BEST MANAGEMENT PRACTICES AND SPECIFICATIONS FOR RUBBLIZING CONCRETE PAVEMENT

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Introduction

The most common form of rehabilitation for Portland cement concrete (pcc) pavement is a Hot-Mix Asphalt (HMA) overlay. The pcc fractured slab technologies offer a cost-effective alternative prior to a HMA overlay for a composite flexible pavement design with less reflective cracking. Fractured slab technologies are: 1) crack and seat, 2) break and seat, or 3) rubblization. Cracking and seating is done on existing jointed plain (non-reinforced) concrete pavement (JPCP) and maintains some degree of aggregate interlock and load transfer capability. For jointed reinforced concrete pavement (JRCP) cracking alone is not always sufficient. Both the steel reinforcement and the concrete have to be "broken," hence the name "break and seat." The third alternative and the most effective for reducing reflective cracking involves completely "rubblizing" the in-place pcc, thus eliminating slab action. Rubblizing can be done successfully on JPCP, JRCP, and continuously reinforced concrete pavement (CRCP).

Rubblization saves time, money, and is a road user-friendly construction technique which is a characteristic of best practices in project assessment and planning. Debris and unused materials do not need to be removed to another site. The rubblized roadbed is left in-place and has value as part of the new road structure. Many agencies have had great success in implementing rubblization technology. The focus of this best management practice is on rubblizing pcc prior to a HMA overly and contains a guide specification on the use of rubblization of concrete pavement (Attachment 1).

The intent of rubblizing concrete pavement prior to a HMA overlay is to produce a structurally sound base layer which prevents reflective cracking by obliterating the existing pavement distresses and joints. A rubblized and compacted concrete pavement is an assemblage of concrete segments that form a tightly keyed, interlocked, high-density, good aggregate base material layer. A rubblized concrete layer is fractured and can no longer sustain flexural stress, however it possesses high shear strength and rutting resistance.

The savings with rubblization of pcc then overlaying with HMA can be quantified with construction costs and user delay costs (Newcomb 2008). An example is a project in Oklahoma in which three alternatives were compared: 1) rubblize and HMA overlay, 2) unbonded concrete overlay, and 3) remove and replace concrete. Not only were the initial costs lower for rubblizing and overlay with HMA, there were significant time and money savings to the road users because they spent considerably less time in traffic during the rehabilitation of the road. Rubblization does not require the complete closure of a roadway as traffic can be maintained during the rehabilitation.

Preparation of the Concrete Surface
Any existing overlay must be removed prior to rubblizing the underlying concrete. The cleaner the concrete surface, the better the energy of the rubblizing equipment is transferred to the concrete. Occasional thin layers of asphalt (often caused by the milling machine working over faulted concrete slabs) are acceptable if the rubblizing equipment can adequately break the concrete through these thin layers.

A typical rubblizing specification requires the removal of all loose patching material, joint fillers, expansion material, or other similar materials after rubblizing and compacting the concrete if any of these items are loose at the surface and may negatively impacting paving the HMA overlay. It may not be necessary to remove these items if an intervening base layer is placed over the rubblized concrete (e.g. grade raise segment).

Existing Joints
Before rubblizing, saw full-depth joints and completely sever all load transfer devices to isolate the rubblized area. Sawing jointed pavements at an existing joint has worked satisfactorily. Do not damage adjacent pavement during rubblization. Remove reinforcing steel exposed at the surface by cutting below the surface and disposing of the steel. It is not necessary to remove unexposed reinforcing steel. Water may be used to control dust until overlaying the rubblized pavement as coordinated with the Engineer.

Drainage
If specified, underdrain systems should be installed and functioning before rubblizing begins. In areas of weak subgrade or high water table the drainage system should be functioning as far in advance of rubblizing as possible to allow for the subgrade to be as stable as possible. The drainage system also serves to remove rainwater from the rubblized concrete layer, base layer, and subgrade during construction.

Subgrade Investigation
To help determine the foundation support conditions and strength before construction, a supplementary subgrade investigation can be performed. Falling Weight Deflectometer (FWD) and Dynamic Cone Penetrometer (DCP) testing are two methods of evaluating the current subgrade condition. FWD testing will provide information on subgrade uniformity by analyzing the computed deflection data. DCP testing, which requires coring of the existing concrete pavement, will provide information on the subgrade bearing capacity. For more information on either of these tests, go to www.dot.state.mn.us/materials/pvmtdesign/fwd.html or contact MnDOT's Pavement Engineering Division.

