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16. Abstract

Patching asphalt pavement is an important, necessary part of TxDOT operations. Cracked and failed areas need to be replaced by high quality, sound pavement in order to meet the needs of the traveling public. This report documents the placing, cost, and performance of the HeatWurx™ pavement patching process, which uses infrared heating to make the pavement soft enough to mill and scarify so that it can be mixed with a rejuvenator and pavement millings to form a patch that stays bonded to the surrounding material. A total of 83 4 ft by 8 ft patches were placed.

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HEATWURX PATCHING AT TWO LOCATIONS IN SAN ANTONIO

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented here. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Thomas J. Freeman.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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CHAPTER 1. INTRODUCTION

Patching is an integral part of TxDOT operations so new and innovative, potentially cost- and energy-saving equipment and materials deserve serious consideration. With this in mind, TxDOT sponsored a project through the Texas Transportation Institute (TTI) to investigate the HeatWurx™ technology and equipment. This report documents that evaluation.

1.1 NEED FOR PATCHING

Pavement patching is the correction of a surface distress that usually involves the removal and replacement of material. It is used as pavement preservation when localized failures result in potholes or other distresses, which intermittent replacement of materials can mitigate until more severe or extensive distresses call for pavement rehabilitation. Patching is also used as a preparatory treatment to more extensive pavement preservation or rehabilitation activities, such as chip seals and overlays, in order to remove and replace materials, which would lead to premature failure of the corrective action.

Of the more than 174,000 sections in the 2011 Texas Department of Transportation (TxDOT) Pavement Management Information System (PMIS) database, there were about 16,500 pavement failures, most of which needed patching. There were almost 30,000 PMIS sections with alligator cracking, many of which needed patching, and over 72,000 sections with longitudinal cracking, some of which might need patching. These extensive numbers of failures and distresses indicate that there is a both a need for patching and for options when selecting the most cost-effective patching technique. Because of TxDOT's aggressive patching program, many problem areas are patched even before they are recorded in the database.

1.2 TYPES OF PATCHING OPERATIONS

TxDOT currently uses many different types of localized pavement repair. The following maintenance function codes all identify the different techniques, situations, and types of patches.

110-Removal and Replacement.
120-In-Place Repair.
211-Leveling or Overlay with Laydown Machine.
212- Leveling or Overlay with a Maintainer.
213-Leveling by Hand.
214-Leveling or Overlay with Drag Box.
232-Strip or Spot Seal Coat.
241-Potholes, Semi-Permanent Repair.
242-Potholes, Permanent Repair, Square Cut.
252-Milling or Planing.
253-Spot Milling.
270-Edge Repair.

1.3 NEED FOR HOT PATCHING

There have been many studies regarding the use of patching with hot materials versus using cold materials (often called "throw and go.") Cold patches are usually placed as an emergency or temporary treatment, usually in cold or wet weather, until a more permanent patch can be placed. This report will not discuss these previous studies, except to note that hot patching typically outperforms the cold patch technique (*1, 2*).

1.4 RECYCLE, SUSTAINABLE, GREEN

To provide the most economical patch while minimizing environmental impact, a patching process should:

- Reuse (not dispose of) the existing pavement and add only the materials needed to restore the integrity of the pavement.
- Minimize the use of natural resources.
- Be long-lasting.
- Cause a minimum of disruption to traffic.
- Reduce energy consumption and emissions.

1.5 REQUEST FOR EVALUATION

TxDOT sponsored a project at the Texas Transportation Institute to develop a testing plan and conduct research to evaluate a new patching technique that recycles the existing pavement in-place. The name of the company that developed the new technique is HeatWurx, located in Park City, Utah.

1.6 SCOPE AND OBJECTIVES OF STUDY

The objectives of this research project were to:

- Develop a familiarity with the HeatWurx patching process.
- Conduct training for TxDOT crews on how to patch pavement with the HeatWurx equipment.
- Apply the process on actual roadways.
- Evaluate the efficacy of the HeatWurx process.
- Document the research.

The scope of the research included:

- A review of literature pertaining to the HeatWurx process.
- Training that included placement of trial patches constructed in the TxDOT San Antonio District's maintenance yard.
- Full-scale roadway trials at two sites.
- Follow-up performance, material sampling, and material testing.
- Report preparation.

CHAPTER 2. BACKGROUND AND RESEARCH

In order to evaluate the HeatWurx system, it was necessary to investigate other instances where this equipment was used. The following describes what was found out about other test sections and describes the operation in detail.

2.1 LITERATURE SEARCH

The HeatWurx process is a new patching method that involves the use of infrared energy to heat a distressed pavement surface, scarification of the surface, blending new material with the existing material, filling the hole, and compacting the material. Literature available on the HeatWurx process included a report by the Utah Department of Transportation (UDOT) (*3*) and a HeatWurx website, www.heatwurx.com.

The UDOT report presented information on the test sites on US89 (also called SR89) and on IH84. The US89 site had fatigue and transverse cracking, and skin patches. The repaved area was 4 ft wide and 40 ft long. Each of eight areas was heated for 20 minutes with a target of 275° to 300°F. Temperatures were not measured. The heated area was milled to a depth which averaged 4 inches, and then approximately 1 gallon of a rejuvenator and imported millings were added and mixed into the surface. After shaping and compaction, the material was compacted and the edges of the patch sealed. The average patch density was 115 lb/ft^3. Total work time was just under 8 hours.

A visit to the site five months later showed that a transverse crack had reflected upwards through the crack, but no other distress.

The HeatWurx contractor estimated that if this had not been a demonstration project and the material quantities had been higher, that the costs for the treatment would have been approximately \$57.60/yd^2, at an average depth of 4 inches. UDOT patching costs on similar projects were \$34.42/yd^2.

At the IH84 site, the work was performed for a pothole on a bridge deck. The location was chosen "because of the difficulty in keeping a patch in place during wet winter months. Maintenance forces were required to repair the patch using the "throw-and-go" method after every storm." One area (2.22 yd^2) was repaired.

Due to the time required for the repair, the regular mill and fill procedure would have been a better treatment. It was also noted that the HeatWurx treatment did fuse the repaired area to the existing pavement better than their standard methods. The work on the bridge deck of IH84 did appear to be a better candidate for this type of repair.

2.2 DESCRIPTION OF PROCESS

2.2.1 Generator

The HeatWurx process uses a 45KV generator to generate electricity that powers an infrared heater. The generator components (Figures 1 and 2) are stacked on top of the heating elements. The generator uses diesel fuel.

2.2.2 Heating Equipment

The heating unit is shown on Figures 1, 3, and 4. A small skid steer loader is used to unload, position, and reload the combined generating and heating unit (Figures 4, 5, and 6).

Figure 1. HeatWurx Generator and Heater.

Figure 2. HeatWurx Gauges on Generator.

Figure 3. Unloading Generator and Heater.

Figure 4. Positioning Unit.

