Rubblization Using Multi-Head Breaker Equipment

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A comprehensive nationwide National Asphalt Pavement Association (NAPA) study published in 1991 indicated that rubblization was the most effective procedure for addressing Hot-mix-asphalt overlay (HMA OL) reflective cracking in portland cement concrete (PCC) pavements. In recent years, rubblization has also been effectively utilized to rehabilitate PCCs showing D-cracking and ASR (alkali-silica-reaction) distresses.

Since the late 1980s and early 1990s, PCC rubblization has gained favor and rubblization equipment and construction procedures have been considerably improved. Rubblization is currently the most-widely used PCC slab fracturing technique.

A prototype lane-width/one-pass multi-head breaker (MHB) developed by Badger State Highway Equipment, Inc., Antigo, Wisconsin, (MHB Badger Breaker®) was first utilized by Antigo Construction, Inc. (Antigo) in the 1995 construction season. This paper documents the development, capabilities, and effective utilization of the MHB for rubblizing PCC.

INTRODUCTION

NCHRP Synthesis of Highway Practice No. 144 (*1*) summarized Breaking/Cracking/Seating (B/C/S) practice and technology for PCC pavements. The primary goal of B/C/S was is to reduce (hopefully eliminate) HMA OL reflective cracking. The *NCHRP Synthesis* (*1*) considered B/C/S performance based on the monitoring reports of several agencies. In general, the techniques retarded but did not eliminate HMA OL reflective cracking. The delay period typically varied from 3 to several years, and longer delays were achieved with the thicker HMA OLs. B/C/S specifications that required smaller-sized B/C/S PCC segments typically displayed better performance.

At the time of the NCHRP Synthesis, rubblization applications were not as widespread as B/C/S, but several states had utilized the procedure. A comprehensive nation-wide National Asphalt Paving Association (NAPA) study published in 1991 (*2, 3*) indicated that rubblization was the most effective procedure for addressing reflective cracking. Rubblization destroys PCC slab continuity and eliminates transverse joints and the associated joint opening/closing which cause reflective cracking. Rubblization breaks the concrete into pieces that are substantially debonded from any reinforcement. In recent years, rubblization has also been effectively utilized to rehabilitate PCCs showing D-Cracking and ASR distresses.

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The Resonant Pavement Breaker (RPB) was a particularly significant early (mid-1980s) development. A prototype lane-width/one-pass MHB developed by MHB Badger Breaker was first utilized by Antigo in the 1995 construction season. This paper documents the development, capabilities, and effective utilization of the MHB.

DEVELOPMENT OF MHB BADGER BREAKER®

The MHB is a rubber-tired, self-propelled unit that carries hammers mounted laterally in pairs with half the hammers in a forward row and the remainder diagonally offset in a rear row. Thus, there is continuous breakage from side to side. Each pair of hammers is attached to a hydraulic lift cylinder that operates as an independent unit, develops varying energy depending upon drop height selected, and cycles at a rate of 30 to 35 impacts per minute. The 8-ft (2.44-m) wide machine carries 12 hammers 8 in. (200 mm) in width. A wing, carrying two hammers 12 to 15 in. (300 to 381 mm) in width, can be added to each side for a total effective breaking width of up to 13 ft (3.95 m). The breaking energy is applied to the pavement via 1.5-in. (38-mm) wide steel strike bars welded to the bottom of the hammers. Breaking widths can be as narrow as 3 ft (0.91 m) or increased in increments to as wide as 13 ft (3.95 m). The operator adjusts the travel speed of the MHB to match the conditions encountered throughout the project. Adjustments in hammer drop heights and travel speed are made to maintain the optimum breaking pattern. These adjustments allow the MHB to produce a wide range of breaking patterns. Larger-sized PCC segments provide increased "load-carrying" capacity (decreased falling weight deflectometer deflections and basins).

The prototype MHB (Figure 1) was built on an existing Bomag MPH100 chassis and first used in 1995. It was outfitted with 1,000-lb (4.4-kN) interior hammers and 1,500-lb (6.6-kN) wing hammers. The maximum hammer drop height was 48 in. (1.2 m). A second MHB prototype was built in 1996 on an existing Wirtgen concrete breaker chassis with the same hammer specifications as the first MHB. After operating these two MHBs for 2 years, a standard design was developed and the third and fourth MHBs were manufactured from the ground up and went to work in 1997 with the same hammer specifications as the prototypes. Figure 2 shows a current MHB model.

FIGURE 1 The "prototype" MHB (1995).

FIGURE 2 A recent model MHB.

