Pothole Patching

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BACKGROUND

The treatment of potholes is a very costly and time-consuming activity of many highway organizations. At the same time, potholes cause significant economic loss to the road user. This user loss, which takes many forms such as damaged tires, vehicle repairs, personal injuries, etc., is beyond estimation.

Potholes have always been a problem to maintenance organizations. This problem is greatly increased when the winter is particularly severe. The task of repairing potholes is made more difficult because of adverse weather conditions, patching material condition, the sheer number and condition of the potholes, etc.

The study was initiated by the Research and Training Center at West Lafayette. At the request of the Assistant Chief Engineer of Operations, a study plan was prepared and subsequently approved early in 1979. The placement of experimental pothole repairs was started in March 1979 and the performance of the repairs was closely observed the following summer. This observation period was terminated in November 1979. During the observation period, one interim progress report was prepared at the request of the Assistant Chief Engineer of Operations.

OBJECTIVES

The major objectives of this study are:

1. To compare the performance of pothole repairs made with heated and unheated stockpiled WS patching mixture;
2. To determine the optimum amount or degree of hole preparation;
3. To compare compaction methods and equipment; and
4. To determine the combination of factors which will result in the most satisfactory pothole repair.

Because of the many variables that affect pothole repairs the study was designed with as few variables as possible. This approach was used with the hope that the isolation of major variables will lead to a better understanding of pothole repairs and the factors having a significant effect on their performance.

SCOPE

The original study involved a total of 288 experimental patches containing eight different types of pothole treatment. Following the final evaluation of these patches in June 1979, it became apparent that additional experimentation would be needed to clarify the high percentage of failures that occurred as the result of settlement and mix displacement. To do this, an additional 36 patches were placed using two different types of pothole treatment. Here additional placement refinements were used with the intent to maximize the performance of the 36 patches.

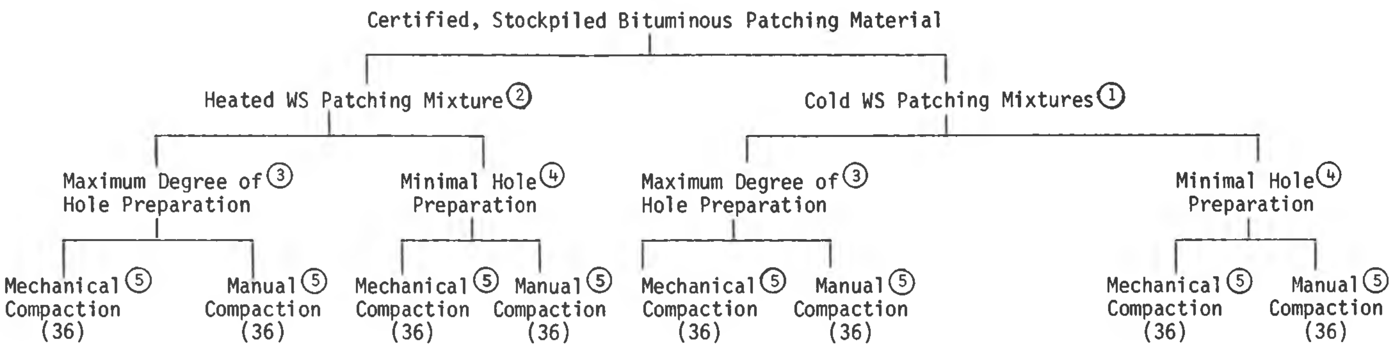
Figure 1 shows the various types of patches used in the original study. Additional information on the various methods of patch treatment is given in Table 1. The treatment of patches in the extended portion of the study is given in Table 2. The location of all the patches in the study is shown in Figure 2.

DETAILS OF CONSTRUCTION

All the experimental pothole repairs in the study were made on US-52 both north and south of Lafayette. The decision to place all the patches on US-52 was made by Crawfordsville District Maintenance personnel. This choice was intended to help minimize the traffic and climatic variables and at the same time facilitate periodic inspection of patches. The selection of individual potholes for patching was made by the Research and Training Center personnel at the job site.

This section of dual lane highway is a bituminous, overlaid, jointed, P.C. concrete pavement. Typical depth of the repairs ranged from one and one half to three inches. The pothole areas involving minimum hole preparation ranged from one to three square feet and those with maximum hole preparation ranged from four to sixteen square feet.

The experimental pothole repairs were made by crews from two areas. The Crawfordsville Subdistrict crew placed 288 patches and the Fowler Subdistrict crew placed 36. All repairs were made in the travel lanes of US-52. About 60% of the potholes were made in the right wheelpath and about 30% in the left. The remaining 10% of the repairs were made at various locations in the lane, such as the pavement edge, between wheelpaths, or near the centerline of both lanes. All potholes were repaired with one lift of mix and were constructed flush with the existing pavement surface as much as possible.



1. At this time, the study will involve the use of WS Mixtures as outline in Section 620.06 (1978 Specs. p. 268). Cold mixtures will be transported to the job site in heated hot boxes containing an additional compartment for heated tack and sealing material.
2. Heated Mixtures will be prepared by placing the cold WS Mixtures into a Porta Patcher and heating to at least 180°F. The heated mixture will be transported to the job site in heated hot boxes.
3. Maximum hole preparation will be in accordance with the procedure outlined in the Division of Maintenance Performance Standard, Code 201, for Shallow Patching (dated July 1, 1978).
4. Minimal hole preparation will involve no squaring of edges or tacking of bottom or sides but will require the removal of loose material and standing water.
5. All patches are to be sealed and chocked with sand.

Fig. 1 Attachment From the Plan of Study

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Pothole Research

Table 1 Pothole Failures (Original Study) (Placed Between March 14 and April 30 1979)

Number Patches Placed	Total Placed = 288 Potholes	Type of Failure: Settlement (1)	Type of Failure: Shoving (2)	Type of Failure: Settlement & Shoving	Total Failures	Percent Failures
36	Heated, maximum hole preparation, mechanical compaction tack and sealed, sanded (weather; cloudy, dry, 31 °F)	4	5	5	14	38.9
36	Heated, maximum hole preparation, manual compaction tack and sealed, sanded (weather; sunny, dry, 37 °F)	2	4	0	6	16.7
36	Heated, minimum hole preparation, mechanical compaction no tack used, sealed, sanded (weather; cloudly, dry, 44 °F)	0	6	0	6	16.7
36	Heated, minimum hole preparation, manual compaction no tack used, sealed, sanded (weather; sunny, dry, 55 °F)	0	3	0	3	8.3
36	Cold, maximum hole preparation, mechanical compaction tack and sealed, sanded (weather; cloudy, dry, 25 °F)	17	1	2	20	55.6
36	Cold, maximum hole preparation, manual compaction tack and sealed, sanded (weather; cloudy, damp, 32 °F)	34	0	0	34	94.4
36	Cold, minimum hole preparation, mechanical compaction no tack used, sealed, sanded (weather; cloudy, damp, 55 °F)	30	0	0	30	83.3
36	Cold, minimum hole preparation, manual compaction no tack used, sealed, sanded (weather; cloudy, damp, 40 °F)	18	2	0	20	55.6