Utilities
Underground utilities must be clearly marked prior to rubblizing. Special attention should be given to identifying any covers or shutoffs that are not exposed at the surface, such as a manhole cover under an asphalt patch. When necessary, the breaking energy should be reduced in the proximity of sensitive utilities to avoid damage. A typical rubblizing specification also allows the contractor to remove the pavement over or around utilities and backfill with aggregate.

Test Section
During the initial rubblization activity (first half-day) determine the particle size after rubblization by excavating two test holes approximately nine square feet each. It is suggested to excavate at least one test hole per lane mile thereafter unless the Engineer directs or allows otherwise. Backfill and restore the stability of each test hole. In some cases, more than one test section may be warranted to establish and confirm the rubblization for variable conditions and self-propelled breakers.

Rubblizing Equipment
A typical rubblizing specification requires the use of a self-contained, self-propelled breaker to break the concrete slab to specified maximum particle sizes and create a stable construction platform for the HMA overlay. There are two types of machines that meet this requirement and have been used in Minnesota.

One is the multi-head breaker (Figure 1) which has sixteen 1,200 to 1,500 pound drop hammers mounted laterally in pairs with half of the hammers in a forward row and the remainder diagonally offset in a rear row, providing continuous breaking of up to 13 feet wide. Each pair of hammers is attached to a hydraulic lift cylinder that operates as an independent unit, develops between 1,000 and 8,000 foot pounds of energy depending upon the drop height selected, and cycles at a typical rate of 35 impacts per minute. The drop height of each pair of hammers can be instantaneously adjusted to control the amount of breaking energy that is transferred to the concrete. This allows the operator to adjust the breaking for varying conditions along and across the pavement. The multi-head breaker rubblizes a full lane width in a single pass. Typical production rates for rubblizing have been one lane-mile per shift per rubblizing machine. Several machines have been used when project schedules dictate.

Figure 1 – Multi-Head Breaker


Figure 2 - Resonant Pavement Breaker

The other machine is the resonant pavement breaker (Figure 2) that is a self-propelled device that produces low amplitude, high frequency blows with a foot force of 2,000 pounds. This is accomplished by vibrating a large steel beam that is connected to a six to 12 inch wide foot, and is moved along the concrete surface at the front of the machine. The foot, beam size, operating frequency, loading pressure, and speed of the machine can be varied. Resonant breakers require multiple passes to rubblize the full lane width.

Breaking the Concrete

A typical rubblizing specification requires the breaking of the concrete down to specified maximum particle dimension while giving the engineer the discretion to direct or allow larger maximum particle dimensions. These specified particle dimensions are what can be expected when rubblizing over a fair to good base/subgrade. The particle sizes that can be produced are directly related to the condition of the base/subgrade. A firm and stable base/subgrade will allow for the production of smaller particle sizes than when working over a less firm and stable base/subgrade. Engineering judgment must be used when evaluating the rubblizing process, keeping in mind that the intent of rubblizing is to produce a structurally sound base that reduces reflective cracking by obliterating the existing pavement distresses and joints. The intent is not to meet a specific gradation requirement but to break the concrete uniformly across the pavement width into particles that have a maximum dimension.

Attention must also be paid to constructability. Even if it is possible to produce small particle sizes, the resulting rubblized layer must still provide a working platform for paving operations, staging, traffic travel considerations, and construction of the HMA overlay. In cases of isolated and extremely weak subgrade, subgrade correction may be appropriate. Another way to compensate for a weak subgrade is to modify the rubblizing pattern to produce larger particle sizes which maintain more of the existing concrete pavement's structural support. Experience has shown that segments of twelve to eighteen inches in the lower half of the slab are still effective for reducing reflective cracking.

Test holes are excavated to determine that the process is meeting the rubblization objectives. Once the engineer has verified the specification requirements are being met, he/she can waive additional test holes. For large projects, normally at least one test hole per lane-mile is conducted. Numerous test holes create non-uniformity in the structure, therefore backfilling and restoration for stability of each test hole is important.

