Pothole Repair in Pennsylvania

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INTRODUCTION

In the Commonwealth of Pennsylvania, the manual repair of potholes involves an annual expenditure exceeding $25 million, which is second only to snow removal in the maintenance budget. Prior to 1980, it was common practice for repair crews to practice a "throw and go" policy, with patch material placed in the potholes without removing debris or loose material. Frequently, there was no compaction at all or only minimal compaction, often with the back of a shovel or truck tire. Such repairs were typically short-lived. A crisis situation gradually developed because the crews were unable to keep pace with the number of potholes that developed each spring. Many of the potholes were filled several times each season, which inconvenienced the public and caused poor public relations.

A value engineering study (*1*) indicates that the cost of pothole repair that is repaired with a "throw and go" policy is approximately $307.68/ton. A properly repaired pothole, because it needs to be repaired only once, costs approximately $65.22/ton.

This situation caused the Pennsylvania Department of Transportation to review its methods of pothole repair. A comprehensive evaluation of current (1980) practice, materials, equipment, and manpower utilization was undertaken. As a result of this evaluation, a new specification for cold stockpile patching material was developed, a do-it-right policy including a revised set of procedures was adopted, and an intensive training effort was undertaken. In this paper, pothole patching is discussed as it occurs on state highways ranging from low-volume roads (< 400 ADT) to major expressways. It is assumed that the patching occurs from later winter to spring as a result of the spring thaw. Utility patching and large-scale mechanized patching are not included. This paper describes the results of studies conducted by The Pennsylvania State University for the Pennsylvania Department of Transportation as well as the results of studies conducted within the Department.

PROCEDURES

The procedures described in this paper have been developed for use with cold stockpile patch material or hot mix. Standard wearing course hot mix is used for pothole repair when it is available; otherwise cold stockpile material is used. Cold stockpile material (*2*) is made with MC-400 cutback or MS emulsions in a conventional hot mix plant. Traveling plants or blade-mixed cold mixes are not permitted because adequate quality control is difficult to obtain.

Marking

Marking defines the amount of material that should be removed. The crew foreman is responsible for deciding how much pavement material should be removed. Marking is a form of written communication between the foreman and his crew, a way of leaving instructions for the crew so that the foreman can look after other operations. This step may seem trivial to some, but extensive production studies have shown that almost one-third of the time available for cutting is lost because the worker operating the pavement breaker is waiting for instructions.

In some cases, the foreman's estimate of the weakened area that must be removed will change after the cutting begins, especially on severly distressed pavements. In those cases the foreman must review the cutting operation as it proceeds and direct the person doing the cutting to enlarge or reduce the area as necessary.

Cutting

The purpose of cutting is to remove weak and deteriorated material so that there will be firm material around the repair. Repairing a pothole can be compared to repairing a rust spot on a car. For the patch to hold, all of the rusted material must be cut out. However, it is important that no more material than necessary be removed during cutting. Cutting excess material is costly in terms of time and material.

Vertical sides—After cutting is completed, the sides of the hold should be vertical. Vertical sides are important because they confine the patch material. This confinment is an aid during compaction and prevents the patch material from pushing out of the hole later under traffic loads (Figure 1).

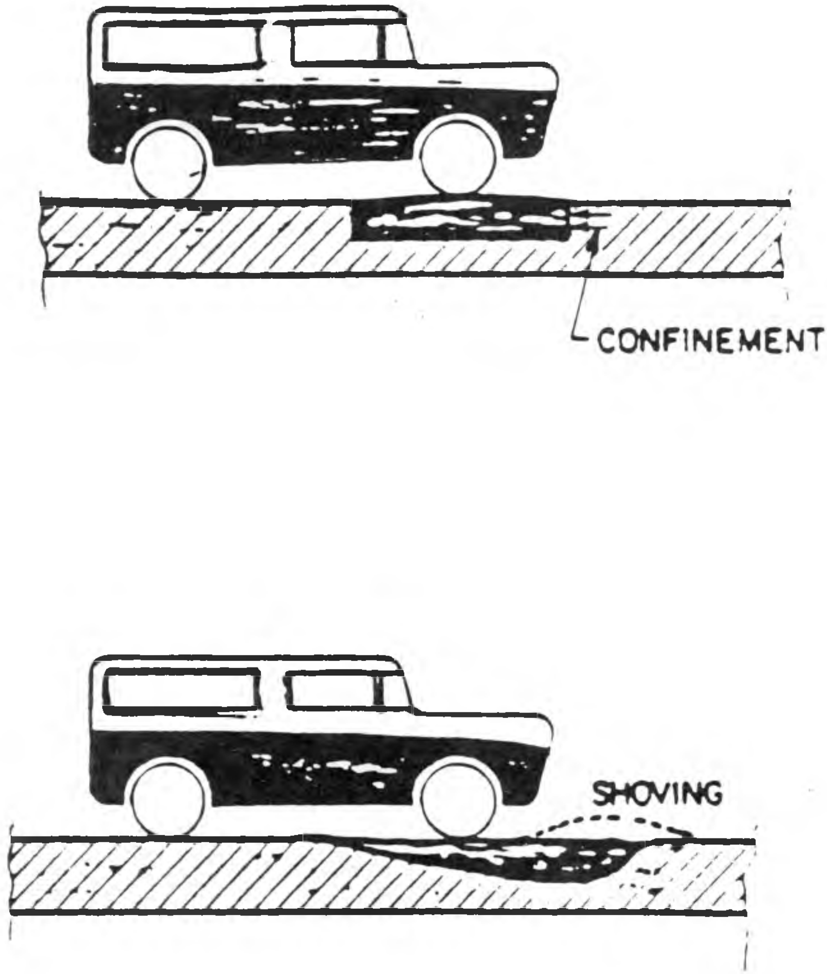

Figure 1. Confinement as a compaction aid.