Figure 5. Positioning in Traffic.

Figure 6. Positioning Multiple Units.

Figure 7. Condensed Water along Unit.

Figure 8. Water after Unit Removal.

The pavement is heated until it meets or exceeds the temperature that the supervisor or operator selected. The unit can be lifted and the temperature tested with an infrared temperature device. If the temperature is still lower than preferred, the unit is replaced over the distressed area and heating is continued. As shown in Figures 7 and 8, moisture in the pavement is evaporated forming steam, which can then condense along the sides of the heater unit.

2.2.3 Milling, Sizing, and Mixing

Once the desired temperature is reached or exceeded, the heating unit is removed and the softened asphalt concrete is milled and scarified with the HeatWurx HWX-AP40 (see Figures 9 and 10). The processor unit has a standard attachment for a skid steer loader. Figures 11–14 show the milling head and shaping wings.

Figure 9. After Heater Removed, IH410Fr.

Figure 10. After Heater Removed, IH10Fr.

Figure 11. HWX-AP40 Attachment.

Figure 12. Milling and Scarifying Teeth.

The processor head is lowered to the pavement surface and the scarifying and milling teeth engaged. Two to three passes of the equipment are made, depending on the speed of travel, to break the pavement into small pieces (see Figure 15). Typically, about 90 percent of the processed material would pass a 1-inch sieve.

Figure 13. Preparing to Mill and Scarify.

Figure 14. Milling and Scarifying.

Figure 15. Size Distribution after First Milling Pass.

During and immediately after the first milling pass, additional moisture trapped in the pavement is often released (see Figure 16).

2.2.4 Shaping

Figure 17 shows the processing equipment head rotated into the shaping position. Material is manipulated into the form of the patch.

Figure 16. Preparing to Mill and Scarify.

Figure 17. Shaping Material.

2.2.5 Addition of Patching Material

After the first milling pass, additional material, in the form of asphalt millings from another project, is added to the patch (see Figures 18 and 19). The patch crew estimates the quantity of material to be added from their experience with previous patches.

Figure 18. Adding Millings.

Figure 19. Size Distribution of Millings.

2.2.6 Final Mixing and Processing

After the millings are added, the rejuvenator is applied to the hot, scarified material using the wand from an asphalt distributor containing the specialized rejuvenator. The patch crew visually estimates the amount of rejuvenator required based on their experience on previous patches (see Figure 20).

After the rejuvenator is added, all of the materials are mixed with the processor and reshaped in three additional passes. If the material appears dry after it is shaped, additional rejuvenator is often added. After the last shaping pass, excess material is shoveled into a waste bin.

2.2.7 Compaction

After the fourth mixing and shaping operation, the patch is rolled using a small vibratory hand roller (Figure 21). Edges are rolled first and then the interior of the patch. The number of passes is determined by the roller operator, in order to leave a patch that is well-compacted and flush to the surrounding pavement.

Figure 20. Adding Rejuvenator.

Figure 21. Rolling Finished Patch.

Figures 22 and 23 show completed patches. The surface of the patch in Figure 22 looks dirty because the water in the roller tracked mud onto the patch and not due to the HeatWurx system. The patch in Figure 23 shows how multiple patches can be laid adjacent to previous patches.

2.3 CREW SIZE

A crew size of eight to nine people is standard for this patching operation.

2.4 EQUIPMENT

The following equipment is required:

- 2 3/4 ton pickup trucks.
- 2 Skid steer loaders.
- 3 Trailers (for transportation of equipment).
- 2 10-yard dump trucks.
- 1 Arrow board.
- 2 HeatWurx generator and heater elements.
- 1 Processor for scarifying, milling, mixing, and shaping.
- 1 Small vibratory roller.
- Necessary traffic control.

Figure 22. Completed Patch

Figure 23. Multiple Patches and Overlap.

CHAPTER 3. RESEARCH PROGRAM

Prior to the training and construction of the test patches, an extensive research program, containing all of the important variables was established. The final plan was not completely implemented.

3.1 RESEARCH PLAN

The original plan (Table 1) called for multiple test sites with the following variables:

Table 1. Original Variables to be Studied.

Pavement Distress	Type of Asphalt Bound Pavement	Traffic Volume
Rutting	Hot mix asphalt, conventional asphalt binder	Auto
Raveling	Hot mix asphalt, polymer modified asphalt binder	Truck
Flushing	Hot mix asphalt, reclaimed asphalt pavement	
Delamination	Limestone rock asphalt	
Slippage	Cold patching material	
Fatigue Cracking	Previously patched areas	
Transverse Cracking		
Longitudinal Cracking		
Pothole		

In addition, the millings to be added during the patching process were to include millings from all of the types of asphalt bound pavements listed above. There was never any plan to construct a full factorial of all these variables, but it was hoped that many would be included. However, due to the weather and other problems, TxDOT agreed to place sections in only two locations.

3.2 TRAINING

HeatWurx personnel trained TxDOT crews to operate the HeatWurx equipment beginning with a classroom session on January 10, 2011, in the San Antonio District Office. Later, the hands-on training with the HeatWurx equipment took place in the equipment yard. After this one-day class, training was suspended in order to modify the equipment. After the equipment was modified, additional patches were placed in a nearby parking area. The training concluded with the first field trial on January 31, 2011. Major topics covered in the training included:

- Safety related to HeatWurx equipment operations.
- Transportation and placement of equipment.
- Generator and heater operations.
- Milling and mixing operations.
- Rejuvenator addition.
- Reshaping operations.
- Compaction and cleanup.

CHAPTER 4. CONSTRUCTION OF PATCHES

As part of the evaluation process, a total of 83 patches were constructed. At the first two sites, the patches were distributed throughout the section, while on the third section multiple patches were grouped in the same area.

4.1 GENERAL DESCRIPTION OF PATCH LOCATIONS

4.1.1 Locations

All patches were located on the IH410 eastbound frontage road, east of the Jackson-Keller intersection (IH410Fr) or on the eastbound IH10 frontage road south of the Huebner Road intersection (IH10Fr) at the Alamo Cafe.

4.1.2 Sites

Two sites were located on the IH410Fr location and one site was located on the IH10Fr location. The IH410Fr sites were located in a high-traffic area at an exit ramp off IH410 with very short sightlines and difficult traffic control requirements.

<u>IH410 Frontage Road, Site 1 (IH410Fr-1)</u>

This site had block cracking and raveling. Cracks were as wide as 0.5 inches and the raveling was extensive and severe (see Figures 24 through 27). Deterioration of the cracks resulted in considerable roughness. This site has lower volumes of high speed traffic as compared to IH410Fr-2, which has higher volumes of slower traffic near an intersection. Two patches were placed at this site.

<u>IH410 Frontage Road, Site 2 (IH410Fr-2)</u>

This site had less cracking, but more raveling than Site 1 (see Figures 28 and 29). Existing cracks were raveled and widened. Six patches were placed at this site.