These MHBs were effective rubblizing 6- to 9-in. (150- to 225-mm) thick concrete in Wisconsin and neighboring states. In 1998, Antigo rubblized a 14-in. (356-mm) thick PCC pavement on a section of the East–West Tollway (Interstate 88) in DeKalb County, Illinois. It was determined that more breaking energy was required to rubblize the thicker concrete while maintaining the desired production rate of 1 lane-mile (1.6 lane-km) per shift. The weight of the interior hammers was increased to 1,200 lb (5.3 kN) and the maximum drop height of all hammers was increased to 60 in. (1.52 m). This configuration was used effectively on all MHBs for several years.

Two 2002 projects led Antigo to increase the maximum breaking energy. A project at Selfridge Air National Guard Base near Detroit, Michigan, included the rubblization of a concrete runway with two layers of concrete with a total thickness of 21 in. (533 mm). Another project on I-495 in Massachusetts had very high strength concrete that caused a significant reduction in the hourly production rate. By increasing the front row hammers to 1,500 lb (6.6kN) and the wing hammers to 1,750 lb (7.7 kN) the MHB was able to maintain its production rate even when rubblizing very thick and/or very hard (high strength/high modulus) concrete. Wings with 2,000 lb (8.8 kN) hammers were also developed and are used on the occasional project that requires the extra breaking energy. A one-hammer style of wing is available for those conditions where a narrower pass is required. Another option Antigo has utilized is to pre-break thick PCCs with a single hammer, 12-kip (53.3-kN), guillotine-style breaker before completing the rubblization with the MHB. That option was used on the Selfridge project.

To date, 18 MHBs have been built. The combination of hammer weights varies across the machines. Some have all 1,200 lb (5.3 kN) hammers, some have all 1,500 lb (6.6 kN) hammers, and others have a combination of the two weights. The appropriate MHB and wing set-up are chosen depending on project job conditions.

PRODUCTION CAPABILITIES

Typical MHB production rates are 500 to 600 ft/hour (152 to183 m/hour) when rubblizing a typical 9-in. (225-mm) PCC. Production rates will vary depending on the strength/modulus of the concrete and underlying base/subbase/subgrade conditions. As many as four MHBs have been operated together to meet aggressive project HMA OL production schedules.

TRUCK-MOUNTED MHB

The most recent MHB development was the introduction in 2003 of a truck-mounted MHB (MHBT) shown in Figure 3. This is an 8-ft (2.44-m) wide MHB mounted on a truck. The operator can drive the truck from project to project and operate it in the same manner as the conventional chassis MHB. In order to meet maximum axle weight rules, the MHBT carries 1,200 pound (5.3 kN) hammers but the front row hammers have a maximum drop height of 72 in. (1.83 m). The higher drop height compensates for the lesser weight hammers when compared to the current standard 1,500-lb (6.6-kN) hammers on the chassis MHBs. The MHBT utilizes a wireless remote control that allows the operator to control it from the best vantage point.

FIGURE 3 The MHBT.

SUMMARY: MHB DEVELOPMENT

With the increased hammer weights and maximum drop heights, the MHB can effectively/efficiently rubblize thicker and stronger/higher modulus concrete pavements. A variety of fractured slab specifications (from rubblization to B/C/S) can be met with the MHB. However, the primary advantage of the MHB has not changed since the first one was built in 1995—the ability to vary drop heights across the machine and vary travel speed to produce an optimum breaking pattern while rubblizing a full lane-width in a single pass.

MHB BADGER BREAKER WHEEL LOADS

Wheel loads and loading conditions are important factors to consider in selecting rubblization equipment. MHB wheels only load the unfractured PCC slab. Only one machine pass is required since the MHB has lane-width capability. These factors are particularly important when

1. Rubblizing thin PCCs;
2. Base/subbase layers are thin and/or unstable; and
3. The subgrade is weak (low strength and modulus). The MHB considerably reduces (frequently eliminates) operational problems associated with the factors presented above.

The MHB Badger Breaker has two modes of operation. The base machine carries 12 8-in. (200-mm) wide hammers for a breaking width of 8 ft (2.44 m). Wings carrying two wider hammers can be added to each side for a breaking width of up to 13 ft (3.96 m). The 13-ft (3.96-m) wide mode is typically used when rubblizing on highways and airport pavements. The 8-ft (2.44-m) wide model is typically used when rubblizing urban streets. There usually are manholes and other utility items that must be avoided on urban projects and the narrower mode is better suited for this type of work.