Shape—The hole does not have to be cut in the shape of a square. Often an L- or T-shaed cut is more effective. The cut should be made with a series of straight lines. An irregular or circular shape should be avoided. Because the bits on the cutting tools are flat, it is difficult to make a clean cut unless the cut is in a straight line. Excess material should not be removed, but the hole must be cut back to sound material (Figure 2).

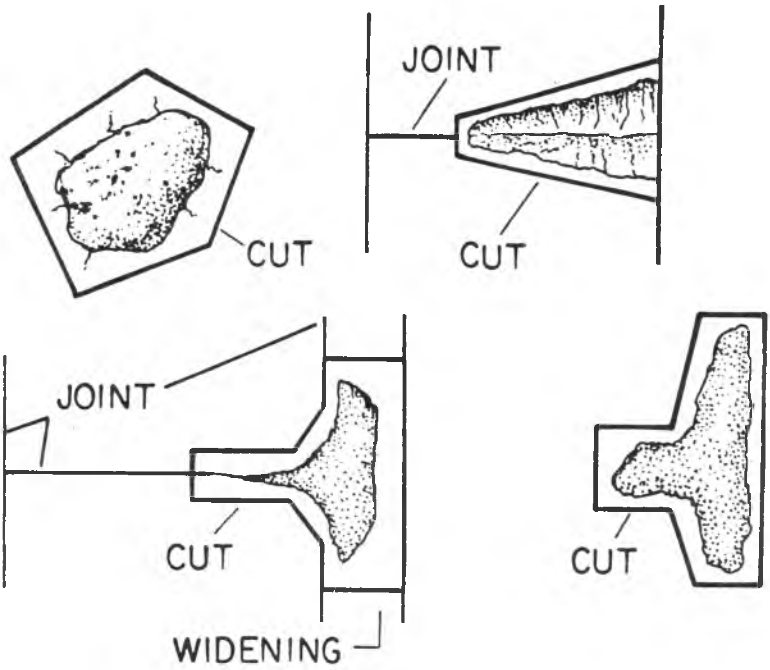

Figure 2. Cutting patterns.

Using the cutting tool—The cutting should begin at the center of the hole and proceed to the edges; the material should be broken and loosened as the cut is widened. The cutting bits are sharpened with a single bevel, and the bevel edge of the bit should be pointed toward the center of the hole. By proceeding in this manner, the disturbance at the edge of the cut will be minimized. The practice of using the cutting tool to make an initial cut to outline the hole should be avoided because it tends to fracture the pavement on both sides of the cut (Figure 3).

When the cutting is finished, the edge of the hole should contain sound, unbroken material. If the cutting tool is wedged into the pavement or rocked back and forth, it may crush the stone and crack the surrounding pavement. The repair will not easily adhere to such an edge.

Studies conducted at The Pennsylvania State University have shown that the sharpness of the bit has a very strong influence on the rate of cutting. The cutting rate with dull bits is 30 to 40 percent greater than the rate with sharp bits. A sharp bit will also cause less pavement damage. Crews should carry several spare sharp cutting bits.