<u>IH10 Frontage Road, Site 1 (IH10Fr-1)</u>

This site had block cracking and raveling (see Figures 30 through 32). Some of the cracks had begun to deteriorate, resulting in considerable roughness. Seventy-five patches were placed at this site.

Patching at this site occurred on February 10, 11, 14, 15, and 16 and these patches are referred to as 2/10, 2/11, 2/14, 2/15, and 2/16, respectively. The production rate for these days was 9, 12, 18, 18, and 18 patches, all placed adjacent to one another.

As can be seen in Figures 24 through 32, these sites were good candidates for minor patching. Due to their high traffic volume and a need to provide a more durable repair, the mostly likely fix for these sites would have been be to mill the top two inches and replace the surface. Some locations where there was alligator cracking would need spot repairs prior to placing the final surface.

Figure 24. General Location of IH410Fr-1.

Figure 25. Location of Patch 1 on Site IH410Fr-1.

Figure 26. Close-up of Location of Patch 1 on IH410Fr-1.

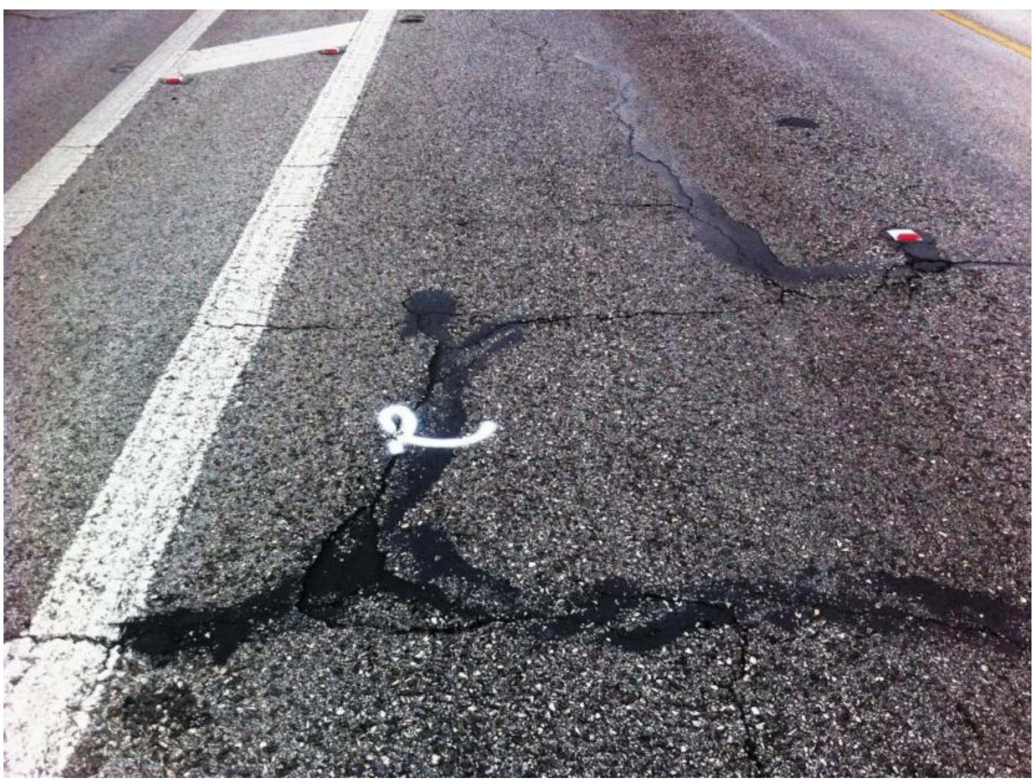

Figure 27. Location of Patch 2 on IH410Fr-1.

Figure 28. Location of Patch 4 on IH410Fr-2.

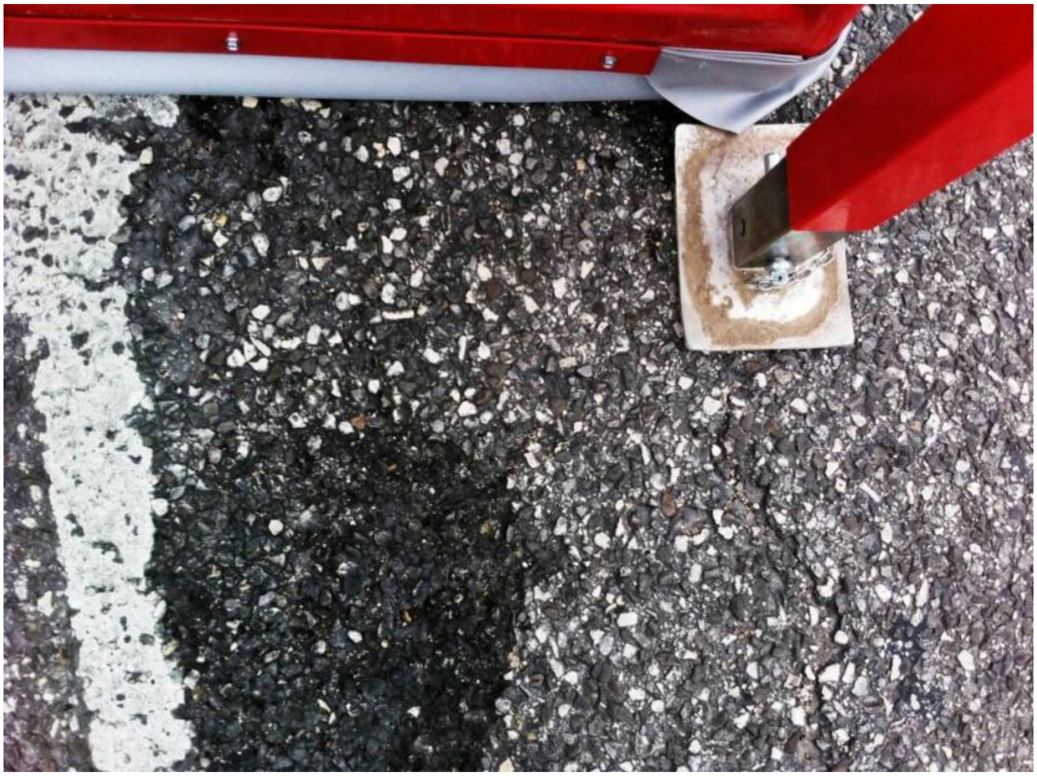

Figure 29. Close-up of Location of Patch 4 on IH410Fr-2.

Figure 30. Location of Patch 2/14-8 on IH10Fr.

Figure 31. Close-up of Location of Patch 2/14-8 on IH10Fr-1.

Figure 32. Location of Patch 2/15-2 on IH10Fr-1.