Compaction

When compacting rubblized concrete over weak or wet subgrade or in the proximity of sensitive utilities, it may be necessary to reduce the vibratory roller's amplitude to prevent damage to the subgrade or the utilities. (*Note to Engineer: In extreme cases the roller should be operated in the static mode.*)

When the multi-head breaker is used the contractor usually chooses to use a "grid roller" for the first two vibratory steel roller passes. The Z-pattern bars that are attached to the roller drum serve to further pulverize the broken concrete particles at the surface (Figure 3).

Figure 3-Roller Fitted with Z-pattern bars.

When an intervening base layer is placed over the rubblized concrete prior to the pavement overlay, compaction of the base layer will be as required by the specification for that base layer.

Observation of the compaction process is an effective way to determine the stability of the rubblized layer. If there still are concerns after compaction, proof rolling with a loaded tandem-axle truck is a quick and effective procedure for determining the stability of the rubblized layer. (*Note to Engineer: The reference section of this document contains more information or see MAPA Design Manual, Chapter 3, pp. 3-19 available at www.asphaltisbest.com.*)

Filler Aggregate
Filler aggregate or HMA may be utilized (see also **HMA Overlay**) to fill holes and localized depressions in the rubblized concrete. It is not the overall intent to use aggregate as a means of adjusting the grade.

Clearance/Elevation
When elevation is a concern, such as at overpasses and bridges, the pavement design can consist of full-depth, deep strength, perpetual pavement, and/or crack and seat alternatives.

Partial-Width Construction
When partial-width rubblizing and paving is required, if possible, the contractor should leave a six to twelve-inch wide strip of rubblized concrete unpaved when overlaying the first lane. This strip provides additional space to operate on the second lane without encroaching upon the first lane's overlay.

Rain
Light to medium rain does not affect the rubblizing operation. For safety considerations, the rubblizing operations should be temporarily suspended for heavy rains and/or lightning. Rubblized concrete drains well, especially if edgedrains are functioning, and paving operations can usually begin shortly after the rain has stopped. Caution is required when rubblizing over a moisture-sensitive subgrade. In these cases, rubblizing and paving should be coordinated to minimize exposure of the subgrade to rain.

HMA Overlay Design
When designing the thickness of the asphalt overlay, the rubblized concrete layer is assigned a support value. The support value is the product of the layer coefficient assigned to the rubblized concrete and its thickness. Similar calculations are made for the subbase, if any present, and for the HMA surface. The required total pavement structure thickness is the sum of all calculated thickness; thus, the rubblized concrete becomes an integral part of the pavement structure in addition to providing a working platform for paving operations and a stable foundation for the HMA surface.

Estimated quantities for the first layer of HMA are to be calculated using the following formula:
*[width (ft.)] * [length (ft.)] * [{115 lb/SY-in. * Depth (in.)} + 20 lb/SY] * [1 SY/9 ft.²] * [1 ton/2000 lbs] = ___ tons*

This method adds 20 lb/SY to account for possible irregularities in the rubblized surface.

Paving
The paving of a HMA overlay on a rubblized and compacted concrete surface is very similar to paving on a prepared crushed aggregate base. Care must be taken to maintain the compacted

condition of the rubblized surface up to the time of paving. If local traffic or construction traffic has impacted the rubblized surface, a vibratory steel roller may be used to reestablish a stabilized surface prior to paving.

Because concrete rubblizing and HMA overlay projects often involve opening the roadway to traffic prior to the total designed thickness being paved, consideration must be given to the thickness of the first or second lift. It must be thick enough to adequately cover the rubblized concrete surface and carry traffic temporarily until the additional lifts are paved. The number of large trucks determines the minimum thickness needed to carry traffic. When making cross-slope corrections with the first lift, attention must be paid to maintaining an adequate thickness not only at the centerline but also at the edge of the pavement. Additional thickness may also be required in areas of low base/subgrade support. (*Note to Engineer: See MAPA Design Manual, Chapter 3 for ESAL calculations available at www.asphaltisbest.com*)

If the thickness of the HMA overlay is decreased when approaching a bridge or overpass, rubblizing should stop at the point where the thickness of the overlay begins to decrease. It is important to maintain the designed thickness over all rubblized areas.