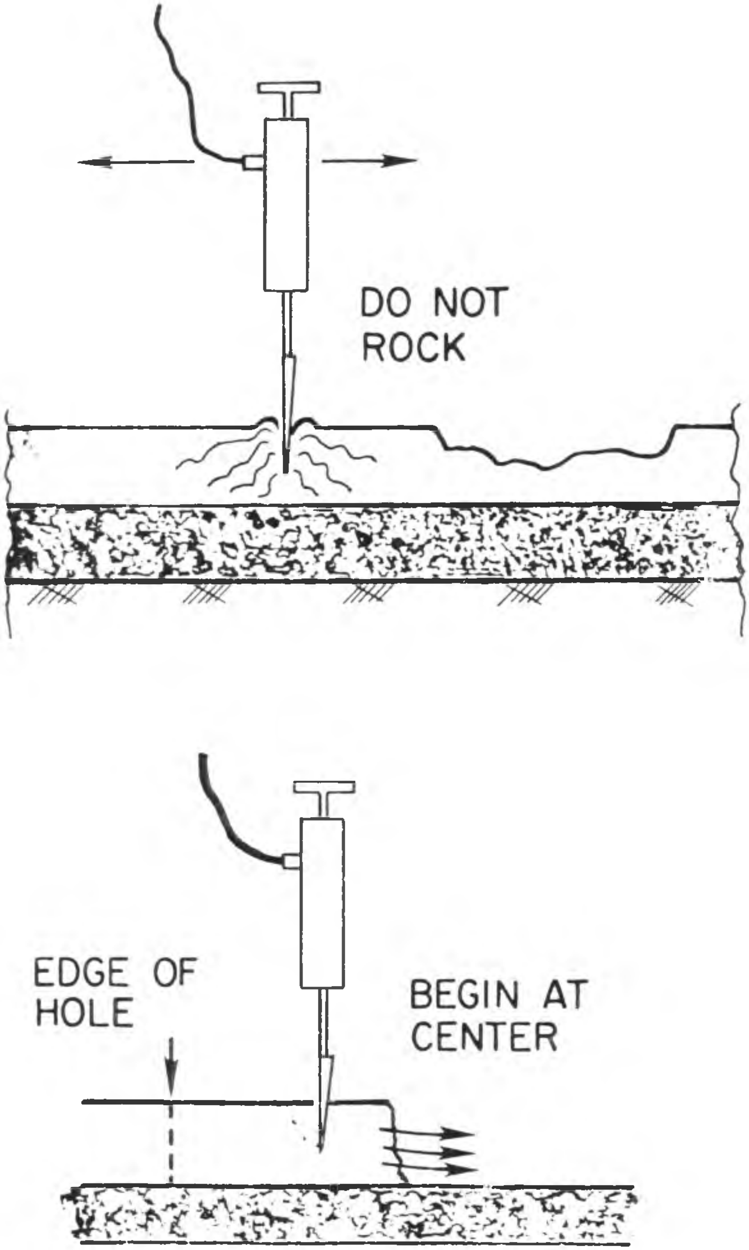

Figure 3. Proper cutting technique.

Cutting versus sawing—At first, sawing appears to be an attractive alternative to cutting. However, it results in a smooth cut, to which it is difficult to bond materials, especially asphalt-based repair materials. There appears to be little advantage in expanding the use of sawing in pothole repair.

Depth of cut—The cut should be deep enough to remove all loose and deteriorated material. Often this is a matter of removing a thin surface layer. In rigid base pavements, it is important to remove all the loose material from the bottom of the hole, as shown in Figure 4. This layer of loose material does not provide a bond, and traps water and salt that continue to destroy the concrete and cause the repair to fail prematurely. If the loose concrete extends below the steel reinforcement, or if the loose material cannot be completely removed from the pothole, the repair cannot be considered permanent; more extensive repairs will have to be scheduled. Failed or pumping concrete joints cannot be repaired successfully by the usual pothole repair methods. Water beneath the pavement will push the repair out of the hole if the slab works up and down with traffic. The repair procedure shown in Figure 4 acceptable as a temporary measure in the winter, but the pavement should be scheduled for permanent repair as weather permits.

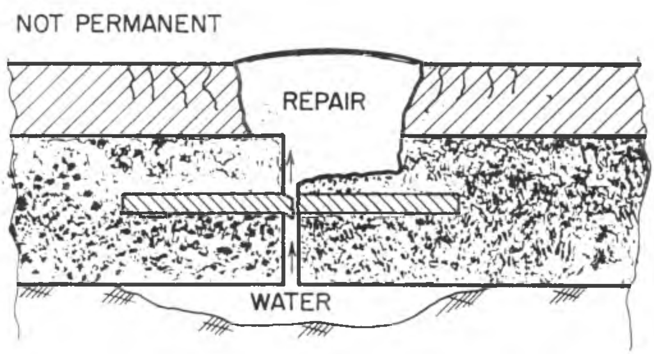

Figure 4. Deteriorated concrete pavement.

Multiple surface treatments are an alternative procedure for repairing potholes in thin pavements. These repairs are generally made without any cutting or cleaning. A rapid setting emulsion or rapid curing cutback and 3/8- to 1/2-in top-size stone are used to build up the repair. Such repairs are confined to low-volume roads.

Cleaning

The purpose of cleaning is to provide a surface to which the patch or the tacking material can adhere. Water, loose dirt, or debris must be removed from the vertical faces and bottom of the hole. Loose pieces of pavement should be knocked from the edge and the bottom during cleaning. The corners are hard to clean, but they are particularly important because they are the weakest area of the patch.

Compressed air delivered from a blowpipe is the best cleaning method (Figure 5). The blowpipe directs the air stream and helps to dislodge material from the corners of the hole. When compressed air is available, it should be used for cleaning. A second low-pressure line for cleaning purposes may be added to some compressors.

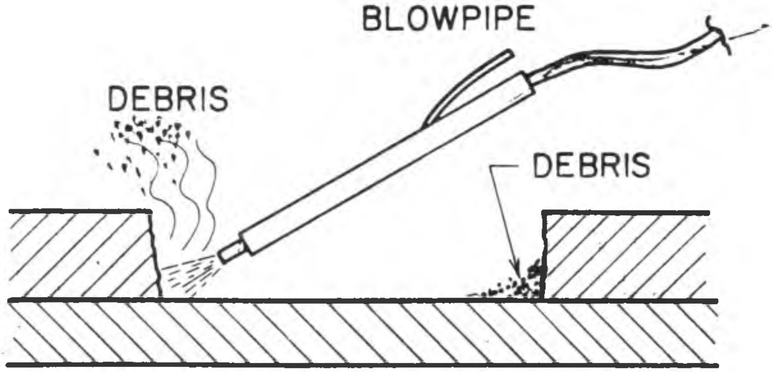

Figure 5. Cleaning with blowpipe.

Cleaning the hole with compressed air should always be done with the second line of the air compressor. This will avoid interrupting the cutting operation and will improve productivity and production. When this practice is not followed, production will be reduced by 10 to 15 percent.

Brooms do not work very effectively in the corners of the hole, and, therefore, particular attention should be given to the corners during brooming. Care should be taken not to fill up the corners with debris when cleaning with a broom. A stiff broom is best because it helps dislodge loose stone particles.

Tacking

The purpose of the tack is to "wet" the old pavement so that new patch material will stick or bond to it. Tack is not used with cold mix because cold patch materials are made with a soft asphalt (cutback or emulsion) that will stick without heating. The stockpile cold mix used in Pennsylvania (*2*) is rich in asphalt and, if the hole is clean, it should self-tack. Adding tack to cold mix may cause an excess of asphalt, which will cause the patch to rut and shove. The solvent in cutback tack can dilute the asphalt, permitting water to strip the asphalt from the stone, causing raveling and shoving.