4.2 HEATING TIMES AND TEMPERATURES OF PATCHES

At the IH410 frontage road location (IH410Fr-1 and -2 sites), the air temperature was between 59° and 70°F, and the pavement surface temperature was between 67° and 87°F. Table 2 shows that the average heating duration was just under one hour and the temperature of the pavement, as measured by a handheld infrared temperature gun after heating was about 375°F.

Table 2 lists the times and temperatures for the IH410Fr location. Data taken at the IH10 Frontage road site (IH10Fr) was lost before it could be transferred to the research team. However, the next section shows that infrared camera readings of temperature were available for IH10FR. Figure 33 illustrates the heating time versus pavement temperature curve for the IH410Fr-1 and -2 sites.

Table 2. Relevant Times and Temperature Readings from IH410Fr-1 and -2 Site.

Test Site	Patch Num	Heater Num	Start Time	Stop Time	Duration (min)	Temp after Heating (°F)	Time (min) to Mix, Treat, and Roll	Temp after Rolling (°F)	Treatment Depth
IH410Fr-1	1	1	9:50	10:50	60	370	15	133	2.0
IH410Fr-1	2	2	9:55	11:03	78	488	15	160	1.5
IH410Fr-2	1	1	11:03	11:47	44	325	16	130	0.75
IH410Fr-2	2	2	11:07	12:19	72	360	15	140	1.0
IH410Fr-2	3	1	11:49	12:40	51	340	12	133	1.5
IH410Fr-2	4	2	12:22	13:12	50	385	13	160	1.5
IH410Fr-2	5	1	12:43	13:35	52	350	15	150	1.5
IH410Fr-2	6	2	13:12	13:55	43	370	15	140	1.5
	Average				56.3	373.5	14.5	143.3	1.4

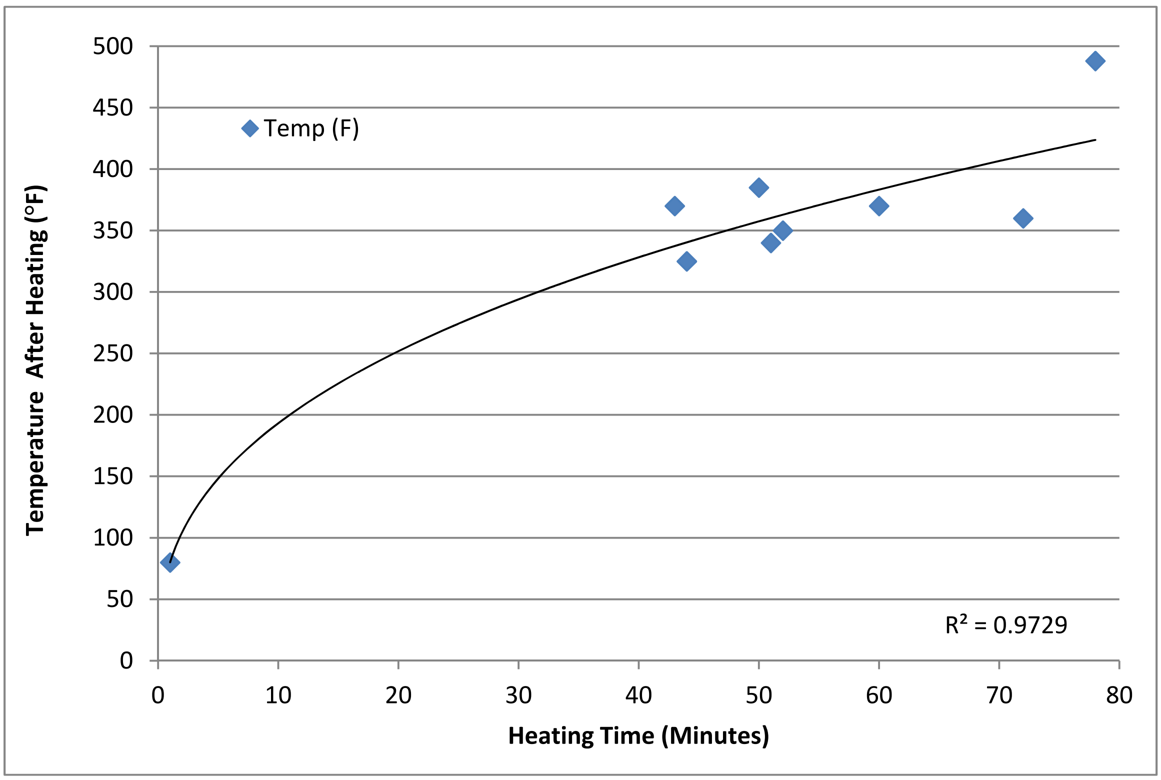

Figure 33. Pavement Temperature versus Heating Time (IH410-1 and -2).

4.3 TEMPERATURE MEASUREMENTS

At the IH10Fr site, an infrared camera was available to help document the surface temperatures. Table 3 contains the data documenting the repairs from the site. Figure 34 shows plots of temperatures for the locations where a full set of infrared temperatures was measured. When two patches were placed side by side, there is a temperature for each patch after the removal of the heater. Since the material is mixed together for both patches, the data represents the combination of the two patches. On two occasions, researchers recorded the temperature of the individual patch locations after the first milling. Figures 35 through 42 show a few sample infrared pictures.

The temperatures after the removal of the heating unit varied from a low of 368°F to a high of 629°F. The lower temperatures for the last two patches were an attempt to see if the work could be done at a lower temperature with less heating time. Table 3 and Figure 34 illustrate the variability in temperature experienced in the HeatWurx process. Unfortunately, the recorded temperatures could not be tied to the performance of the patches, as this site was completely repatched about four months later. This is discussed in the section on performance.

Table 3. Temperatures (°F) from Infrared Camera, IH10Fr Site.

Date	Patch Num	Untreated Area	Remove Heater	Between Patch	Mill Pass 1	Mill Pass 2	Mill Pass 3	Mill Pass 4	Pre-Roll	After Roll
2/15	1		488		179	155	143	130	122	109
2/15	2		424							
2/15	3		539	141	262	203	171	151	137	
2/15	5		451		319	268	226	205	192	170
2/15	6		481		299					
2/16	1	73.6	423	145	218	210	156	144	126	128
2/16	2		456							
2/16	3		514	236	266	224	203	166		137
2/16	4		629							
2/16	5		368	143	171	165	150	142	132	118
2/16	6	77	392							
Average		75.3	469.5	166.3	244.9	204.2	156.3	174.8	141.8	132.4
SDev		2.4	73.3	46.5	57.3	41.1	32.9	26.6	28.6	23.5