Failures in heated WS mix = 29 each or 20.1% failures
Failures in unheated WS mix = 104 each or 72.2% failures

(1) Settlement failure was one where the mix settled ¾ or more inches.
(2) Shoving failure was one where the mix is being pushed out of the pothole

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Table 2 Pothole Failures (extended study) (Placed between August 6 and August 9, 1979)

Number Patches Placed	Total Placed = 36 Potholes (all were uniform size)	Type of Failure				
		Settlement (1)	Shoving (2)	Settlement & Shoving	Total Failures	Percent Failures
9	Compaction, Tack on sides and bottom, Tack cured with torch, sealed, sanded (weather; sunny, dry, 88°F)	0	1	0	1	11.1
5	Heated, maximum hole preparation, maximum mechanical compaction, tack vertical sides only, cured tack with torch, no seal, sanded lightly (weather; sunny, dry, 87°F)	0	0	0	0	0
4	Heated, maximum hole preparation, maximum mechanical compaction, tack revtical sides only, cured tack with torch, no seal, sanded lightly, (weather; sunny, 90°F)	1	0	0	1	25.0
4	Cold, maximum hole preparation, maximum mechanical compaction, tack on sides and bottom, cured tack with torch, no seal, sanded lightly, (weather; sunny, dry, 90°F)	2	0	0	2	50.0
14	Cold, maximum hole preparation, maximum mechanical compaction, tack on sides and bottom, cured tack with torch, sealed, sanded (weather; sunny, dry, 95°F)	7	1	0	8	57.1

Failures in heated WS mix = 2 each OR 11.1% failures

Failures in unheated WS mix = 10 each OR 55.5% failures

(1) Settlement failure is one where the mix in the pothole has settled ½ inch or more. In the original study this criteria was ¾ inch or more. The lesser value was selected for the added study because here the patches were compacted much better.

(2) Shoving failure is one where the mix is being pushed out of the pothole.

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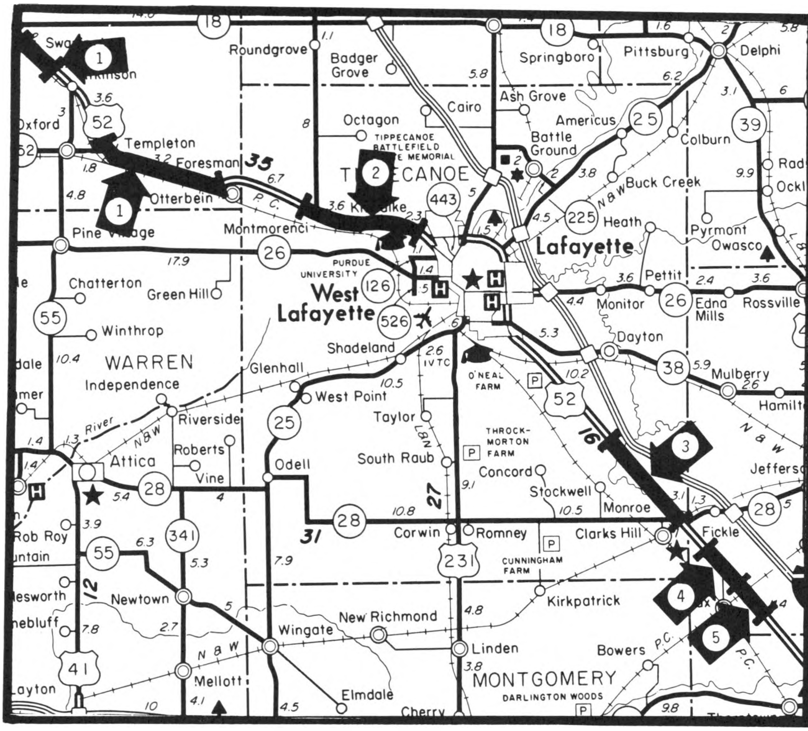


Figure 2 **Location of Potholes in the Study**

1. **Cold Mix, Minimum Preparation, Manual Compaction, Original Study, ADT is 3600 VPD**
2. **Cold Mix, Maximum Hole Preparation, Mechanical Compaction, Original Study, ADT is 6500 VPD**
3. **Heated Mix, Maximum and Minimum Hole Preparation, Manual and Mechanical Compaction, Original Study, ADT is 4200 VPD**
4. **Cold Mix, Maximum Hole Preparation, Maximum Mechanical Compaction, Added Study, ADT is 3200 VPD**
5. **Heated Mix, Maximum Hole Preparation, Maximum Mechanical Compaction, Added Study, ADT is 3200 VPD**

The patches requiring mechanical densification were compacted with "Stomper," Model VR-15, tamping compactor weighing about 135 lbs. A small number of patches were compacted with a 32 lb. "Racine," pole type compactor which was powered by the hydraulic system from the truck. Its use was discontinued due to its poor performance. The patches requiring manual compaction were all compacted with a regular hand-tamp weighing about 12 lbs.

The amount of mechanical densification to be applied was determined by visual means at the time the experimental patches were started. After that, the same effort of compaction was applied to all patches in the original study. For both heated and unheated mix, five to six passes were applied with the mechanical tamping compactor. On patches in the extended portion of the study, where maximum densification was required, the number of passes required to achieve maximum density was determined with the nuclear gauge and based on a gauge reading obtained at the point where the mix could not be further densified. All patches compacted with a hand tamp received a minimum of four coverages and the need for additional coverages was determined and applied by the hand tamp operator.

The bituminous material used to tack and seal the repairs was AE-150. When the hot-box was used, the material was heated in a separate asphalt container on the unit. On the cold mix patches the AE-150 material was carried in a 55 gallon barrel and applied cold. In both instances the AE-150 was applied by pouring from a container and spreading the liquid material with a broom. All patches in the original study were sealed but only half were tacked.

As the patches were completed, a detailed report was prepared on each pothole that was treated. All pertinent factors were noted and documented at the time of construction, including before and after photographs. Periodic inspections were made over a period of three months after the repairs and photographs were taken from the same angle after each inspection.