Emulsion—Slow-setting are preferable for tacking. They can be applied to a damp or wet pavement. The emulstion cures partially by evaporation, but it will stick to damp surfaces. Hot mix may be applied against the emulsion immediately, as long as the emulsion is properly applied in a thin film. Emulsion may be applied by brushing or spraying, but it should not be poured from a can. Pouring does not give even coverage and produces a thick film. Acceptable methods of application are summarized in Figure 6.

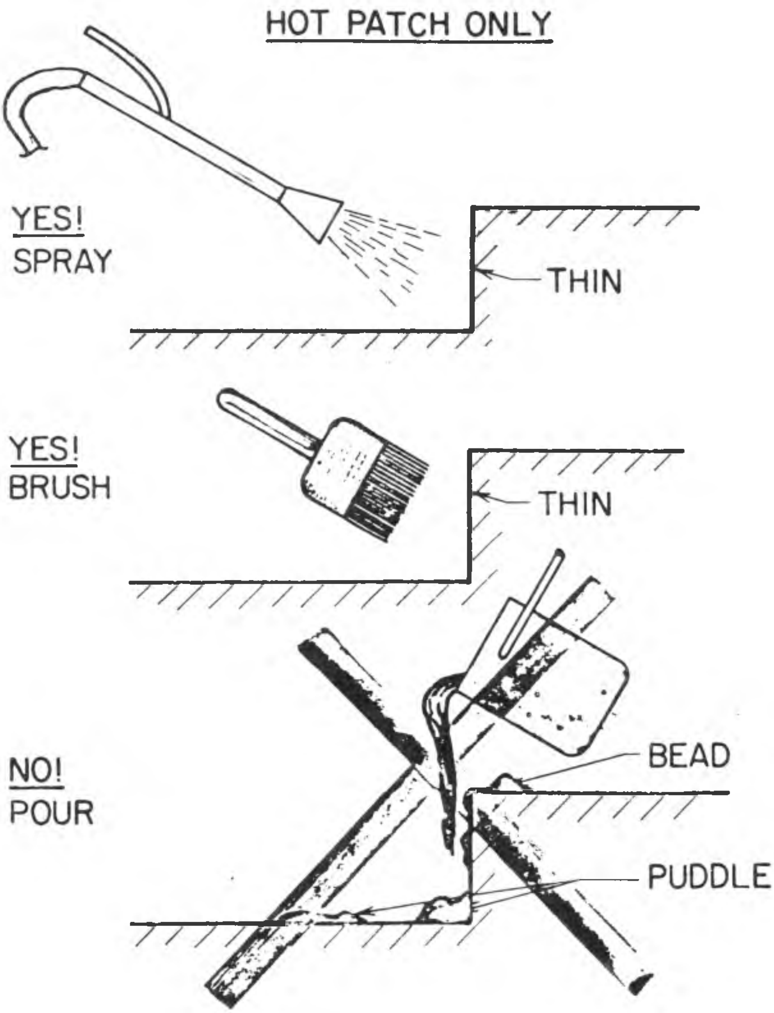

Figure 6. Proper tacking techniques.

Cutback—In the winter or early spring, an RC-250 cutback may be used as a tack. It may be sprayed or brushed on; pouring is not acceptable. Cutback materials are the least desireable tacking materials because they are difficult to handle without heating and because the solvent can soften the patch.

Hot asphalt cement—Hot asphalt cement is generally not available during winter months. It is not an effective tack material unless it is sprayed onto the edge of the repair. Hot asphalt cement should not be poured from a "tar pot" because the rate of application cannot be controlled and excess material will be applied.

Quantity of material—The adage "the more the better" is not appropriate for tacking materials. The tack should form a thin film on the old pavement. Hot asphalt cement poured from a can is not acceptable because it cannot be applied thinly enough. Excessive tack material, especially if not given time to cure, is often the cause of a bleeding or shoving patch.

Filling

The next step in the repair procedure is the filling of the pothole. While this step appears simple, it can contribute to poor performance if it is not done properly. The patch material should be shoveled into the hold from the tailgate of the truck. Patch material should not be raked off the tailgate into the hole because this may cause the patch material to segregate. Loose material should be tamped into the corners and edges. The blade of a shovel is an effective tamping tool, as shown in Figure 7.

The patch material should be placed in even layers until there is sufficient material mounded above the surface of the pavement. It is very important that enough initial material be placed in the hole so that after final compaction, the surface of the patch is slightly above the pavement surface.

Potholes which are deeper than 5 to 6 in. should be filled in more than one lift. Lifts thicker than 5 to 6 in. are difficulty to compact.

Material must not be spilled onto the old pavement. This will limit compaction, as shown in Figure 8. Excess material should be shoveled from around the hole during the first few phases of the roller.