When a yielding subgrade is the suspected cause of depressions in the rubblized layer, consideration should be given to a HMA leveling course in place of the use of filler aggregate. This would add greater strength to the section over the yielding subgrade than would filler aggregate and may be a more effective means of achieving smoothness.

Public & Construction Traffic

Construction traffic on rubblized concrete should be monitored. The engineer and contractor should coordinate traffic to minimize the amount and weight of construction traffic on the rubblized surface until adequate structural capacity is established. Minimum interim structural thickness should be calculated when allowing construction and/or public traffic on the pavement during construction and can be addressed with the project's specifications. This is especially important in areas with weak subgrade.

Traffic Control

Concrete rubblizing and HMA overlay projects are constructed using a wide variety of traffic control scenarios. A significant benefit of rubblization is that it can be accomplished while traffic is still moving in adjacent lanes. Then the HMA overlay can be placed on the rubblized pcc, and traffic can then be switched to newly surfaced roadway while the next lane is rubblized. Thus, the impact to road users is greatly reduced since a complete closure of the roadway isn't required.

As a general rule, public and construction traffic over the non-surfaced rubblized concrete should be minimized as much as possible. Various traffic type and volumes can be accommodated if the shoulders are adequate to carry this traffic. Low volume traffic can also cross rubblized concrete to gain access to driveways and cross roads. If possible, high volume intersections should be rubblized and compacted shortly before the first lift is paved. In cases where the rubblized concrete is exposed to public traffic, close attention must be paid to the condition of the rubblized surface prior to any overlay with HMA.

Curb and Gutter and Partial-Depth Concrete Milling

Partial-depth concrete milling is sometimes used to create a butt joint along the gutter flange to match the thickness of the HMA overlay, or to reduce the thickness that is placed over the gutter. Partial-depth concrete milling is also used for cross-slope correction. Also, a saw cut at the curb can be done prior to rubblizing. Adjustments must be made when rubblizing this area as the reduced thickness of the concrete will cause this area to rubblize differently than the full-depth concrete. Typically, less energy should be used to rubblize this area in order to maintain a "structurally sound base". Sometimes one or more lifts are paved over the gutter to the curb face to reestablish the flow lines. If new curb and gutter is placed it should be allowed to cure before rubblizing adjacent to it.

Figure 4 – Rubblizing adjacent to curb & gutter.

Rubblization of Airport Pavements

Rubblization is a viable pavement rehabilitation alternative for airport pavements. Information is available at http://www.aaptp.us/reports.html regarding Airfield Asphalt Pavement Technology Program Project 04-01: Development of Guidelines for Rubblization. Thicker pavements can be rubblized, in fact the 24" thick pcc pavement at the Grand Forks Air Force Base was successfully rubblized and overlayed in 2005.

Rubblization to Perpetual Pavement

The technology and case projects exist to rehabilitate old pcc pavements by rubblization and reconstruct with a perpetual pavement design. One would rubblize the pcc and design the HMA thickness on the rubblized pavement as shown in Figure 5.

The 3-layer system (Figure 5) basically consists of: Layer 3 – a HMA fatigue resistant layer, Layer 2 – HMA layer with selected aggregates for rut resistance, and in Layer 1 – HMA surface layer with a renewable and 100% recyclable wearing course for specific applications. Mechanistic design principles are used for the design considering "ultimate" loads rather than designing for fatigue or rutting failure of the system.

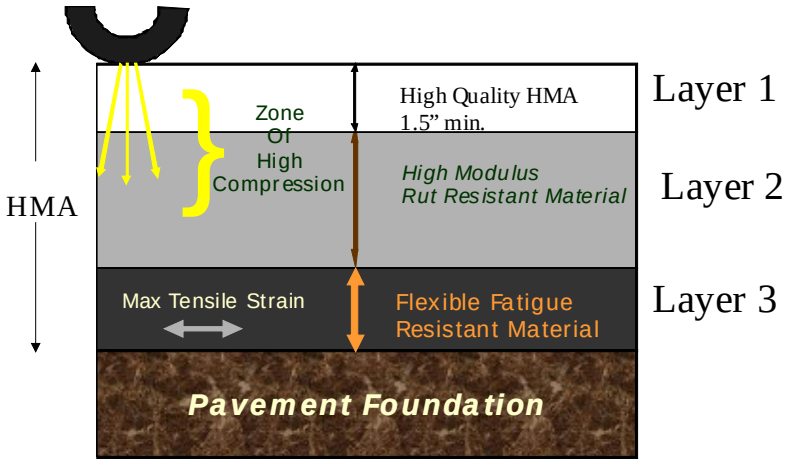

Figure 5 - Perpetual Pavement Design.