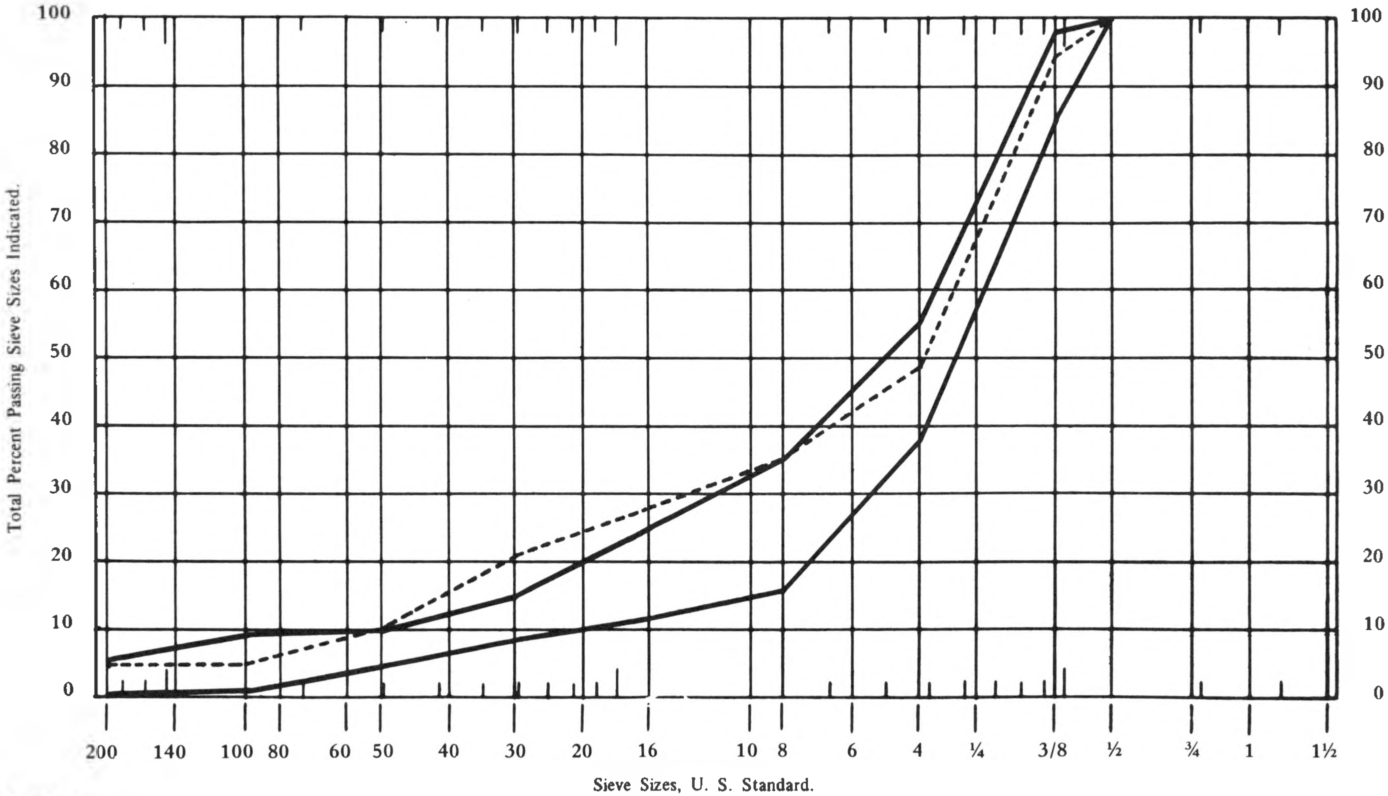
MIX CHARACTERISTICS

Before any patches were placed, the WS cold mix was sampled and tested from stockpiles at three locations. The mix located at the Crawfordsville Subdistrict unit was selected to be used for the study. The WS mix in this stockpile was the Medium-Textured, meeting the requirements of Section 620.06 and 620.06(a). Tests on the mix were performed by the Research and Training Center, the Crawfordsville Materials and Tests, and finally by the Division of Materials and Tests at Indianapolis.

Mix Analysis

Tests indicate the mix had good uniformity; was produced with 100% crushed, coarse aggregate; met the required criteria for stripping; and had good workability. The average asphalt content in the mix was 4.9%. Penetration of the asphalt recovered by the Abson method from the heated mix was 170 at 77°.

The gradation of the mix is shown in Figure 3. As indicated the mix was out of gradation somewhat on No. 16 and No. 30 sieves. It was decided to use the mix anyway because all its other characteristics were



Gradation Band for Medium Textured Cold-Mix as Per. Sec. 620 ________

Actual Gradation of the Cold-Mix Produced Under PO. 78901459 ------

Fig. 3 Required and Actual Gradation of Medium Textured Cold-Mix Used in the Study

favorable and at that particular time none better was available. Subsequent tests revealed that the variation in gradation did not detract from the mixtures good stability.

Mix Stability

Stability tests were conducted on WS patching mixture used in the study. The Hveem stability of the mix was 35 when densified with the kneading compactor and 50 when densified with the gyratory compactor. The value of 35 is well above that required (20) by Section 620.06 for this particular mixture. The significant increase in stability obtained with the gyratory compactor shows the mix had the potential to contribute to stable pothole repairs.

The Division of Materials and Tests also conducted tests on the effect of water on the mixtures cohesion. Tests made in accordance with AASHTO T-165 indicated that the compacted mix lost 50% of its compressive values of retained compressive strength range between 70% and 80% for mixtures with good serviceability.

The significance of this high loss in strength, as the result of the presence of water in the mix, underscores the need for good field densification to minimize high void contents which permit water to enter the patch. Many of the pothole repair failures are reported to be due to the penetration of moisture into the patches before they could be densified by traffic.

Mix Compactability

During the placement of the experimental patches it was suspected, but not readily confirmed, that the density one could attain depended on the temperature of the mix. This was followed-up by constructing a test pad at the Center and by compacting some of the mix at various temperatures until maximum density was obtained. Figure 4 shows the results of this evaluation. It indicates the highest densities that can be attained at various mix temperatures, together with the number of passes required with the "Stomper" compactor.

The higher density with the least compactive effort was obtained with the heated WS mix at 200°F. Acceptable densities continued to be obtained until the cold mix temperature went down to 70°F, but with a considerable increase in compactive effort. Below 70°F the ability of the cold mix to densify, together with the effectiveness of the compactive effort, dropped-off sharply.

What this seems to indicate is that when the Medium-Textured WS cold mix is used at temperatures below 70°F proper density cannot be obtained with the mechanical compaction equipment used in the study (Stomper) and certainly not by hand tamping. Figure 5 shows that some

