unit, and develops between 1,355 to 10,800 joules (1,000 to 8,000 foot-pounds) of energy depending upon the drop height selected, and cycles at a rate of 30 to 35 impacts per minute.

Figure 5. Multiple Head Breaker

By controlling the individual lift cylinder for each pair of hammers, the MHB can rubblize in 0.6 to 4 m (2 to 13 ft) widths at a production rate of approximately 418-1,254 m^2 (500-1,500 yd^2) per hour. This allows the multiple-head breaker to rubblize a 3.8 m (12.5 ft) wide lane, while traveling at a speed ranging from 0.11 and 0.32 km per hour (0.07 to 0.20 miles per hour). Production rates are comparable to the RPB, and depend upon the strength and thickness of the slab and the underlying subgrade.

Rubblization using a MHB requires a single pass over the area to be rubblized. The tractor or power unit travels on the unbroken slab as it moves forward and tows the breaking unit behind. Because it is a single pass technique, there is no need for the MHB to travel on the rubblized surface. Fracturing of the slab is controlled by a set combination of the drop height, the frequency of the impacts, and the forward speed of the machine, as determined by doing a test strip/pit.

Guillotine Pavement Breaker: For heavy-duty airfield pavements (i.e., greater than 14 in thick), it may be necessary to utilize a guillotine pavement breaker, prior to a MHB, to expedite the rubblization process. This type of breaker (Figure 6) has rubber tires, is self-propelled, and generally weighs about 5,440 kg (12,000 lb). The drop height of the hammer is adjustable up to nine feet. The guillotine breaker makes the initial pass and pre-fractures the existing pavements, allowing the MHB to complete the rubblization. Another situation that may require the teaming of both a guillotine breaker and a MHB is if an interface exists within the PCCP, such as with an unbonded or partially-bonded rigid overlay. The interface between the two lifts creates a shear plane that absorbs some of the breaking force, requiring the PCCP to be pre-broken to ensure the bottom lift is adequately rubblized.

Figure 6. Guillotine Style Breaker

PROCESS DIFFERENCES

The two types of just described rubblization equipment operate in completely different modes to achieve the required rubblization of the PCCP. The RPB is a high frequency, low amplitude process, while the MHB is a low frequency, high amplitude process. Research is currently underway to document the effects of the different equipment types on the underlying subgrade integrity, rubblized layer permeability, and effective modulus.

The size of rubblized particles is dependent upon the amount of rubblization energy put into the pavement, the strength of the pavement itself, and the amount of support provided by the subgrade. The size distribution of particles is confirmed by digging test pits through the rubblized pavement, then visually inspecting to confirm project specifications are being met.

On light-load airfield pavements, soft spots within the subgrade can be detected by noticing a change of particle size, assuming the rubblization energy and PCCP thickness/ strength remains constant. When soft or unstable subgrade areas are detected, a solution must be worked out. The solution may be as simple as allowing additional time for the underdrains to work, putting floatation tires on the RPB, or changing the drop height of the MHB. More extreme cases may require undercutting and backfilling with suitable material.

PREPARATION OF THE EXISTING PAVEMENT SURFACE

For the rubblization equipment to work properly and transmit the optimal amount of energy to the existing PCC pavement, all HMA overlays must be removed prior to rubblizing the underlying concrete.

Adjacent pavements, that are not to be rubblized, must be isolated from the rubblized pavements. This is best accomplished by cutting a relief trench with a wheel saw (Figure 4), or by utilizing two parallel full-depth diamond blade saw cuts spaced approximately six inches apart. Either method allows the rubblizing equipment to work up to the project limits without damaging the structural integrity of the pavement that is to remain in place.

Underground structures, utilities, and in-pavement fixtures must be identified as needing protection during the rubblization process. Specifications are then written which require the contractor to operate his equipment in such a manner as to not damage these existing features. In–pavement features on airfields, such as drainage inlets, electrical fixtures and conduits, must be noted during design. Isolation or removal and replacement may be required during the rubblization process. Provisions also must be made to raise all in-pavement features to the grade of the new HMA pavement.

Installation of Underdrains: Experience has shown that a key element to a successful rubblization project is the installation of a properly designed underdrain system. Underdrain systems serve two purposes. Prior to the rubblization process, underdrains dry out and stabilized the subgrade, while during the service life of the new pavement, they prevent water from becoming trapped inside the different layers of the pavement structure.