The weight of the MHB in the 8-ft (2.44-m) wide mode is approximately 47,000 lb (207 kN). When the two wings are added the weight increases to approximately 58,000 lb (255 kN). The weight is carried on three axles: the steer axle (5 kips/22 kN), drive axle (43 kips/185 kN) and trailing wheels [total on two wheels is 10 kips (44 kN)]. The steer and drive axle widths are narrower than the 8-ft (2.44-m) wide breaking width and the breaking takes place at the rear of the machine, thus these wheels do not travel over the rubblized concrete. To help stabilize the machine, the trailing wheels are mounted behind the hammer cage. When necessary, two hydraulic cylinders mounted between the chassis and hammer cage can be extended to lift the trailing wheels off the rubblized pavement thus transferring all of the machine's weight to the unbroken pavement. Though slightly less stable, the MHB still operates effectively in this mode.

CRACK/BREAK AND SEAT WITH THE MHB BADGER BREAKER

The MHB Badger Breaker has been used primarily to rubblize concrete pavement prior to an HMA overlay. However, some specifications for fractured PCC result in fractured slab segments that could be characterized as coarse rubblization or small-sized B/C/S. Kentucky's Breaking and Seating specification requires that 80% of the PC segments be less than 24 in. (600 mm).

The ability to achieve a variety of fracture patterns with one machine is advantageous. The MHB has also proven to be effective as a crack/break and seat machine. The MHB has two types of operational controls: the hammer drop height and the machine's travel speed. The hammer drop height determines the amount of breaking energy that is applied to the concrete pavement. Each pair of hammers is attached to an individually controlled hydraulic cylinder and the drop heights can be varied across the width of the concrete being broken. The travel speed determines the hammer strike spacing.

When rubblizing concrete to meet a typical specification the hammer drop heights and the travel speed are set to break the concrete into particles with a maximum dimension of 2 in. (50 mm) at the surface of the slab and 9 to 12+ in. (225 to 300+ mm) at the bottom of the slab. Typical MHB operating settings for rubblizing a highway pavement are 5-ft (1.52-m) drop height and 3- to 4-in. (75- to 100-mm) strike spacing.

When cracking/breaking concrete to meet a typical specification the hammer drop heights and travel speed are set to produce visible, full-depth breaks in the concrete that produce broken pieces of concrete with a maximum dimension of between 12 and 24 in. (300 and 600 mm) depending on the particular specification. Surface spalling is kept to the minimum possible while still achieving full-depth breaking. The MHB operating settings are adjusted to meet the specification and are adjusted as necessary throughout the project to account for varying pavement and base conditions. The first step is to determine the minimum drop height that adequately breaks the concrete full depth. This may vary across the pavement being broken. Once this has been determined, the travel speed is set so as to produce the segment sizes required. If the specification calls for 12-in. (300 mm) size segments, the strike spacing is usually in the 10- to 12-in. (250- to 300-mm) range. The strike spacing is increased to produce larger PCC segments.

In summary, the operating settings of the MHB can be adjusted to provide concrete breaking patterns across the complete spectrum from total rubblization to light cracking. This flexibility allows for the use of the appropriate fractured slab technique to match each project's particular requirements. This flexibility is particularly valuable when unexpected conditions are encountered on a project as it allows for an immediate response to those conditions.

DISTINCTIVE FEATURES (ADVANTAGES)

Some distinctive features that contribute to MHB utility are

- The MHB is a lane-width/one-pass machine.
- The MHB can operate close to the pavement centerline/edge (traffic is frequently diverted to the adjoining shoulder lane/shoulder during construction) and traffic barriers without unduly interfering with traffic (Figure 4).
- By varying MHB operating characteristics (hammer weights, number of hammers, hammer drop heights, and travel speed) the MHB can produce a wide range of fracture patterns to accommodate individual project conditions such as
  - Differing specifications (rubblization to B/C/S),
  - Variable support (PCC thickness/concrete quality, base/subbase) conditions, and
  - Subgrade strength/modulus.
- Drop height and travel speed can be adjusted by the MHB operator "on the fly."

FIGURE 4 The MHB operating working close to a barrier.

- The MHB is particularly well adapted to "assembly line/tightly spaced" construction (PCC rubblization/compaction/HMA OL paving) since lane-width/one-pass rubblization is achieved. On a typical project, all of the operations can be observed within a short length.
- On many projects, rubblization is started only a few hours prior to HMA paving. More than one MHB can be utilized to achieve desired production rates and/or to rubblize more than a lane width.
- The MHB is very reliable. Due to the simple nature of its operation—hammers being lifted and dropped—it is able to perform hour after hour, day after day, with only minimal time required for maintenance and repair.

TYPICAL CONSTRUCTION SEQUENCE

A typical MHB construction sequence [per the current Illinois Department of Transportation (IDOT) rubblization specification] is

- Install (if specified) the underdrain system.
- Remove any existing HMA overlay(s).
- Repair/replace any "unsound" PCC patches (either concrete or HMA).
- Rubblize the PCC to meet specification. (The surface of the MHB rubblized PCC is typically "flaky" in nature—see Figure 5).