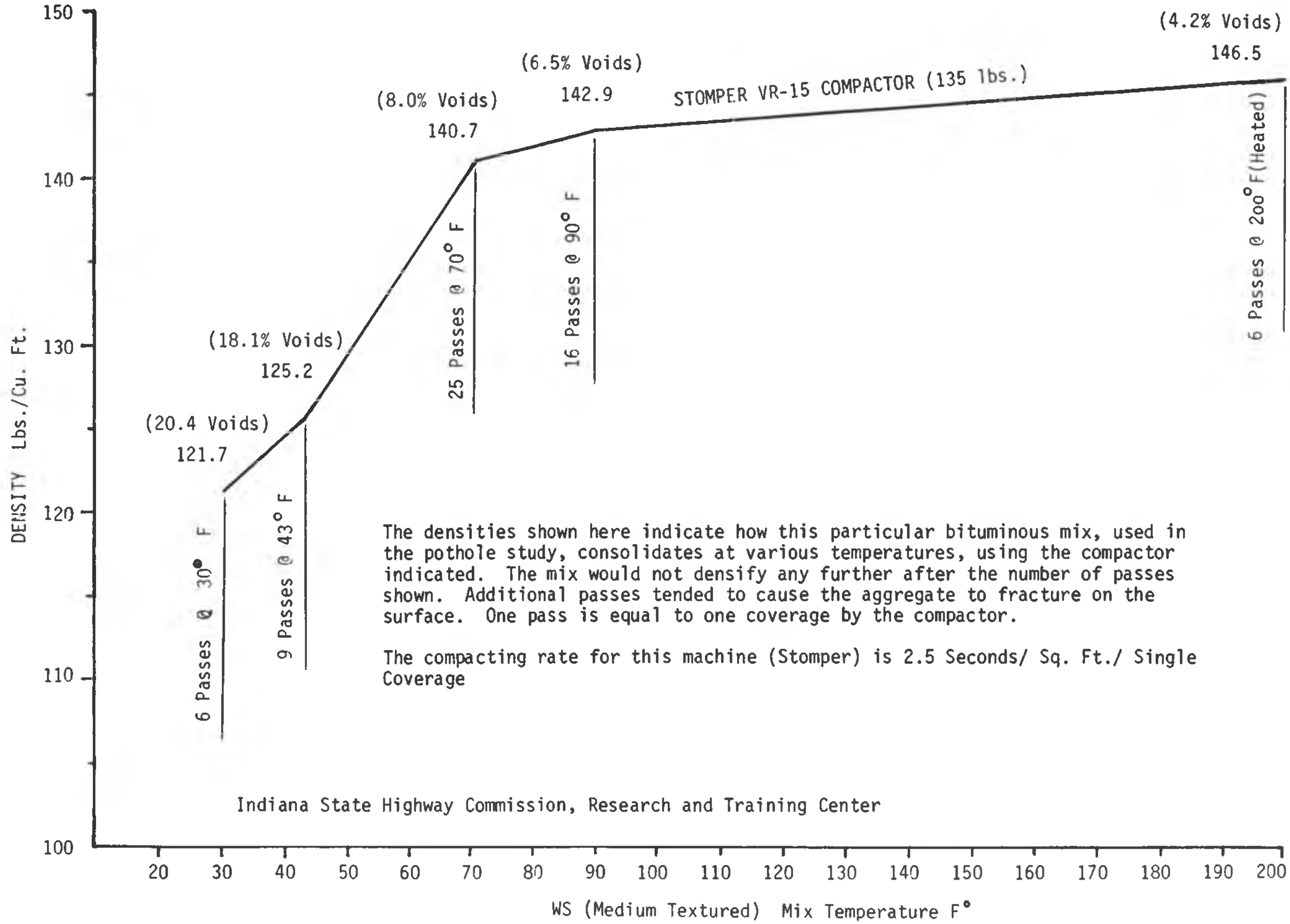


Figure 4. Compactability of the Mix—The Highest Density that a Mix Will Compact to Using Accepted Compaction Equipment

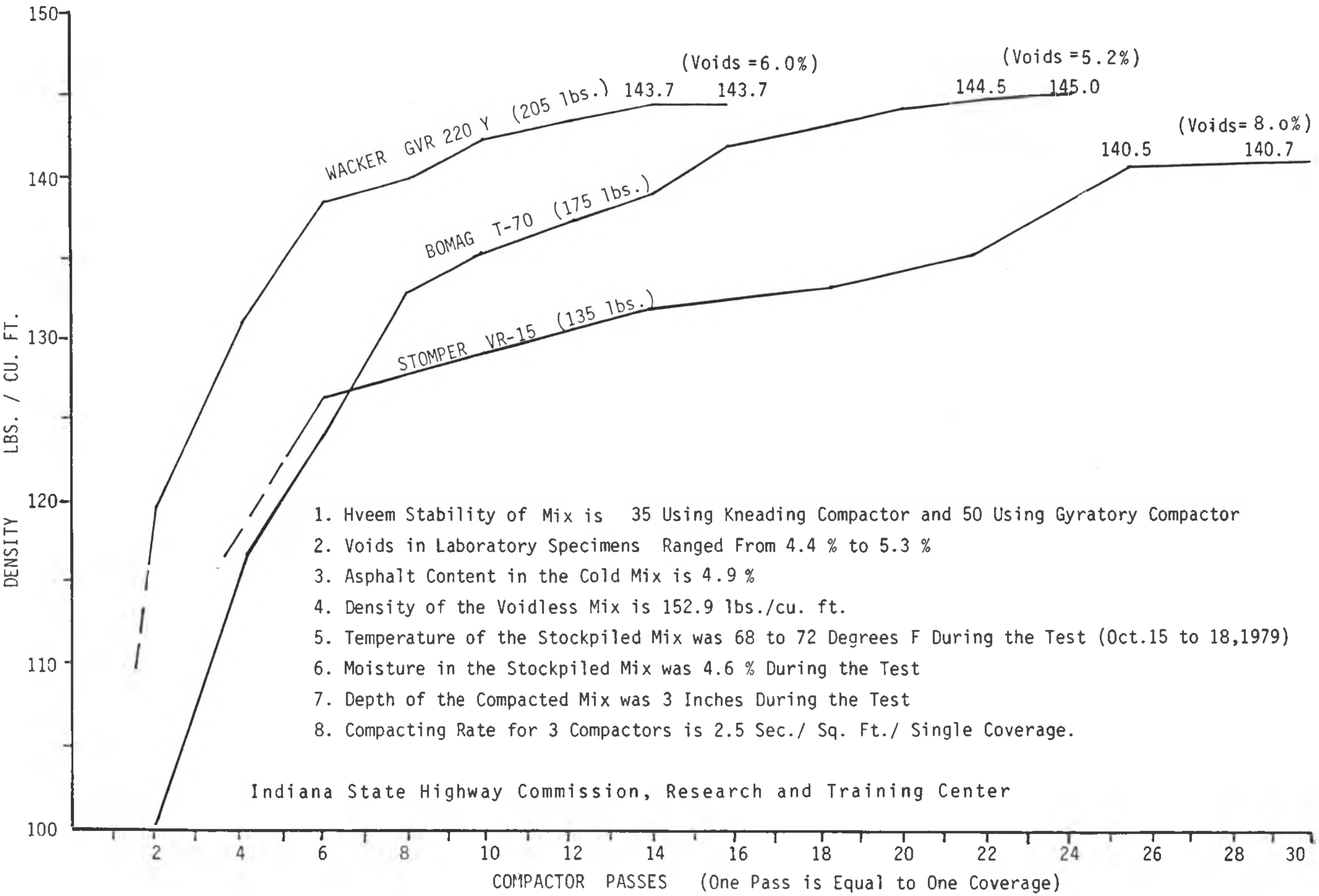


Figure 5. Density Growth Curves—Medium-Texture WS Cold Mix Compacted at 70°F Using Three Different Types of Compactors

additional density can be obtained by using heavier compactors but this advantage is lost when the air and mix temperature is at 60°F. Patches placed at lower temperatures are likely to settle, due to postcompaction by traffic, as soon as the temperature increases. Such patches will also have a tendency to ravel unless they are heavily sealed. Also, the patches will have high void contents making them susceptible to the intrusion of water and subsequent instability. Under these conditions it may be imprudent to expend extra effort in trying to make the patches permanent.

Mix Degradation

Tests on cores taken from patches that had settled and shoved, indicate that the aggregate in the mix undergoes considerable fracture due to the impact of traffic. The initial instability of the patch seems to continue even after the patch is repaired the second time.