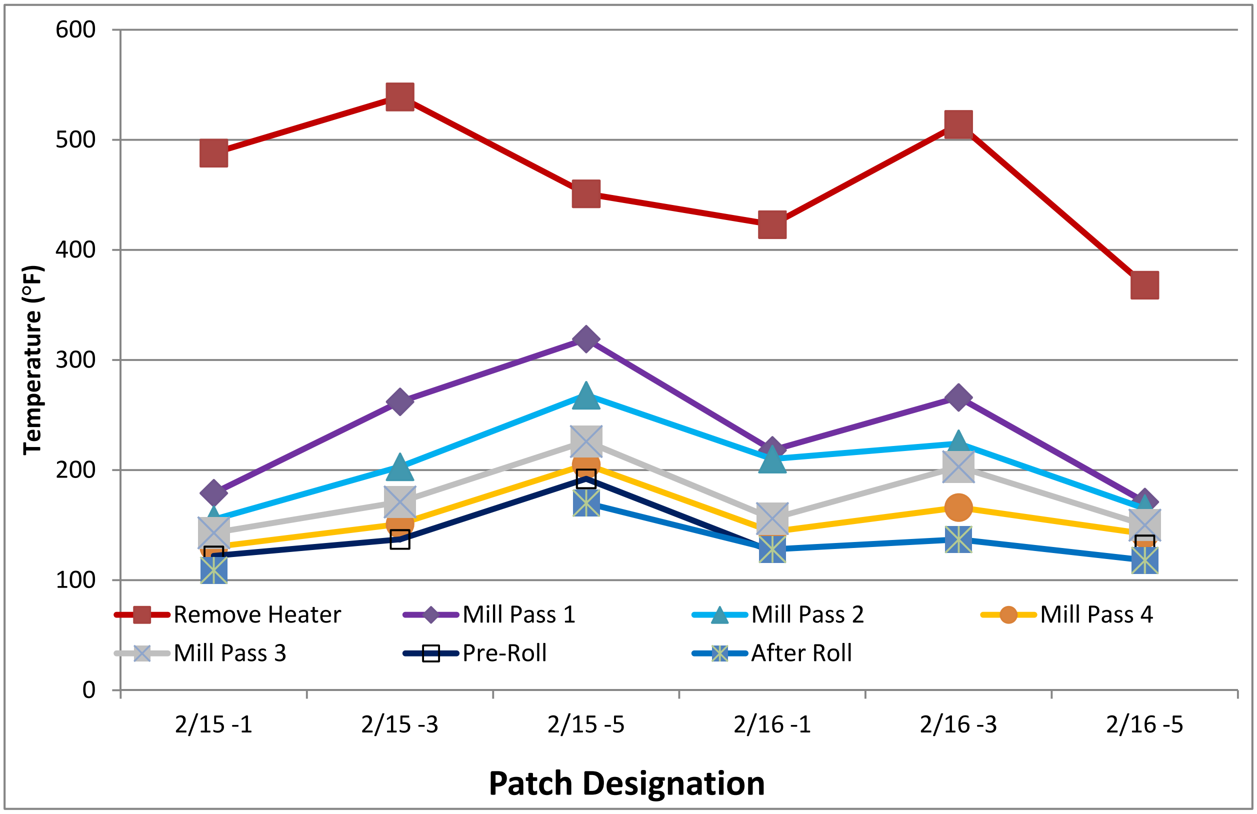

Figure 34. Graph of Temperatures at IH10 Site.

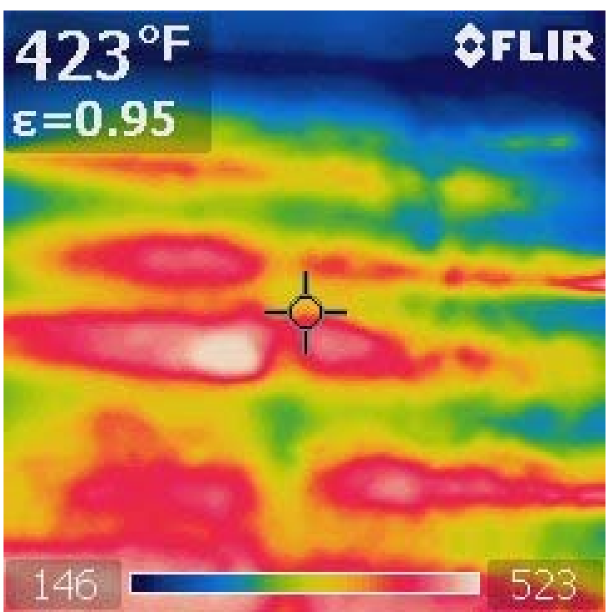

Figure 35. Remove Heater, Patch-1.

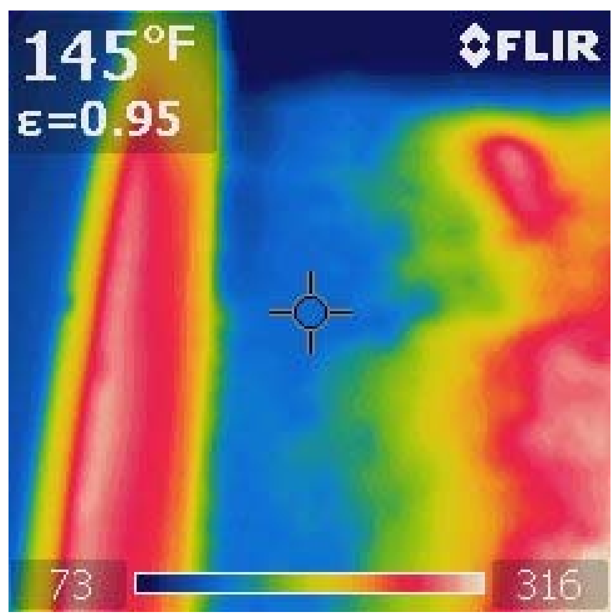

Figure 36. Between Heaters, IH10Fr between Patches 2/16-1 and 2/16-2.

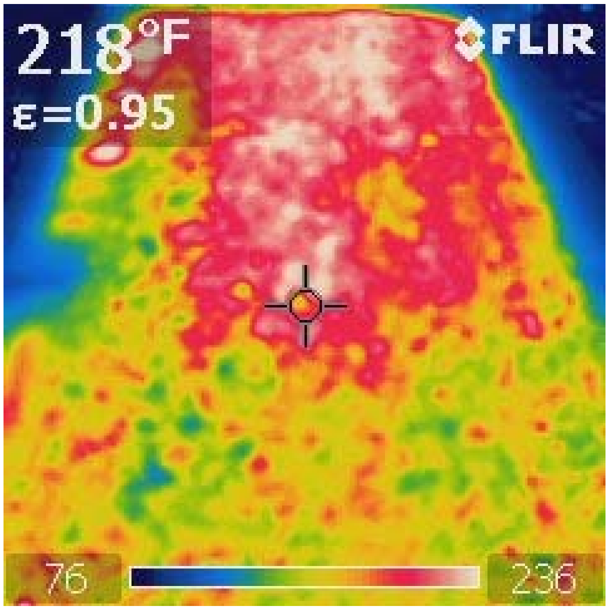

Figure 37. After Mill Pass 1, IH410Fr-Patch 2/16-1.