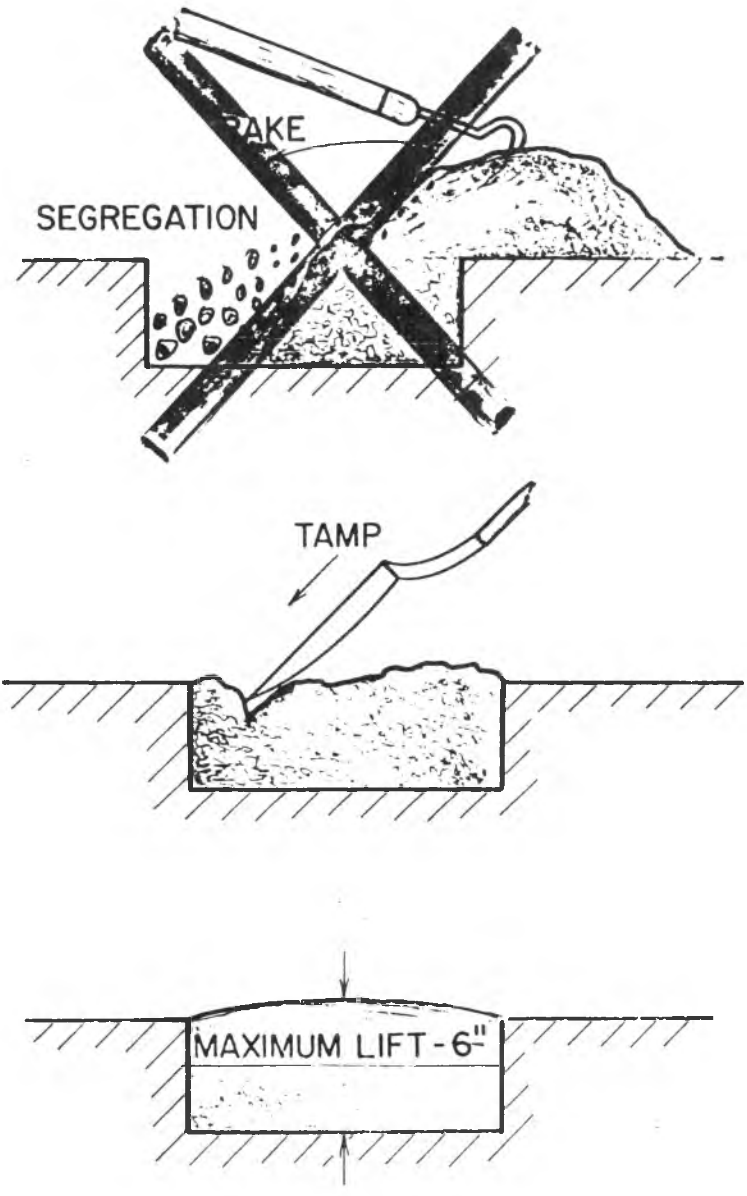

Figure 7. Proper filling technique.

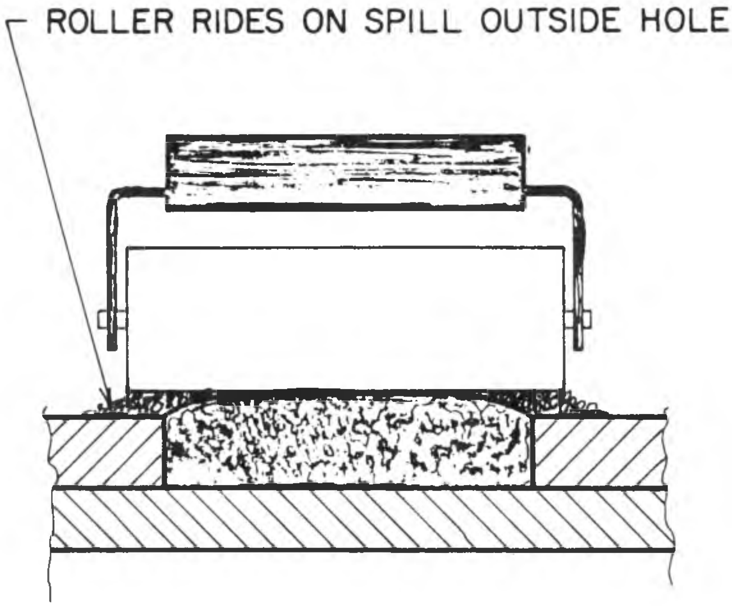

Figure 8. Spillage outside repair.

Compaction

Compaction is one of the most important steps in the repair process. If the material is not adequately compacted, it may push out of the hole; compact under traffic, causing a depression in the hole; or ravel out of the hole. It is important that the material be compacted against the edges of the hole to prevent raveling, water damage, and shrinkage between the repair and the old pavement.

The first few passes should be used to pinch the patch material into the hole. Subsequent passes should be made over the middle of the hole. A few passes with the outside edge of the roller on the inside edge of the patch help to push the patch material against the edge of the holes. When there are ruts in the road, the roller should be run across the road, if possible, rather than down the road. This will minimize the tendency of the roller to bridge the ruts, as shown in Figure 9. When compaction is completed, the finished repair must be slightly higher than the original pavement. This will ensure that the roller is "pushing" on the patch rather than bridging the repair, as shown in Figure 10. This point is very important: the authors found that most of the dishing experienced in the field was caused by poor compaction resulting from insufficient patch material in the hole.