During the rubblization process, water trapped in the subbase or subgrade will weaken the subgrade and cushion the impacts from the pavement breakers. This loss of subgrade support will substantially reduce the amount of pavement fracture and increase the overall size of the rubblized particles. To insure proper subgrade drainage, rubblization specifications require underdrains to be installed a set period of time prior to commencing rubblization. In most specifications, this is a minimum of two weeks.

During the service life of the pavement, the underdrain system must have sufficient capacity and depth to collect and carry the water being discharged from the subgrade, the old permeable base, and the top or “permeable zone” of the rubblized layer (see Figure 7). The trench depth must be deep enough to accomplish the intended drainage function. It is recommended that the trench depth be deep enough to allow the top of the pipe to be located a minimum of 5 cm (2 in) below the bottom of the permeable base material. The filter fabric and trench backfill material must also be designed with sufficient capacity to handle the outflow from the new pavement structure. Erosion of fines into the side drain system should not pose any problem, as neither the base or the rubblized concrete should contain erodable fines that would tend to clog the system.

Polyethylene tubing, as used in agriculture, and thin “fin” style drains, as used along highways, do not have sufficient strength or capacity to handle the outflow and should not be used for airfield underdrains. Pipe underdrains, such as rigid corrugated PVC with smooth interior walls, are recommended because of their strength, high flow capacity, and their configuration for easy maintenance.

Installation of the outlet pipe is critical to the edge drainage system. It is recommended that a metal or rigid (PVC) non-perforated pipe be used for the outlet pipe for strength and capacity. A grade of at least three percent is recommended, so that the pipe will continue to drain if there is a light variance of the pipe grade. Since the purpose of subsurface drainage is to remove water as quickly as possible, it is recommended that the outlet spacing be a maximum of 75 m (250 ft). The edge drainage design should be coordinated with surface drainage to handle removal of all sources of water.

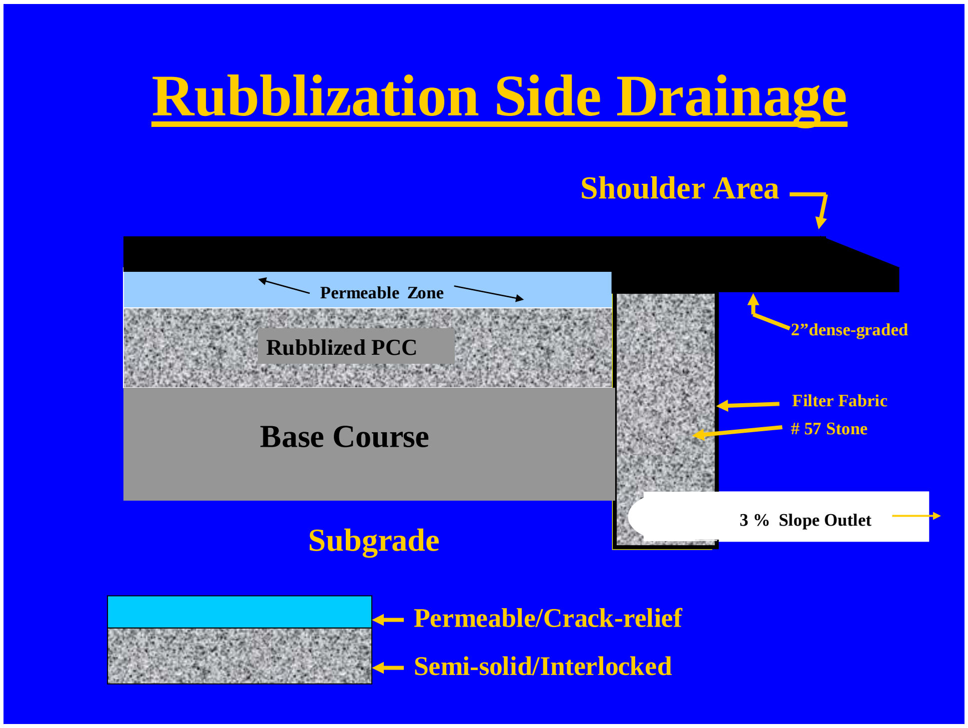

Figure 7. Typical Drainage System

PREPARATION OF THE RUBBLIZED SURFACE

After rubblizing the PCCP, and prior to placing the HMA overlay, the surface of the rubblized material must be given one of the following rolling treatments. The purpose of the rolling is to tighten the surface, by seating loose particles, as well as smoothing the surface in preparation for repaving. This rolling is not intended to achieve additional densification of the rubblized material or underlying layers. Excessive rolling could actually destroy particle interlock and cause a weakening of the rubblized layer.