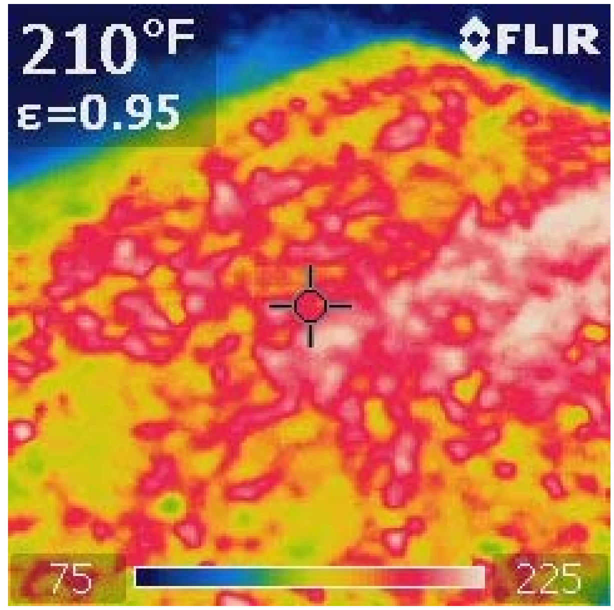

Figure 38. After Mill Pass 2, IH410Fr-Patch 2/16-1.

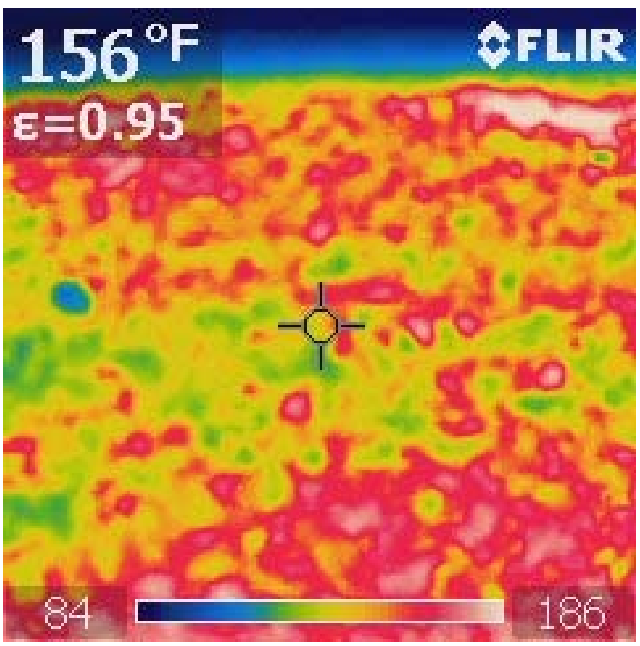

Figure 39. After Mill Pass 3, IH410Fr, Patch 2/16-1.

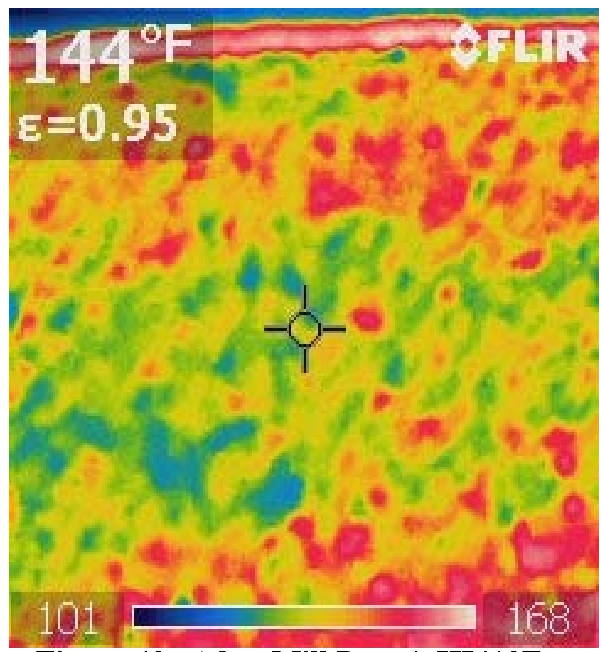

Figure 40. After Mill Pass 4, IH410Fr, Patch 2/16-1.

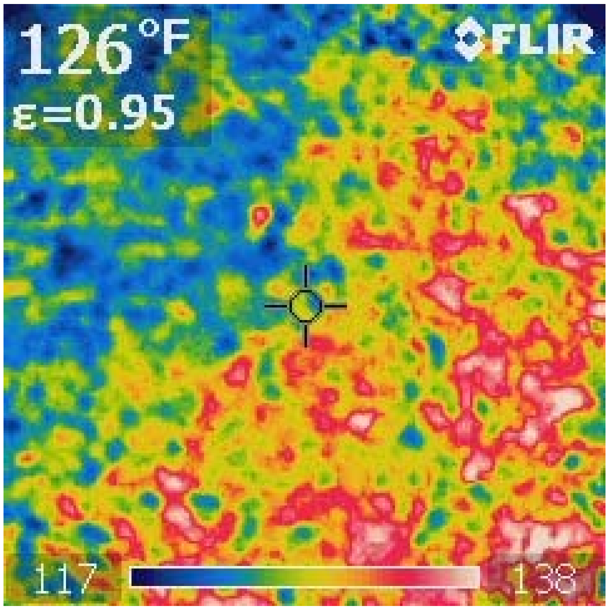

Figure 41. Pre-Roll, IH410Fr, Patch 2/16-1.

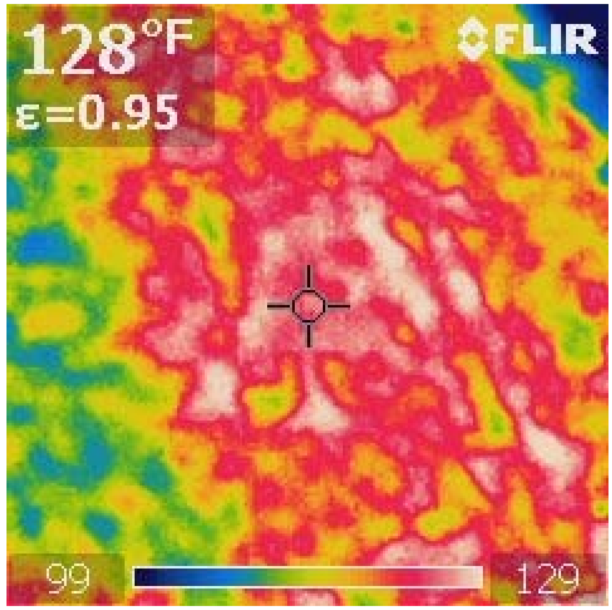

Figure 42. After Roll, IH410Fr, Patch 2/16-1.

4.3 VIDEO DOCUMENTATION

As part of the documentation process, the TTI Communications Division, Visual Media Program set up several devices and documented the HeatWurx patching process. The crew set up cameras on tripods, and used handheld shoulder cameras and wireless cameras that could be attached directly to the equipment. The entire process, from placing the heater through the final compaction rolling, was documented.