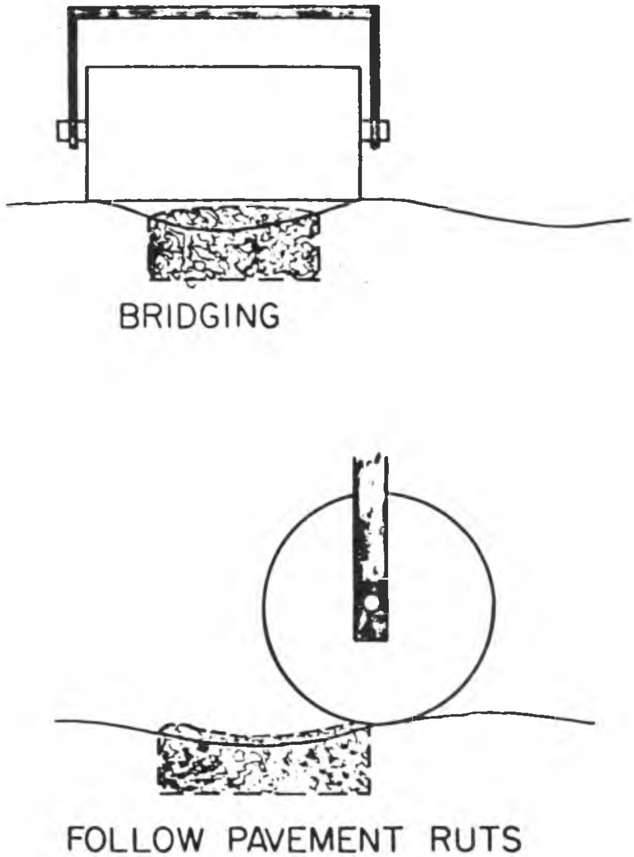

Figure 9. Transverse rolling.

Edge Sealing

The purpose of edge sealing is to keep water from penetrating the joint between the pavement and the repair. The cost effectiveness of edge sealing is questionable and its use may be more cosmetic than functional. In Pennsylvania, it is used at the discretion of the district engineer.

Hot asphalt cement, emulsion, or RC cutback can be used for edge sealing hot mix. Hot asphalt cement must be heated in a melting unit. Emulsion or cutback should be blotted with clean sand or fine screenings. Coarse stone should be avoided because it can damage car windows. Dust and dirt shoveled from the side of the road should not be used, because they often contain too much fine dust.

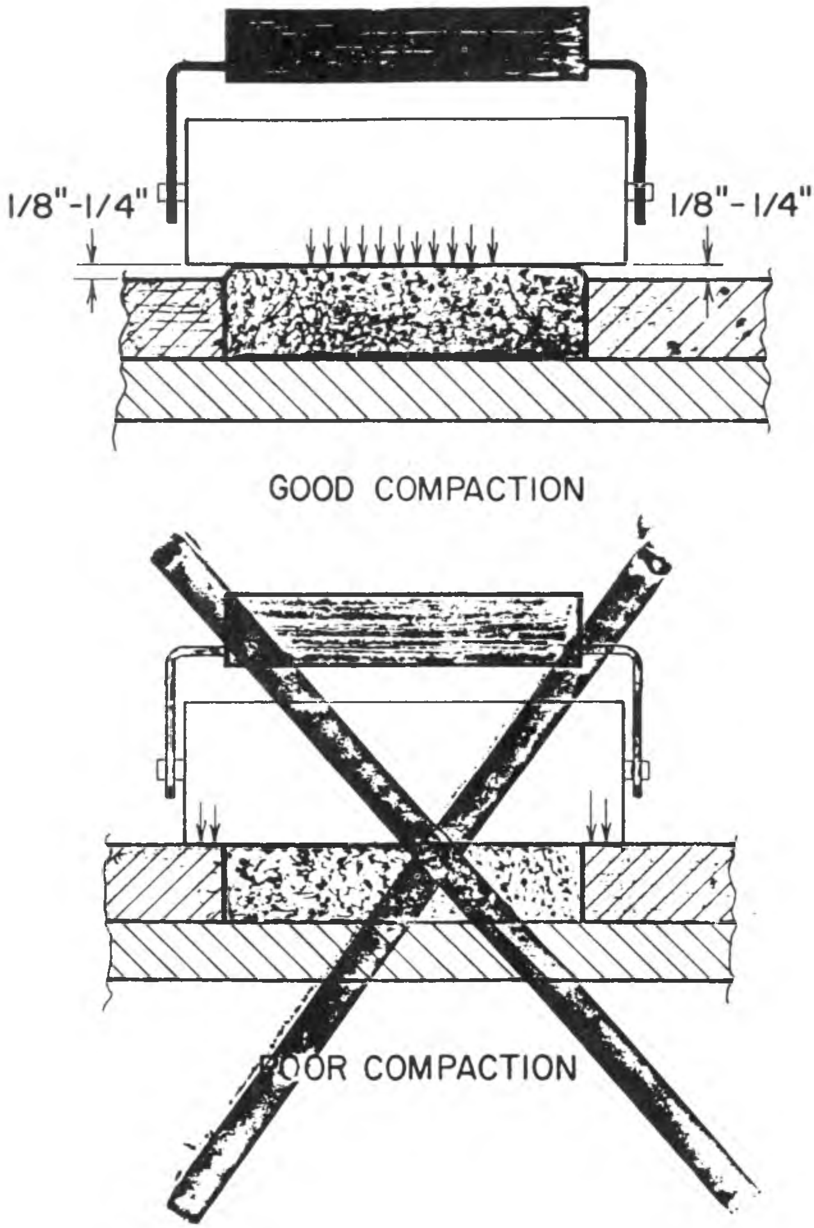

Figure 10. Proper filling of hole.

Edge sealing can be done by making a skin patch around the edge of the hole. RS-2 and CRS-2 (*3*) emulsions are satisfactory for this technique. RS-2 and CRS-2 emulsions may set before they can be brushed or broomed out. If this happens, their use should be discontinued.

SS-1 and SS-1h emulsions can be used to paint the edge of the patch, rather than to build up a skin patch as with RS-2 and CRS-2. SS-1 and SS-1h emulsions should be broomed or brushed out to avoid a build up of material on the surface of the pavement, and they should be sanded to prevent tracking and to help seal the surface.