Generally, rubblization produces very little fugitive dust. The small amount (Figure 8) that is produced is usually not a problem on closed areas of an airfield. However, where traffic is maintained on nearby parallel runways, taxiways, or aprons, dust control may become an issue. Water as a dust palliative should be applied sparingly and only as needed to control fugitive dust.

Figure 8. Dust generated during Rubblization

After rubblizing with the Resonant Breaker – Roll the crushed concrete with at least two passes of a smooth vibrating steel wheel roller weighing a minimum of 9,000 kg (10 tons) for surface smoothing and further alignment of the fractured concrete pieces.

After rubblizing with the Multiple-Head Breaker – Roll the crushed concrete with two passes of a vibratory steel drum roller fitted with a special “Z” pattern grid on the drum face. The grid roller should weigh a minimum of 12,700 kg (14 tons). This provides a uniform surface and reduces the size of the surface pieces. The grid roller is followed by a 22,680 kg (25 ton) pneumatic-tired roller for final seating.

Leveling Course**:** Rubblized surfaces cannot be trimmed or fine graded like conventional granular surfaces. Larger pieces will be disturbed by the fine grading equipment, resulting in the loss of particle interlock and an overall reduction in the strength of the rubblized layer. Leveling courses may be necessary to accommodate grade and profile corrections. Leveling courses have included Item P-209 (FAA’s aggregate base specification) or Item P-401 (FAA’s HMA specification). Aggregates manufactured from recycled PCC pavements that have been removed and processed to meet the requirements of P-209 have also been used successfully as leveling courses.

Traffic Control: Heavy construction vehicles on a rubblized surface can destroy particle interlock and reduce the overall strength of the rubblized layer. Construction traffic on the rubblized surface should be minimized until the first layer of HMA has been applied.

PERFORMANCE SPECIFICATIONS FOR RUBBLIZING

Rubblization specifications, especially for heavy-load airfield PCCP, should be written as “performance based” to include requirements on the size of pieces through the full depth of the rubblized concrete. Recent developments with both equipment types have resulted in different techniques for accomplishing a satisfactory product. Projects described in the next section (Wright- Patterson AFB and Selfridge ANGB) demonstrate that rubblizing heavy-duty airfield PCCP can be successfully achieved with either type of equipment.

FAA Engineering Brief No. 66, *Rubblized Portland Cement Concrete Base Course*: In February 2004, the FAA adopted and published this guidance and specification for rubblizing existing PCCP. The publication of EB 66 will facilitate even more use of the rubblization technology on airfields. For a designer to use EB 66 on a FAA project, a “modification to standards” must still be submitted through proper approval channels. In writing EB 66, the FAA consulted the Asphalt Institute, rubblization equipment manufacturers, the U.S. Air Force and others in the industry. The guidance and performance related specification in EB 66 represents state of the practice for rubblizing airfield pavement and is recommended for use.

It is recommended that, <u>as a minimum</u>, specifications for rubblizing airfields contain the following items:

- Scope of work for rubblizing and rolling as shown on the plans.
- Submittals, including a description of the rubblizing and rolling equipment.
- Preparation of the pavement, including removal of all asphalt layers and full-depth saw cutting to isolate the pavement being rubblized.
- A test strip: Using the proposed equipment, rubblize a test section 3.7 m (12 ft) by 46 m (150 ft) in the outer extremity of the project.
- Test pit excavation and inspection: At no additional cost, the contractor shall provide adequate equipment and excavate a test pit within the test strip area. All test pit excavations shall extend completely through the rubblized PCCP and remove any steel reinforcing that may be present to completely expose the subgrade. The user agency will inspect the test pit for particle size and debonding of steel reinforcing.
- No rubblization will be allowed outside of the test strip area until the rubblization process has been approved.
- Test pits should be required whenever the pavement cross section changes, or every 30,000-40,000 m^2 (35,880-47,840 yd^2), depending on the size of the project.
- Particle size criteria: EB 66 requires the rubblized PCCP to have at least 75% (as determined by visual observation) of particles smaller than 75 mm (3 in) at the surface and 300 mm (12 in) in the bottom half. For reinforced PCCP, the reinforcing steel shall be substantially debonded from the concrete and left in place, unless protruding above the surface. Concrete pieces below the reinforcing steel shall be reduced to the greatest possible extent, and no individual piece shall exceed 380 mm (15 in) in any dimension.
- Rollers: Depending on the method of rubblizing, the user agency shall specify the roller type, minimum roller weight, and number of roller passes, per earlier discussion under *Preparation of Rubblized Surface*.
- Removal of weak areas: Replace with full depth asphalt patches, as required by the user agency. This is considered an additional pay item.

AIRFIELD PAVEMENTS

Tables 1 and 2 list past airfield rubblization projects reported to have been accomplished by Antigo (operates the MHB) and RMI (operates the RPB), respectively. We are not aware of any other airfield rubblization projects beyond those listed. Both tables include the airfield, location, year, square yards and thickness of PCC rubblized. Antigo also provided the thickness of the HMA overlay and some comments, which are included in Table 1. Comments in Table 1 include when the guillotine-type breaker was used to pre-break the PCC (typically when PCC is more than 14 in thick) and when an unbound leveling course was utilized prior to the overlay. Both tables include projects where an HMA overlay was not utilized, either because a PCC overlay was placed or because the rubblization was strictly for removal of the PCC. By listing the projects chronologically, one can see the significance of the Wright Patterson AFB and Selfridge ANGB projects, because those were the first demonstrations of rubblization on heavy-load pavements having PCC thicknesses significantly greater than found in highways.

Additional statistics were provided by Antigo. The total square yards of crack/break and seat performed by Antigo between 1982 and 2006 was 62.9 million, while 1.5 million of that total was on airfields. The total square yards of rubblization performed by Antigo between 1982 and 2006 was 25.2 million, while 0.7 million of that total was on airfields.

Installation, Location, Airfield Designation	Year	Concrete Rubblized (yd^2)	Thickness of Existing Concrete (inches)	HMA Overlay Thickness (inches)	Comments
Rantoul Airport, IL, R/W 18-36 & T/W 'F'	1999	45,670	6-8	5	Demonstrated three maximum surface sizes: 3", 9", 18"
Columbus Airport, IN, T/W 'C' & West Apron Taxilane	2000	24,975	6	7.5	
Watertown Airport, SD, Apron Area	2001	39,456	8	4	Asphalt milling (3") placed prior to HMA overlay
Rantoul Airport, IL, R/W 9-27	2001	3,625	6-8	4.6	
Kalamazoo/Battle Creek Airport, MI, T/W 'E'	2002	5,250	8	11.5	
Selfridge ANG Base, Detroit, MI, R/W 01-19	2002	95,706	13, 16, 19 and 21	7	Pre-break w/ guillotine, crushed agg. (4.5") for grade correction
IN ANG Base, Ft. Wayne, IN, Parking Ramp & T/W	2003	25,258	10	-	13" JPCP overlay
Watertown Airport, SD, Hanger area	2003	1,982	6	3	Asphalt millings (3") placed prior to HMA overlay
Ephrata Airport, WA, R/W 11-29 & T/W B-2	2004	26,500	6	4	
Columbus Airport, IN, T/W 'E'	2004	12,768	6	7	
Capital Airport, Springfield, IL, R/W 4 O.R.	2005	15,000	10	3	
Grand Forks AF Base, ND, R/W 17-35	2005	237,558	19-23	9	Pre-break w/ guillotine, crushed agg. (4 -13") for new crown
Buffalo Niagara Airport, NY, T/W 'A'	2005-06	21,562	11	8	
San Juan International A.P, Puerto Rico, R/W 10-28	2005-07	147,143	15	-	Pre-break w/ guillotine, crushed agg. (3-6") prior to PCC overlay
Pierre Airport, SD, R/W 13-31 Blast Pad	2005	4,984	9	4	
Toledo Metcalf Field, OH, R/W 4-22	2006	29,542	6	3	Crushed aggregate (variable) placed prior to HMA overlay