CHAPTER 5. PERFORMANCE OF PATCHES

The pavements were inspected visually several times. In most cases, crack maps were prepared prior to work being performed, but some patches were placed prior to recording the distress present at the site.

5.1 VISUAL CONDITION

5.1.1 Pre-Patch Condition

As noted earlier, the pavement at all three sites prior to patching was oxidized and cracked, with the cracks beginning to deteriorate. No alligator cracked areas were patched and most patches were placed on longitudinal cracks, with some intersecting cracks. Figure 43 shows an example of a crack map for Site IH410Fr-1, Patch 1 and 2.

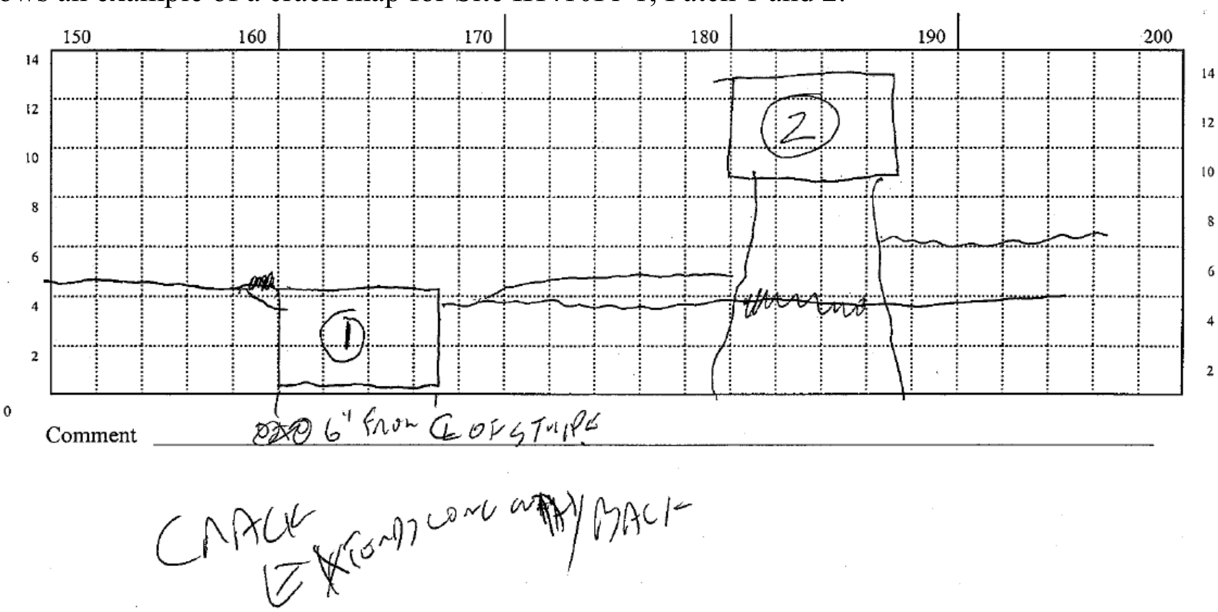

Figure 43. Crack Map of Site IH410Fr-1, Patch 1 and 2.

5.1.2 First Inspection

Immediately after repair, all patches were tight, flat, and level with the surrounding area. There were no cracks and every patch was performing well. At the July inspection, approximately five months after placement, the patches at the first two sites (IH410Fr-1 and -2) were still performing well and no distress was noted. Figures 44-49 illustrate the patches at Site IH410Fr-1 and IH410-2.

Figure 44. Patch 1 on Site IH410-1.

Figure 45. Patch 2 on Site IH410-1.

Figure 46. Patch 3 on Site IH410-2.

Figure 47. Patch 4 on Site IH410-2.

Figure 48. Patch 5 on Site IH410-2.

Figure 49. Patch 8 on Site IH410-2.

However, at the IH10Fr site, patches did not perform well. Patch 2/11-3 had 0.25 inches of rutting, patch 2/10-4 was soft and had 1-inch high shoving, as did patches 2/10-7 and 2/10-9. Patch 2/14-10 had a dip and a hump, as did patches 2/14-1 and 2/14-2. Figure 50 shows the crack map diagram. Figures 51 through 58 document the performance.

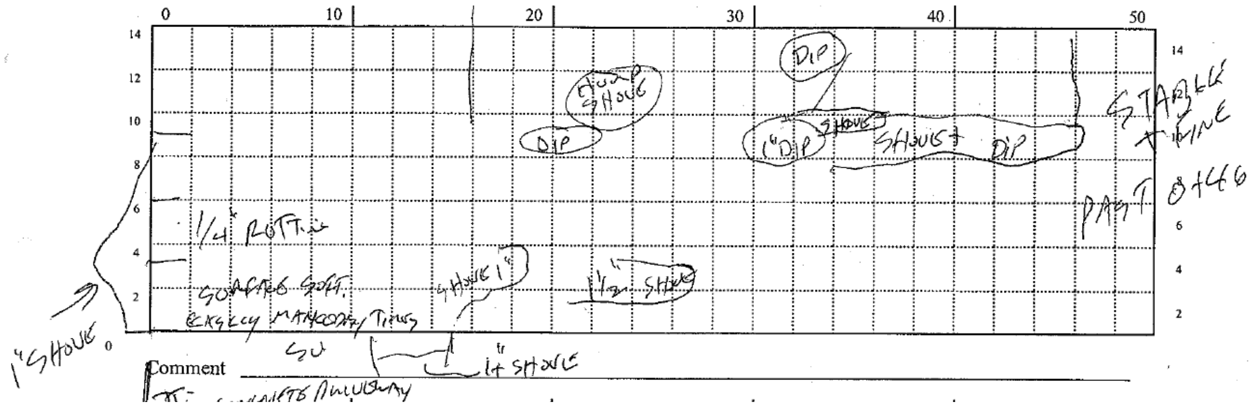

Figure 50. Distress Map of Site IH10Fr.

Figure 51. Patches 2/10-4 and 7 on Site IH10Fr.

Figure 52. Patch 2/10-4 on Site IH10Fr.

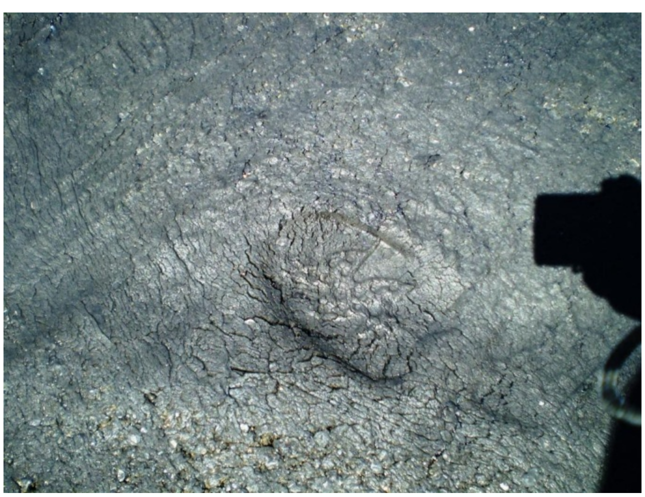

Figure 53. Patch 2/10-4 on Site IH10Fr.