It is important to avoid excess liquid when edge sealing, especially with cold patch. Excess liquid can soften the patch and lead to bleeding and shoving. When an overlay is placed on a pavement, the excess liquid may also soften the overlay.

EQUIPMENT

A detailed evaluation of a wide variety of equipment that can be adapted to pothole repair was made in the field by Penn State researchers. Pothole repair equipment is used in the following areas: cutting or hole preparation, mixing, transporting, cleaning, tacking, and compaction. The equipment was evaluated with respect to cost, reliability, productivity, and effectiveness. The primary conclusion that was drawn from the equipment review is that new and exotic equipment is not the answer to a cost-effective quality repair.

Cutting or Hole Preparation

Cutting can be done with hyraulic, gas-operated, or air-operated cutting tools. The gas-operated machines such as the Pionjar Model 120, are limited to asphalt pavements. Although it is the slowest of the three types of tools, its slowness is compensated for by its mobility. It is not tied to a compressor and, therefore, with a gas-operated cutting tool, the cutting operation is independent of the other operations. The authors do not consider sawing appropriate for pothole repair.

A number of infrared or radiant heaters, such as the Poweray Heat and Serve, are marketed for repairing potholes. These unites apply heat directly to the pavement surface so that the surface may be leveled and rolled again. Hot mix, carried in a hot box that is part of the unit, may be added as needed during the repair. This equipment is best suited for repairing overlays, smoothing and blending of utility cuts, and leveling old patches where the pavement is structurally sound but the surface is uneven. These pavement heaters effectively soften only the upper pavement layer and therefore do not produce a full-depth repair.

Mixing and Transporting

The Pennsylvania Department of Transportation does not allow on-site or stockpile mixing of patch materials except in emergencies. Reclaimed material is not used for pothole repair, and therefore reclaiming equipment was not reviewed during the research.

To obtain adequate compaction it is imperative that hot mix be held at a reasonable temperature (less than 257 F) until it is used. This can be accomplished by the use of hot boxes such as the Poweray 4TSU or the RGS Thermolay units. In addition to keeping hot mix at an acceptable termperature, these units can be used to warm cold mix in cold weather if the units are filled in the evening. The Department makes extensive use of the 4TSU Poweray units.

Self-contained patching units, such as the RGS Thermolay unit, are useful for widely spaced potholes or for responding to complaint calls. The authors have found that the hydralic compactors supplied with these machines are ineffective, and a small vibratory roller such as an Essick V30W-R should be used for compaction.

Cleaning

Studies conducted by the authors on more than 800 repairs show little difference in longevity of repair between holes cleaned by brooming and those cleaned by air blowing. Air blowing is best accomplished with a 3-to 4-ft. blow pipe attached to a hose fitted with a dead man valve. The valve, together with a maximum air pressure of 30 psi, is an OSHA requirement. The blowpipe allows the air to be directed at the corners of the hole without requiring the operator to bend over.

Small blowers that can be mounted on an operator's back were also evaluated and found ineffective for cleaning purposes. Blow torches and heating devices are unnecessary as long as the hole is broomed or air-blown free of water.

Compaction

Proper compaction is essential to repair longevity. Small static rollers of the 4-to 6-ton variety were found inadequate for either cold mix or hot mix. Additional purchases of this roller for pothole compaction have been discontinued. Small vibratory rollers, such as the Essick V30W-R, are satisfactory as long as they are used in the vibratory mode. The Essick V30W-R has the advantage that it can be hung from the tailgate of a dump truck. More compaction effort is required for a pothole than for a continous mat. Approximately twice the number of passes is required, typically 8 to 10 passes (Figure 11).

Small vibrating plate compactors, such as those often used for soil compaction, will give acceptable levels of compaction. However, these

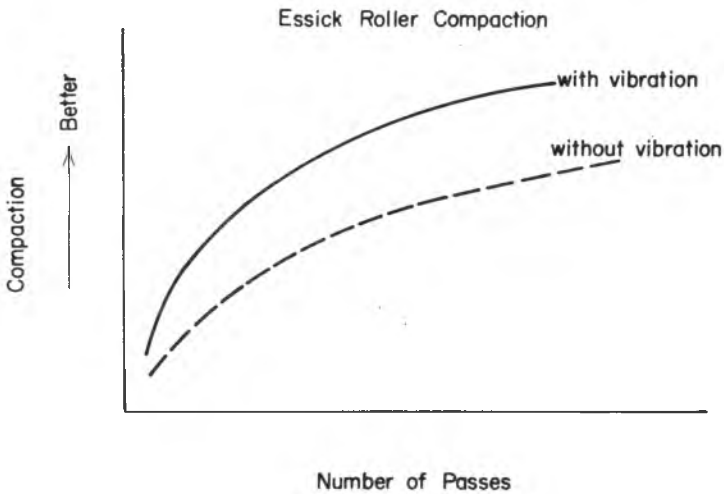

Figure 11. Growth curve for Essick roller.

units require a much longer compaction time than the one or two casual passes used by the typical crew. Several minutes of running time per square foot are usually required.

PRODUCTIVITY

Approximately 50 repair operations were studied to evaluate crew productivity. Deployment to the work site, crew size, assignment of tasks to individual crew members, and equipment utilization practices were also documented. From these studies, the Penn State research team was able to formulate important recommendations to the Department. Also, the departmental planning standards, 6 tons/day and 4.73 man-hours/ton, were verified.