Patches that are stable after construction also show some aggregate fracture but this degradation seems to stop after some inevitable settlement occurs. Figure 6 shows the extent of degradation that occurred after three months.

Mix Adequacy

The data shown in Figure 4 seems to indicate that a good working temperature range for Medium-Textured WS mix is between 70*°F and 200*°F. If all the mix was to be heated to 200° a slight reduction in the asphalt content would be in order, as the 4.2% void content is somewhat low for patches not yet subjected to traffic.

Data from the study seems to indicate that in most instances where tack and seal was applied the mix in the patch was contaminated with excess asphalt and irreversible instability developed. Table 3 indicates samples one to five were taken from patches that were very carefully tacked and sealed. All these show low void contents, high asphalt contamination and severe instability. These patches were among the first that were placed in the original study.

Samples 6 and 7 are cores taken from patches in the extended portion of the study, where the tack was cured with a torch and the patch was very carefully sealed. These cores show, that in spite of careful treatment, there is also high asphalt contamination. The patches seems to be stable now but may become unstable later. Patch 802 in the same series has already developed instability.

Samples 8, 9, and 10 were placed without tack or seal and show no ill effects from this omission. They appear to be stable and cores show that the mix is not contaminated with excess asphalt.

Patches placed with unheated WS cold mix appear to be less

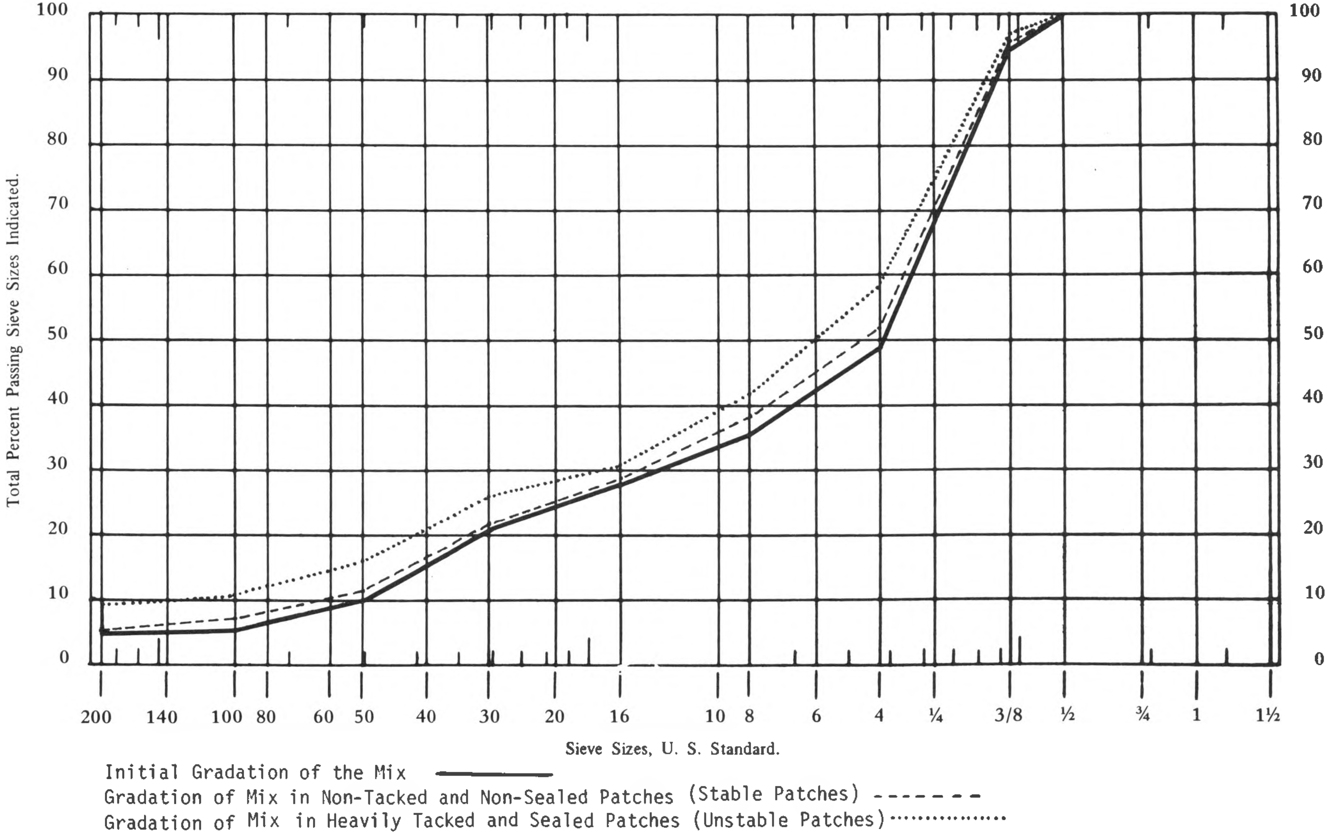


Figure 6. Degradation of Mix Under Shoving and Non-Shoving Conditions

Table 3 Laboratory Investigation of Cores Taken From Patches Using Heated Cold-Mix (200°F)

	Patch No.	Date Placed	Date Cored	Density	Voids %	Asphalt Content %	Pen. 77F	Remarks
1	012	3-14-79	7-23-79	151.1	1.2	6.35	125	Maximum Hole preparation, mechanical compaction tacked and sealed but tack was not cured. Patch Is Now Unstable and Shoving.
2	013	3-14-79	7-23-79	146.0	4.5	6.59		Maximum hole preparation, mechanical compaction, tacked and sealed but tack was not cured. Patch Is now unstable and shoving.
3	017	3-14-79	7-23-79	147.3	3.7			Maximum hole preparation, mechanical compaction, tacked and sealed but tack was not cured. Patch is now unstable and shoving.
4	018	3-14-79	7-23-79	148.8	2.9			Maximum Hole preparation, mechanical compaction tacked and sealed but tack was not cured. Patch is now unstable and shoving.
5	030	3-15-79	7-23-79	147.3	3.7			Maximum hole preparation, mechanical compaction, tacked and sealed but tack was not cured. Patch is now unstable and shoving.
6	803	8-07-79	8-28-79	149.1	2.5	6.90		Maximum hole preparation, maximum mechanical compaction, tacked and sealed, tack was cured with propane torch, top of patch was sanded prior to final compaction. Patch is now stable.
7	805	8-07-79	8-28-79	147.9	3.3	6.52		Maximum hole preparation, maximum mechanical compaction, tacked and sealed, tack was cured with propane torch, patch was sanded prior to final compaction. Patch is now stable.
8	A	3-17-79	7-23-79	144.8	5.3	5.04	170	Maximum hole preparation, mechanical compaction, no tack or seal applied, patch is now stable. This patch was not originally part of this study but was placed from the same mix and by same crew.
9	B	3-17-79	7-23-79	146.0	4.5	4.74		Maximum hole preparation, mechanical compaction, no tack or seal applied, patch is now stable. Same applies as patch A above.
10	816	8-08-79	8-28-79	144.8	5.3	4.84		Maximum hole preparation, maximum mechanical compaction, no tack or seal was used. Patch is now stable.

susceptible to contamination with excess tack and seal then those made with heated WS mix. This is attributed to the moisture in the cold mix which tends to occupy the void space and acts as a barrier to prevent contamination.