Table 1. Antigo's (MHB) Airfield Rubblization Projects from 1999-2006 (Antigo)

Installation, Location	Year	Concrete Rubblized (yd^2)	Thickness of Existing Concrete (inches)
Navy Air Base, C-17 Assault Strip, SC	1995	50,000	9
Jacksonville Navy Air Station, TW A, FL	1997	26,000	11
Grant County Airport, RW 4-22, Moses Lake, WA	2000	55,000 of which 31,000 removed	6
Wright Patterson Air Force Base, Parking Apron, Dayton, OH	2002	65,000 All for Removal	21-26
Walla Walla Regional Airport, RW, Walla Walla, WA	2003	140,000	7-9
Buffalo/Niagara Airport, TW A, Buffalo, NY	2003	50,000	12
	2004	36,500	12
Air National Guard Base, Rochester, NY	2004	20,000	12
Naval Air Station, NJ	2004	6,000	9-12
	2005	6,000	9-12
Pratt Airport, R/W 17-35, Pratt, KS	2005	62,400 PCC Overlay	7-8
Dover Air Force Base, Dover, DE	2005	80,000	10-20
Hanscomb Air Force Base	2005	12,500	10-12
Kegelman Auxiliary Field, R/W, near Vance Air Force Base, Enid, OK	2006	135,000	6

Table 2. RMI's (RPB) Airfield Rubblization Projects (RMI)

WRIGHT-PATTERSON AFB, OHIO

The heavy load concrete aircraft parking aprons at WPAFB, near Dayton, OH, were more than 40 years old when reconstruction began in 2000. The first parking apron was reconstructed in a traditional manner, using a lifting and removing technique that was expensive and time consuming, taking more than three months to complete. When the second parking ramp, with thicknesses of 21 to 26 inches of non-reinforced PCCP, was scheduled for reconstruction in the summer of 2002, the contractor decided to try rubblization. The resonant breaker RB-500 rubblized 50,100 m^2 (63,100 yd^2) in ten working days. While rubblization on this project was to facilitate removal, the PCCP was completely rubblized and broken into pieces no larger than 12 inches through the concrete sections. Inspection of the rubblized material proved that the thickest heavy load PCCP's could be rubblized in place and used as high quality base material. In terms of removal, rubblization on this project proved to be more economical than traditional methods of removing PCCP. The contractor estimated that the rubblized concrete pavement removal was accomplished in 1/5th of the time and at 1/3rd of the cost.

SELFRIDGE ANGB, MICHIGAN

Selfridge ANGB, near Detroit, MI, serves five military branches of service. The air operations utilize both a 2,743 m (9,000 ft) runway and a 1,524 m (5,000 ft) runway, along with adjacent taxiways and aprons that contain over 836,000 m^2 (1,000,000 yd^2) of paved surface. The main runway, built in 1959, had non-reinforced PCCP sections up to 53 cm (21 in) thick.
By 2002, the pavement was so badly deteriorated that it could no longer be maintained in a safe condition. To accomplish the reconstruction in the most economical and expedient manner possible, the old pavement was rubblized and used as the aggregate base for a new HMA pavement. A taxiway was pressed into temporary service as a runway, while the contractor was given only five and one-half months to completely rebuild the main runway, or face charges of $15,000/day in liquidated damages.

By specifications, an extensive underdrain system was installed well in advance of beginning the rubblization process. This system was designed to have a maximum spacing of 250 feet between outlets to ensure an adequate amount of drainage. The contractor used a portable crusher on site to recycle the PCCP removed from the touchdown zones. This recycled material was used as a 10 cm (4 in) aggregate leveling course on the rubblized material to adjust grade and crown. The new pavement is 18 cm (7 in) of HMA.

In May 2002, 79,432 m^2 (95,000 yd^2) of concrete runway was rubblized in 16 days. To meet this specification, the PCCP was first broken using a guillotine-type concrete pavement breaker and then completely rubblized with the multiple-head breaker in the sixteen-hammer configuration. A grid roller was then used to further pulverize the concrete particles at the surface and begin the seating process. Final seating was accomplished with a 25-ton pneumatic-tire roller. The contractor was required to prove compliance with the specifications before being allowed to continue with full production rubblization.