On roads where potholes are numerous, the most significant conclusion was that unless the crew is productionized, i.e., each crew member is assigned to perform the same task on each pothole, production and productivity goals will never be reached. An assembly-line approach must be adopted, and crew foremen must demonstrate leadership skills.

Cutting is the most important operation in the repair process because it establishes the pace of the crew. Foremen must remove all barriers to cutting and keep the operation moving. In the Penn State studies, the efficiency of the cutting operation was reduced by 30 percent because of waiting for instructions. Blowing debris from the hole with an air compressor leads to an additional 10 to 15 percent loss in efficiency. Marking the boundaries of the repair and sharp cutting tools were observed to increase productive output.

If cutting is continuous, the other operations will follow smoothly. In the Penn State studies, cleaning, filling, and compaction efficiencies were reduced by 40 to 60 percent because there was no hole available. Filling holes in multiple lifts is also inefficient and was practiced far more often than necessary. If cutting gets too far ahead of cleaning or filling, the repair process will invariably slow down or stop. Since these operations take less time than cutting, delays are most often associated with late material deliveries. Compaction is seldom a factor in reducing production and productivity. However, compaction was found to be very erratic in terms of the number of passes.

The best crew size is five or six including the foreman but excluding persons for traffic control. Larger crews will mean that productivity standards will not be achieved. Where holes are widely dispersed and require travel between holes, the best crew size is three. Production standards cannot be reached, but productivity goals can be satisfied if the hole is completely repaired in 20 minutes.

MATERIALS

When it is available, conventional dense-graded hot mix wearing course (½-in. nominal maximum aggregate size) mix is used for pothole repair. When hot mix is not available, cold stockpile patch material (PaDOT designation 485) is used. Reclaimed material, blade-mixed material, and material mixed on site are not used because it is impossible to provide adequate quality control.

The cold stockpile mix that is currently used is the result of an extensive study by Kandhal and Mellott of the Pennsylvania Department of Transportation (*2*). The resulting mix design represents a compromise between conflicting requirements (*3*):

Aggregate gradation. Open gradation provides good workability, but dense gradation improves durability.

Aggregate shape. Rounded aggregate provides good workability, but angular aggregate is necessary for in-place stability.

Binder viscosity. Low binder viscosity is necessary for storageability and workability, but higher viscosity provides better cohesion after the mix is in place.

Binder content. High residual bitumen content is necessary to provide stickiness and durability of the asphaltic film on the aggregate, but binder content is limited by the fact that excessive binder will drain from hot mix when it is first placed into the stockpile.

Gradation on the 485 cold patch material is as follows: 100 percent passing 3/8 in., 85 to 100 percent passing the No. 4 sieve, 10 to 40 percent passing the No. 8 sieve, 0 to 10 percent passing the No. 16 sieve, and a maximum of 2 percent passing the No. 200 sieve. The result is a workable, stable mix that contains sufficient liquid to be self-tacking. PaDOT Bulletin 26 details the specifications for this mix and contains recommended testing procedures to insure low-temperature workability and maximum allowable liquid content.

Any antistrip additive used in cold patch mixtures should be carefully evaluated with the job mix aggregate and not a standard reference aggregate. The cutback producer should certify compatibility of his cutback with the job mix aggregate. One further note: the 485 cold mix is produced in hot mix plants using heated, dried aggregate. The level of plant inspection is the same as required for hot mix. The current price for 485 cold mix is approximately $25 to $30 per ton. Performance of this material has been excellent, providing a truly permanent repair.

SUMMARY AND CONCLUSIONS

Long-lasting, cost-effective pothole repairs are possible with conventional materials and equipment. Exotic materials are not a panacea for the pothole repair problem. To be effective, a do-it-right policy must be adopted and it must be fully supported by all levels of management.

Cold stockpile mixes can be used for permanent repairs. This is verified by the data shown in Figure 12, which are the result of observations of more than 600 potholes repaired with cold mix. The key to obtaining a long-lasting repair is to use quality materials, properly compacted into a well-prepared hole.

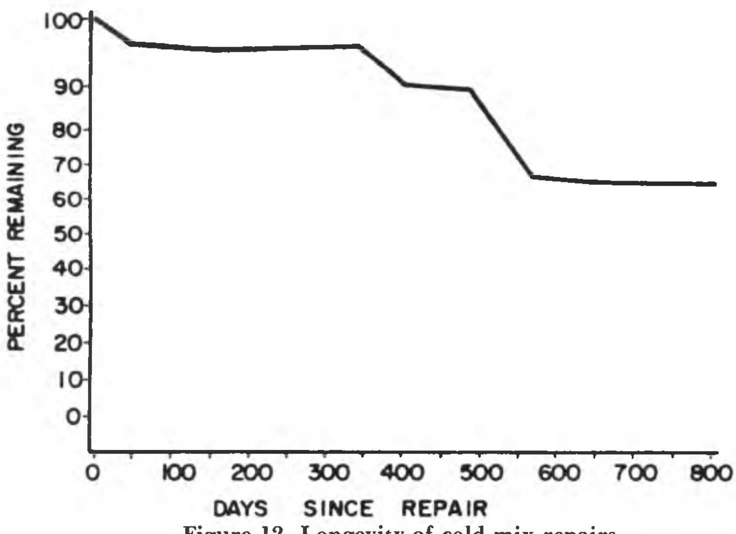

Figure 12. Longevity of cold mix repairs.

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The views and conclusions presented in this paper represent those of the authors and do not necessarily represent those of the Pennsylvania Department of Transportation. None of the statements in this paper should be represented as endorsements of particular manufacturers of equipment or equipment suppliers.

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