PERFORMANCE OF THE WS MIXTURE IN POTHOLES

The study contains two distinct groups of experimental patches. The first involves 288 patches placed early in the spring of 1979 and are described and assessed in Table 1. The second group involving 36 patches placed in August 1979 are described and assessed in Table 2. The decision to add the second group of patches was made on the basis of findings noted in Table 1.

All patches in the first portion of the study was placed with better than average workmanship. The work was monitored by members of the Research and Training Center and the work was within the standards specified and inferred by the study plan.

The weather conditions during the spring of 1979 were about normal with several heavy rains capable of affecting the performance of the experimental patches. However no patches were washed out even though some were submerged under water for several hours at a time. This apparently is due to the sealing of patches immediately after placement.

Performance of the Heated Mix

The patches made with heated WS patching material performed satisfactorily until the occurrence of hot weather in the latter part of June. Then the mix in the patches began to shove and move out of the hole by the action of traffic. Several cores were obtained from the patches that were shoving. Mix analysis of these cores indicated that the aggregate in the mix was undergoing considerable degradation and the asphalt content, on the average, increased from the original content of 4.9% to 6.6%. This increase in asphalt content probably is the result of excess use of tack and sealing material. While efforts were made at the time of the repair to keep the application of the AE-150 sealing and tacking material thin the method of pouring from a pot usually resulted in excess asphalt in the hole and on the patch surface.

At this time, there does not appear to be a practical way of properly applying the liquid asphalt. Satisfactory performance of some patches that were placed without tack and seal seems to indicate that pothole repairs can be made without this material with no noticeable consequences.

The patches in the extended part of the study were placed with critical attention to tacking, sealing, and densification of the mix.

Tacking material was cured with a torch and density was controlled with the nuclear gauge. This care seems to have prolonged the stability of the patches, but the mix in these patches is also high in asphalt content and may become unstable later.

Performance of the Unheated WS Mix

The most significant failure of pothole repairs made with unheated WS cold mix was settlement. This generally occurred within two weeks after placement in patches that were larger than 2 square feet in area. Settlement of the smaller patches did not occur until the latter part of June. Patches greater than 4 square feet and those compacted manually seemed to have the most failures.

Mechanical compaction of patches less than 2 square feet in area was generally not effective since many times the shoe of the compactor was larger than the hole. Sometimes, if care was not exercised, the compactor brokeup the pavement outside the pothole.

No potholes appeared to have failed due to the loss of mix as the result of moisture. The mix was probably retained in the potholes because the patches were sealed. The cold mixture was surprisingly stable. Even though the mix was soft during the first two months after it was placed, very little severe shoving was observed.

The 18 patches that were repaired with cold mix in the extended portion of the study reflect the same pattern of failures as the earlier patches. Here the settlement was not as severe as in the earlier patches, but because it occurred in spite of the maximum effort at densification, some doubt exists whether settlement of patches made with cold mix can be prevented.

PERFORMANCE OF EQUIPMENT USED

Hot Box

The heated WS cold mix was transported to the job site in a hot box equipped with an infrared heating system to maintain mix temperature. A special feature on this unit was a side mounted tank and heater for liquid asphalt used for tacking and sealing the pothole repairs.

The hot box was capable of maintaining mix temperature throughout the day when its heating equipment was activated and was working properly. The heating equipment however, was not able to elevate the temperature of the mix when it fell below the desired level. Contrary to earlier claims of versatility, it was found that if the mix cooled down to 100°F, it was very difficult to get it out of the box in the regular manner.

The use of the hot box to carry cold mix for patching was impractical it was very difficult to get the material out of the unit. It was necessary to use the pick to get the material out of the opening near the bottom of the box. It was also not possible to raise the temperature of the cold mix in the box sufficiently to improve its workability. The hot box worked well for heated mixtures but its use was discontinued for cold mix after one try. It was more convenient to use the WS cold mix from an open truck bed.

The value of the heated liquid asphalt on the hot box is somewhat questionable, particularly the way it is normally used. When the heated liquid material is poured from a container for the purpose of tacking, it quickly cools to ambient temperature before it can be properly distributed with a broom. When heated liquid is poured on a patch made with heated mix as a seal, the material penetrates into the compacted surface before it can be uniformly spread.

Mechanical Compators (Tamper Type)

Most of the mechanical densification of the patches was performed with a "Stomper" Model VR-15 tamping-type compactor. This unit was very effective and easy to use. It could be handled by one man, from pothole to pothole, by the use of quick-attach wheels. The gasoline powered unit was quiet and easy to start. Its 12" x 14" compacting foot made it somewhat impractical for use in placing small patches flush with the original pavement. It tended to damage the surrounding pavement if the operator was not careful.

Some of the patches in the extended portion of the study were compacted with a "Wacker," Model GVR-220 Y, tamping compactor. This machine is heavier then the "Stomper," and is very effective in compacting bituminous patches but somewhat harder to handle in small areas than the "Stomper."

Additional testing was conducted using three different tamping compactors on a special test pad constructed at the Research and Training Center. The results of this testing are shown in Figure 5.

Each compactor was applied, in a controlled manner, to densify a three inch lay of cold mix until peak density was obtained. The final results in Figure 5 show that peak densities vary somewhat, but based on an acceptable void content from 5 to 8 percent at the time of construction, all three compactors seem to be able to attain the desired density. The main difference between the compactors is the number of passes needed to get the desired density. The "Bomag" Model T-70 compactor was able to attain the highest density even though it was lighter than the "Wacker." This is attributed to the "Bomag's" good handling characteristic. The unit was provided to the Center on a trial basis for this test.

The number of passes required to compact the cold mix in Figure 5 was somewhat greater than anticipated before the test was started. It was also found that the time required to make a pass over an area was nearly the same for all three compactors—2.5 seconds square feet/ single coverage. By using this rate and referring to Figure 4, it is possible to estimate the approximate time needed to compact a pothole if the size of the patch and mix temperature is known.

Example:

Assume patch is 2' x 2' and 3 inches deep
Assume mix temperatures of 70°, 90° and 200°F
Assume "Stomper" VR-15 compactor is used
For 70° Cold Mix; 25(2.5)(4)(1/60) = 4.2 min.
For 90° Cold Mix; 16(2.5)(4)(1/60) = 2.7 min.
For 200° Heated Mix; 6(2.5)(4)(1/60) = 1.0 min.

If the "Bomag" compactor is used, the above times would be reduced to 2.5, 1.6, and 0.6 minutes respectively. If the "Wacker" compactor is used, the time needed to compact the same pothole would be 1.3, 0.8, and 0.3 minutes respectively.

Actually as potholes get smaller, it is more difficult to control the compactors particularly the heavier units. Because of this the estimated times above would need to be somewhat greater. The highest time of 4.2 minutes for 70° mix, is not an unrealistic amount of time to spend on a patch. In a regular patching crew, one man is generally assigned to operate the compactor. It was observed that if he is not operating the unit he generally waits while the next pothole is being filled.