Performance of the asphalt overlay has been good, with only minor reflective cracking after five years. Recent falling weight deflectometer testing on the 53cm (21 in) thick PCC layer at Selfridge ANGB shows modulus values ranging from 450 ksi to 750 ksi.

GRAND FORKS AFB RUNWAY

This 2005 airfield rubblization project is clearly the largest to date, in terms of both cost ($27.5M) and rubblized area (237,000 yd^2). The PCC slabs were predominantly 19 inches thick (some thicker), and consisted of a very hard river-run gravel aggregate. A 15-inch gravel base and 34-inch sand subbase were below the slabs. The condition of the pavement before this project is shown in Figure 9.

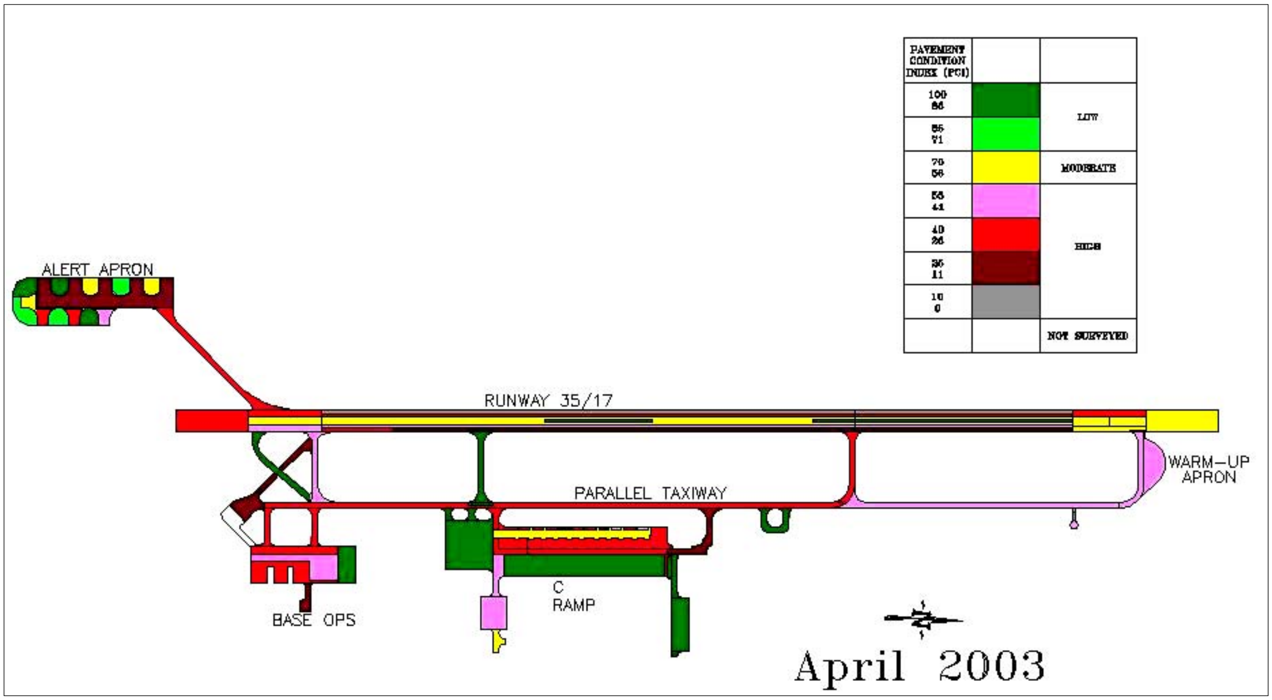

Figure 9. Pavement Condition Rating Prior to Project

The effort at Grand Forks AFB included:

-Demolish/remove 75 feet on each side of the existing 300-foot wide runway.
-Crush the removed PCC for use as aggregate base.
-Rubblize the 150-foot wide center portion of the existing PCC.
-Reconstruct the center 10,000 feet of runway with new asphalt and crushed PCC base.
-Reconstruct 1,000-foot ends with new PCC.
-Construct new asphalt paved overruns and shoulders.
-Install new runway edge lights, threshold lights and approach lights.