Specifications

The last page of this document contains a typical rubblization specification template. Contact MAPA by e-mail at info@mnapa.org or by phone at 651-636-4666 with any questions or comments regarding rubblization of pcc pavements.

References/Information Sources

- Decker, D., *Rubblization-Design and Construction Guidelines on Rubblizing and Overlaying PCC Pavements with Hot-Mix Asphalt*, National Asphalt Pavement Association Information Series 132, 2006.
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- Asphalt Pavement Alliance. *Rubblization: The Quick, Cost-Effective, Environmentally Friendly Fix for Failed Concrete Pavement*, www.asphaltalliance.com, 2003.
- Minnesota Asphalt Pavement Association. *Asphalt Paving Design Guide*, www.asphaltisbest.com, 2003.

Attachment 1
RUBBLIZATION OF PCC - Guide Specification

S-1 (2104) Description

This section describes rubblizing and compacting existing concrete pavement to create a stable construction platform for a pavement overlay with or without an intermediate aggregate base layer.

S-2 (2104) Rubblize Concrete Pavement

Before rubblizing, saw full depth joints and completely sever all load transfer devices to isolate the rubblizing area. Saw jointed pavements at an existing joint. Do not damage adjacent pavement during rubblization. Rubblizing concrete pavement shall be done by using a self propelled concrete breaking machine capable of rubblizing the in-place concrete pavement. The machine shall be capable of controlling the striking force so as to break the concrete into pieces that have a maximum dimension less than or equal to 12 inches. This may be modified for thicker pavements. Also, 75% of the particles, as the engineer determines visually, must have a maximum dimension less than or equal to the following:

- In the bottom half of the slab; 9 inches
- In the top half of the slab; 3 inches
- At the surface of the slab; 2 inches

The Engineer may direct or allow larger maximum particle dimensions if site conditions warrant due to subgrade support. Determination of particle size shall be by excavating two test holes approximately nine square feet each, during the first half day. Excavate at least one test hole per lane mile thereafter unless the Engineer directs or allows otherwise. Backfill and restore the stability of each test hole.

The force used shall be only what is needed to obtain 12-inch and less. The operation shall then be followed by a vibratory steel drum roller outfitted with steel Z-bars. The rolling operation shall cover the full width and be repeated until the adequate surface sizing is achieved and the rubblized slab is well seated. The intent is to break the concrete and compact the concrete on a daily basis. If areas of poor subgrade are encountered these will be handled as directed by the Engineer using Pavement Removal, Muck Excavation, Geotextile Fabric, and/or Select Granular Borrow.

Do not damage pipes, valve boxes, manholes, and other fixtures. The contractor may prevent damage by doing one or more of the following:

1. Use engineer-approved, modified methods around fixtures and above pipes.
2. Remove pavement around fixtures and above pipes, backfill with aggregate and/or hot-mix asphalt mixture and compact.

Prior to hot mix placement all protruding reinforcing steel shall be removed or cut at the surface and all rubber or flexible debris shall be removed. Do not remove unexposed reinforcing steel. This operation shall be incidental to Rubblize Concrete Pavement and no direct compensation shall be made therefore.

S-4 (2104) Measurement

The specifier will measure rubblizing by the square yard acceptably completed.

S-5 (2104) Payment

The specifier will pay for the measured quantity at the contract unit price under the following bid item:

Item Number	Description	Unit
2104	Rubblizing Concrete Pavement	Square Yard

Payment is full compensation for rubblizing; removing pavement adjacent to fixtures and/or above pipes;

removing exposed steel; compacting the rubblized concrete; disposing of removed material; excavating, backfilling, and restoring the stability of test holes; and repairing the adjacent pavement.

Payment also includes water for dust control except if the contract contains the water bid item, the specifier (department) will pay separately for dust control water as specified.

The specifier (department) will pay separately for sawing under the Sawing Concrete bid item as specified.