FIGURE 5 Note the "flaky" rubblized PCC surface.

- Compact the rubblized slab with a Z-pattern roller to reduce the size of "flaky" particles (Figure 6).
- Compact the rubblized PCC with a vibratory roller. (IDOT requires four passes.)
- Compact the rubblized PCC with a pneumatic-tired roller. (IDOT requires two passes.)
- Immediately prior to constructing the HMA OL, compact the rubblized PCC with two passes of a vibratory steel-wheeled roller. A typical finished rubblized PCC surface (ready for HMA paving) is shown in Figure 7.

Note: Compaction specifications for other agencies may vary. Some agencies eliminate the pneumatic-tired rolling and vary the number of required roller passes.

REPRESENTATIVE PRICES

MHB bid prices typically include rubblizing and compaction with the z-pattern roller. They may also include additional compaction operations. Typical bid prices for MHB rubblization are $1.50/yd^2. The price varies depending on the requirements of the rubblizing specification and the size and phasing of the project. As an example, the weighted average bid price on Wisconsin DOT projects (1998–2004) is $1.56/yd^2 ($1.86/m^2).

FIGURE 6 A vibratory Z-grid roller followed by a vibratory steel-wheeled roller.

FIGURE 7 The final rubblized and compacted PCC surface.

MHB PRODUCTION STATISTICS

The MHB was first used in 1995 and since then MHBs have rubblized over 15 million square yards (13.8 million square meters) of concrete pavement on highways, streets and airfields in 25 states and provinces, the United Kingdom, China, and Afghanistan. For the years 1996–2004, the MHB was used in the United States to rubblize about 2,178 lane-mi (3,485 lane-km) of PCC. The projects included 1,950 lane-mi (3,129 lane-km) of highway pavement, 183 lane-mi (293 lane-km) of city streets, and the equivalent of 45 lane-mi (72 lane-km) of airfield and other miscellaneous pavements. The peak year was 345 lane-mi (552 lane-km) in 2001. The states with the most projects are Wisconsin (150), Michigan (61), Iowa (29), and Illinois (17).

PERFORMANCE DATA

Antigo has conducted performance surveys (per the *Distress Identification Manual for Long-Term Pavement Performance Project,* SHRP-P-338) on its MHB rubblization and HMA OL projects since 1999. During 2003–2004, 178 MHB rubblization projects constructed in 14 states were surveyed. The projects were constructed from 1997–2003 (as many as 7 years of service). The projects were from a wide geographical area, with a range of PCC thickness and subgrade/base/subbase conditions, and variable HMA OL thicknesses [many less than 5 in. (125 mm)]. Many roadway types are represented, including interstates with a high number of trucks to lightly traveled residential streets. More than 1,300 lane-mi (2,080 lane-km) were surveyed. These data are available upon request from Antigo Construction, Inc. (P.O. Box 12, Antigo, WI 54409; telephone 715-627-2222).

The performance of the surveyed projects has been excellent. The only pavement distresses typically found are those that also occur in HMA pavements built on aggregate base course. These include low-severity transverse and longitudinal cracks, low-severity surface raveling, and low-severity rutting and bleeding. Of the projects surveyed, 75% had no transverse cracks. It is difficult to determine if a transverse crack is a reflective crack. In none of the projects with transverse cracking was there any indication of "repetitive" transverse crack spacings/patterns. It is concluded that there has been "little to no" apparent reflection cracking. There were no longitudinal cracks in 80% of the projects. Most of the projects had rutting less than 0.25 in. (6 mm). Only one project showed initial signs of low severity block/alligator cracking.

The Antigo MHB performance data base documents the excellent performance of rubblized PCCs with HMA OLs and validates the effectiveness of rubblization in preventing reflective cracking.

SUMMARY

Since the late 1980s and early 1990s, PCC rubblization with HMA OL has gained favor as a PCC rehabilitation process. Rubblization equipment and construction procedures have been considerably improved. Rubblization is currently the most-widely used PCC slab fracturing technique.

The lane-width/one-pass MHB developed by MHB Badger Breaker was first utilized by Antigo in the 1995 construction season. This paper documents the development, capabilities, and effective utilization of the MHB for rubblizing PCC.

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REFERENCES

1. Thompson, M. R. Breaking/Cracking and Seating Concrete Pavements. *NCHRP Synthesis of Highway Practice No. 144*, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., 1989.
2. *Guidelines and Methodologies for the Rehabilitation of Rigid Highway Pavements Using Asphalt Concrete Overlays*. Engineering report prepared for NAPA and SAPAE by Pavement Consultancy Services, June 1991.
3. *Guidelines for Use of HMA Overlays to Rehabilitate PCC Pavements*. Information Series 117, National Asphalt Pavement Association, 1994.