Mechanical Compactor (Pole Type)

This compactor, manufactured by Racine, was provided on a trial basis for this study. The compactor operated from the hydraulic system on the truck. A good evaluation was not possible as the compactor did not seem to operate properly. It appeared to be an ideal compactor for small patches as it had a 6 inch diameter compacting foot which could be controlled easily without breaking the adjacent pavement. Actual operations of this compactor was somewhat complicated because one man had to accelerate the truck motor to a specific speed to make it work. It was also cumbersome because of its dependence on the truck and hydraulic system.

CONCLUSIONS

The main objective of this study was to obtain information which would lead to a better understanding of pothole repairs. The conclusions listed here are not portrayed as a comprehensive analysis of pothole patching, but are in keeping with the original aim of the study which was to establish a few basic facts on which to build.

The conclusions are as follows:

1. The greatest number of successful pothole repairs, under various outside temperature conditions, were madc using stockpiled WS patching mix which was heated before use to 200° in a Porta-Patcher.
2. Pothole repairs made with unheated WS patching mix settled even though they were placed at 90° outside temperature, in good whether conditions, and compacted to the highest density that could be achieved with good compactors.
3. Pothole repairs made with unheated Medium-Textured WS patching mix at ambient temperatures below 70°F could not be compacted to the proper density with the 135 lb. "Stomper" compactor used in the study. Heavier compactors could attain slightly higher densities at 70°F but the advantage of the heavier compactor was lost when the ambient temperature fell to 60°F.
4. Even though the application of tack and seal is considered to be beneficial, the lack of a practical way to apply this material in fog-like manner allowed this heated WS mix to readily absorb the AE-150 and become contaminated with excess asphalt causing the repairs to become unstable and shove.
5. Well-compacted, heated WS mix patches without tack and seal, exhibit no shoving and appear to be more stable than similar repairs made with tack and seal.
6. Even poorly compacted cold WS mix patches have a much better chance against ravelling if they are sealed immediately after being placed.
7. All three types of mechanical compactors tested during the study were able to attain the required density. The only difference between them is the number of passes necessary to obtain the required density. The heaviest compactor tested was the most difficult to handle.
8. Manual compaction can be effective on very small potholes filled with heated mix.
9. In this study, hole preparation did not appear to be a significant factor to the performance of the patch. This may be because most of the potholes treated had near vertical edges.
10. In our study unheated tack and sealing asphalt material ap-

peared to be just as effective as the heated asphalt material and sometimes even better.

11. Once the mix in the patch has begun to shove, the addition of new mix material to restore its level with the existing pavement did not correct the shoving problem. Depending on a second try at filling a patch is a poor maintenance practice.

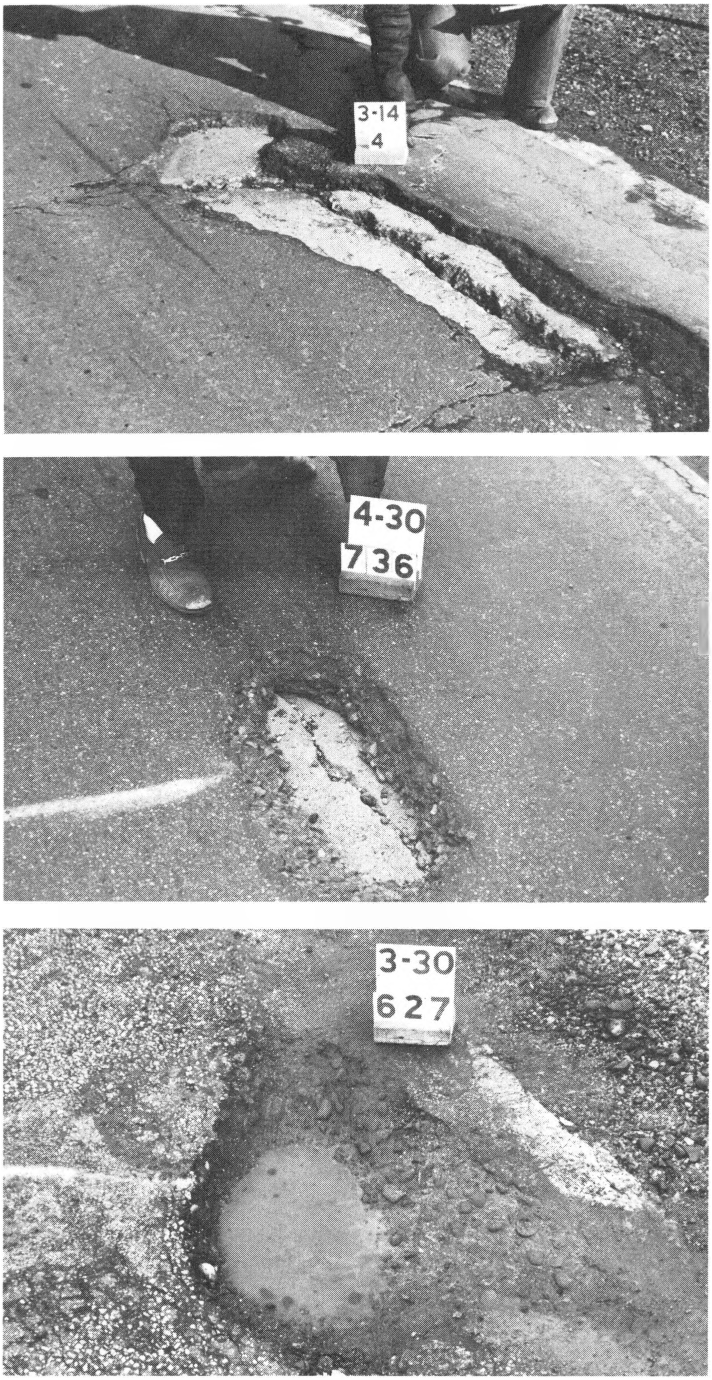


Figure 7. Typical Potholes on U.S. 52.