Two RB-500 units (RPBs) were first utilized on the project and test pits confirmed that specification gradation requirements were met. However, the prime contractor decided production was too slow, so the RPBs were replaced with multiple guillotine hammers and MHBs to complete the majority of the work. Subsequent test pits of the MHB showed that gradation requirements were met at the surface, but not at the bottom of the slab, with some pieces as large as 36 inches. The engineer/ owner waived this aspect of the requirements.

The PCC that was removed from both runway ends was run through a crusher (Figure 10) and re-used as a base course above the rubblized surface to correct grade for a new offset crown.

The project also included installing a substantial underdrain system along the centerline and both edges of the new runway, which required trenching through the full depth of PCC. These trenches were also utilized for new runway lighting electrical conduit.

Figure 10. PCC Crushing Operation

This runway had an offset crown. The crown was reestablished to the centerline of the runway, which required the placement of 4-13 inches of crushed aggregate. Nine inches of asphalt surface was placed on the runway (Figure 11). An aerial view of the completed runway is shown in Figure 12.

Figure 11. Placement of New Asphalt Surface

Figure 12. Aerial View of Completed Runway

KEGELMAN AUXILIARY FIELD RUNWAY

This was a project with “marginal” conditions for effective rubblization. Based on previous USAF Airfield Pavement Evaluation Reports, the plain PCCP slabs were 4.7 to 6.5 inches thick, with a thin to no sand subbase, over a silty-sand subgrade that “turned to mush when wet.” The subgrade K-value from a USAF evaluation test pit was 108. Drainage was poor.

A 5-inch HMA overlay was placed directly over the rubblized surface. No drainage system was installed due to budget issues.

The specification called for using the RPB exclusively. Rubblization started in the Spring, under normal wet conditions. The RPB did not punch-thru, but rather excessive pumping and rutting occurred (Figure 13). High-float tires on the RPB were not used at the start, but were later on, which helped reduce rutting. By the end of the project, the percent of full-depth patching was about 30% of the rubblized area. This percentage grew as the process moved towards the centerline. In the unstable areas, the engineers decided to excavate 2 to 4 feet into the subgrade to ensure all the “mush” was removed (Figure 14). Crushed PCC and aggregate was used as patch material.

Figure 13. Rutting from RPB of Unstable Area at Kegelman that Requires Excavation

Figure 14. Full-depth Excavation Deep Into Subgrade of Patched Area at Kegelman

RECENT OR ON-GOING RESEARCH AND ASSOCIATED WORK

Recent and on-going research in the United States for airfield pavements includes:

- An effort by the U.S. Army Corps of Engineers, Engineering and Research Development Center, funded by the U.S. Air Force, to develop a procedure to determine the required asphalt overlay thickness using layered elastic procedures.

- An effort by The Asphalt Institute, funded by the FAA. The objective of this research is to document rubblization technology and prepare a guide specification and a design and construction manual for use by engineers involved in the design and construction of airfield pavements.

- A major effort at FAA's National Airport Pavement Test Facility to generate full-scale pavement response and performance data for the development/verification of airport pavement thickness design procedures and criteria.

SUMMARY

Rubblization and repaving with HMA is quickly becoming the PCCP rehabilitation technique of choice for old deteriorated PCCP airfields. In the past seven years, well over one million square meters of PCCP had been rubblized, leaving in place a stiff unbound granular base layer ideal for new HMA pavements. The majority of airfield rubblization projects have taken place in the last five years. These projects range from heavy load military airfields, handling some of our largest aircraft, to local general aviation airfields that handle the smallest aircraft. These projects also cover a wide range geographically, from Florida to Washington (state) and from Tennessee to upstate New York.

The Wright-Patterson AFB project, in 2002, demonstrated that the Resonant Pavement Breaker can successfully rubblize up to 26-inches of PCCP, resulting in aggregate particles smaller than 12 inches throughout the concrete thickness. The Selfridge ANGB project demonstrated that the Guillotine Breaker, followed by a Multiple Head Breaker, can successfully rubblize up to 21-inches of PCCP.

With the FAA's recently published guidance and specification for rubblizing airfield PCCP (EB 66), the use of rubblization should continue to grow on both civilian and military airfields. The same benefits that highway agencies realize with rubblization are being recognized by airfield agencies. This is vital, as our airfield pavement infrastructure, much of which is PCCP, continues to age beyond the point of restoration.

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