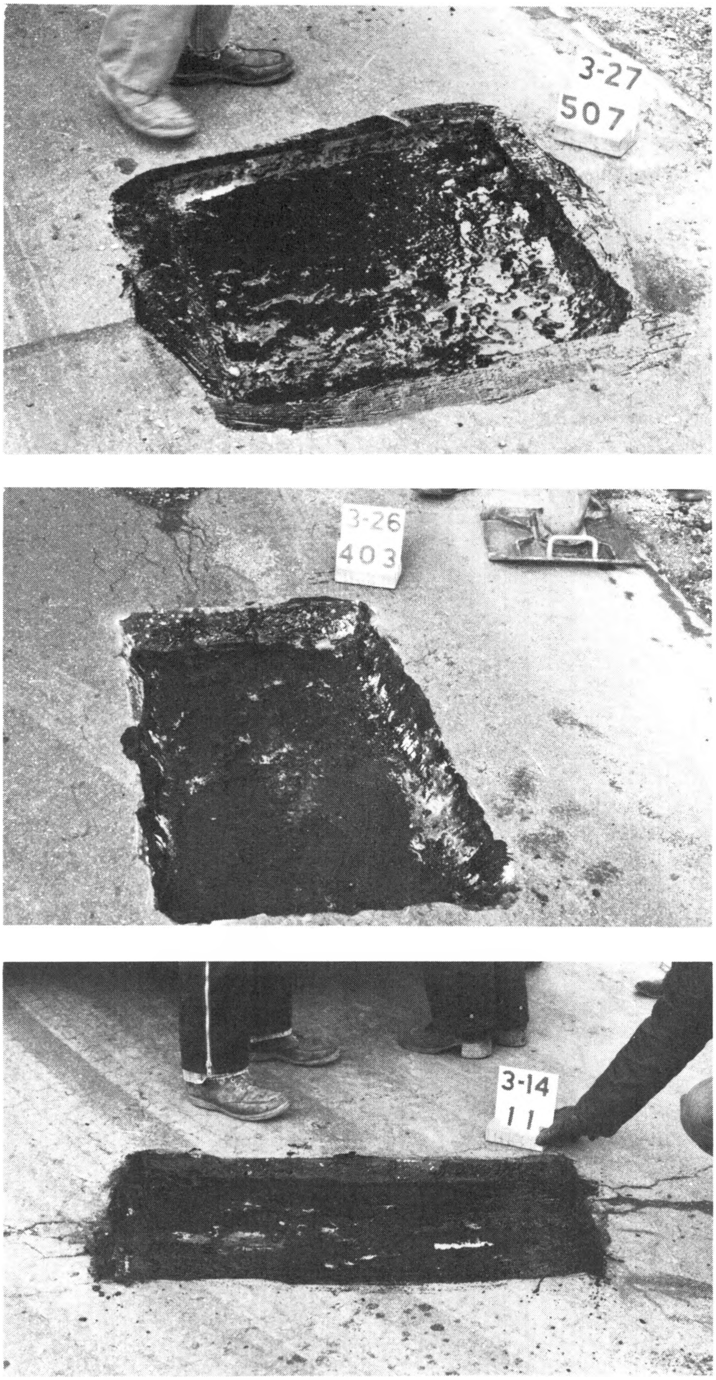


Figure 8. Typical Maximum Prepared Potholes.

Figure 9. Good for Small Patches.

Figure 10. Good for Large Patches.

Figure 11. WS Mix Heated in Porta-Patcher.

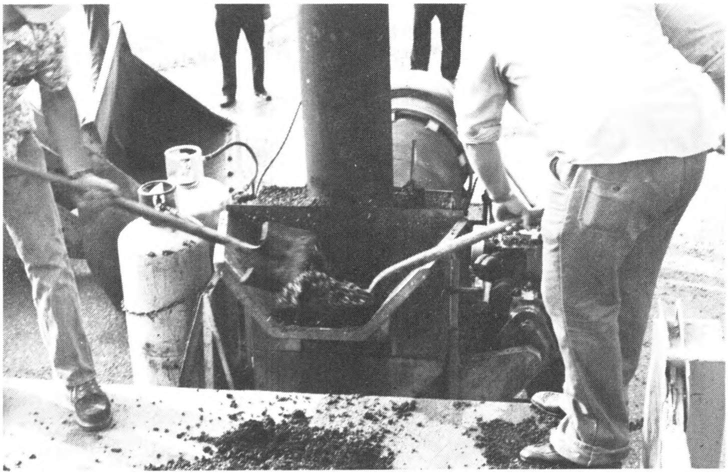


Figure 12. Cold Mix Going In.

Figure 13. Heated Mix Coming Out.

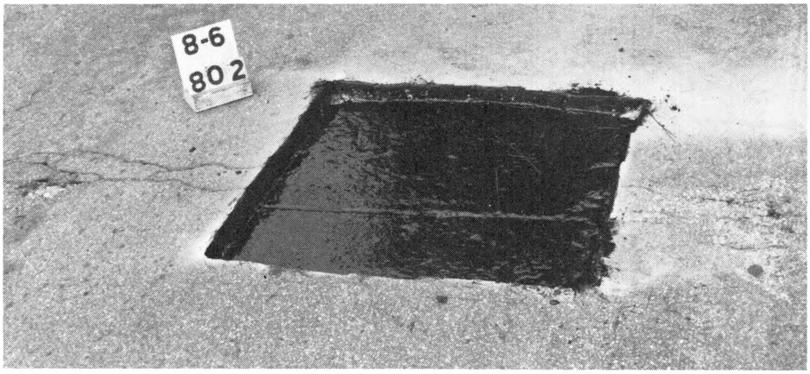


Figure 14. **Typical Extended Study Patches. Tack Was Cured with a Torch. Density Was Controlled with a Nuclear Gauge.**

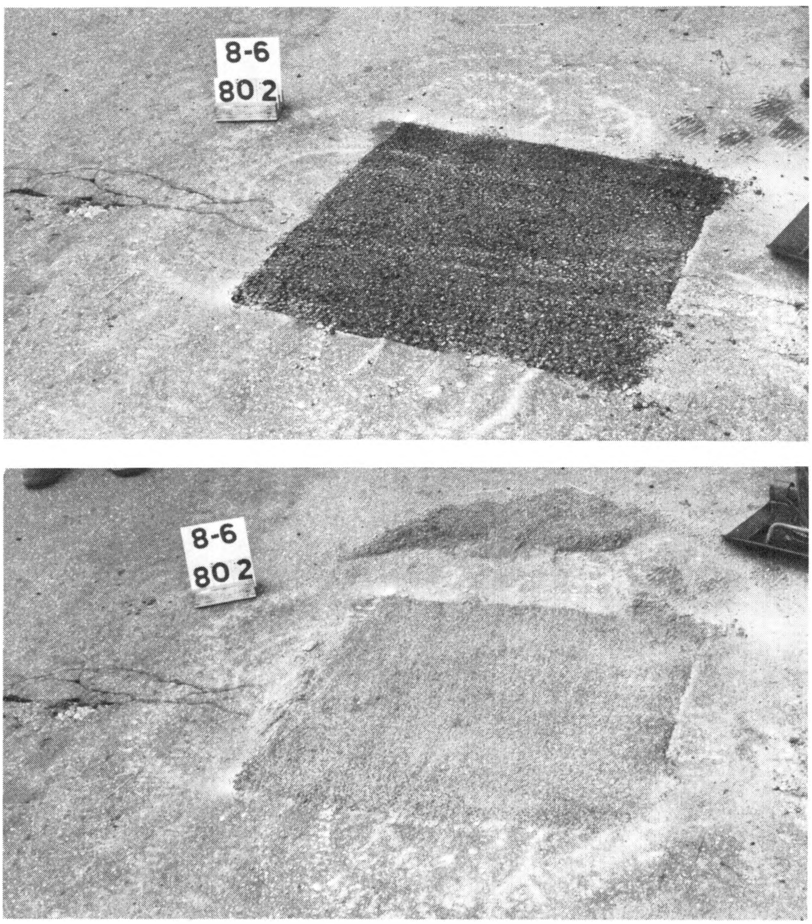


Figure 15. **Typical Extended Study Patches. After Compaction and after the Patches Were Sealed and Sanded.**