Figure 54. Patch 2/10-9 on Site IH10Fr.

Figure 55. Various 2/10 Patches on Site IH10Fr.

Figure 56. Patch 2/14-15 and 17 on Site IH10Fr.

Figure 57. Patch 2/14-16 and 18 on Site IH10Fr.

Figure 58. Various 2/14 Patches on Site IH10Fr.

These figures, especially Figure 54, demonstrate that many of the patches were failing by shoving and settling. Due to the overall condition of this area, the entire area was milled and replaced. In the outside lane, 18 of the first 26 patches showed signs of significant distress. Patches in the middle lane and those further from the beginning performed better, but were replaced.

5.1.3 Second Inspection

The sites were reinspected on January 20, 2012, after approximately 12 months of service. At the IH410Fr-1 and -2 sites location, patches were performing well, but patches 1, 2, 3, and 9 were settled approximately ½ inch.

Figure 59. Patch 1 on Site IH410Fr-1.

Figure 60. Patch 2 on Site IH410Fr-1.

Figure 61. Patch 3 on Site IH410Fr-2.

Figure 62. Patch 4 on Site IH410Fr-2.

Figure 63. Patch 9 on Site IH410Fr-2.

Figure 64. View of Replaced Site IH10Fr.

Figure 65. Replaced Site IH10Fr.

5.2 LABORATORY EVALUATION

Cores were retrieved from the IH10Fr test site. Two cores were taken from each of the patched areas and two from an unpatched portion of the original pavement just prior to the pavement being opened to traffic. These were subjected to:

- Bulk density testing according to ASTM D2726.
- Resilient modulus testing at 39.2°F and 77°F according to ASTM D7369.
- Indirect tensile testing at 77°F according to ASTM D6931.
- Maximum theoretical density according to ASTM D2041.

The test results are summarized in Table 4. Figures 66 and 67 give the indirect tensile strength at 77°F and the resilient modulus at 39.2° and 77°F, respectively.

Table 4 shows that the bulk density of the materials in the patches are lower than the bulk density of the original pavement by about 5 to 10 lbs/ft^3, and that the air voids for the patch material are greater by 0.6 to 3.5 percent. The indirect tensile strength is almost 10 times lower for the patch materials than the original pavement (see Figure 66). The resilient modulus values of the patch materials for both 39.2° and 77°F are lower than the original pavement by about a factor of 5 to 10 (Figure 67). The reasons for the difference between the patching materials in terms of tensile strength and resilient modulus are most likely attributable to two primary factors:

- A difference in the density of the patch materials and the original pavement. Greater air voids in the patch materials mean lower strength and lower stiffness.

- A difference in the age of the patch and original materials. The patch materials had been treated with a rejuvenator that softens the asphalt, whereas the original pavement has been steadily age hardening since its construction.

Table 4. Test Results for Cores from Patch 2/10-4 on Site IH10Fr.

Sample	Bulk Density, lb/ft^3	Air Voids, %	Resilient Modulus @ 39.2°F, ksi	Resilient Modulus @ 77°F, ksi	Indirect Tensile Str. @ 77°F, psi
Original Pavement	143.0	7.4	2686	1512	187
Core 1	133.5	10.9	221	134	17.0
Core 2	137.8	8.1	489	172	26.2

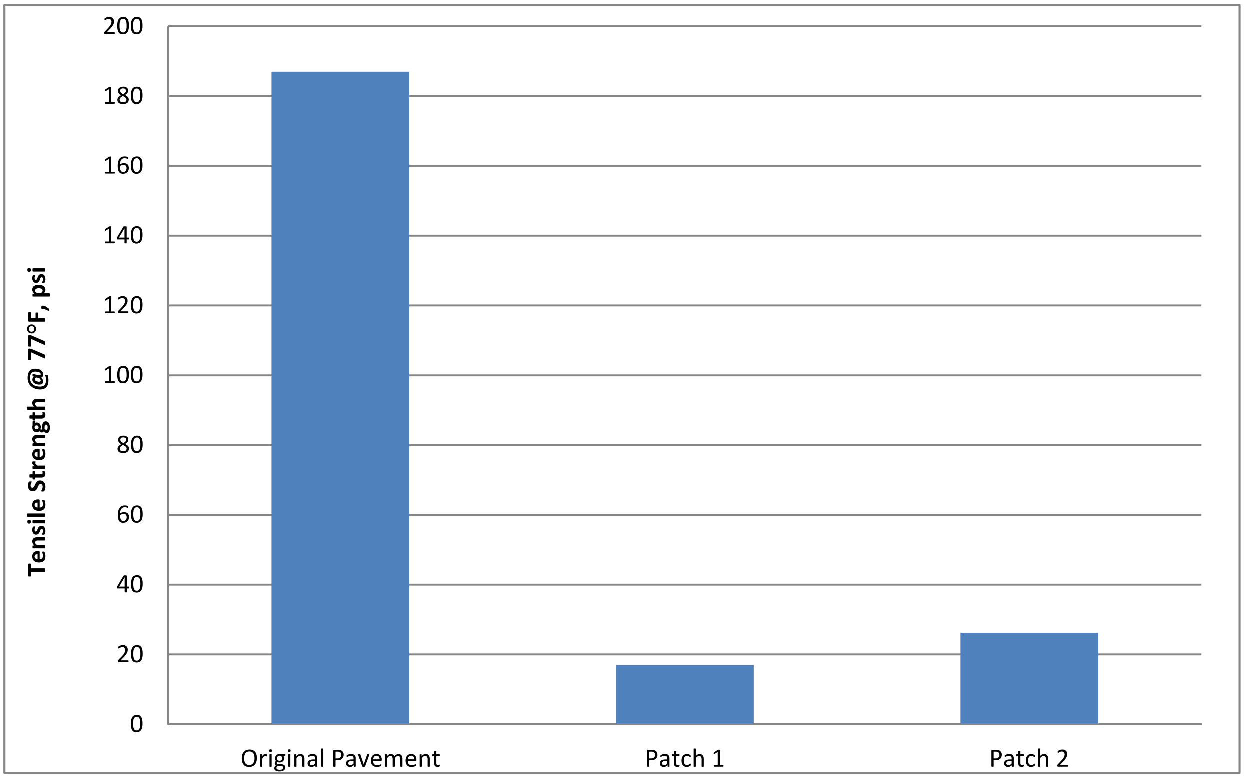

Figure 66. Indirect Tensile Strength of the Original Pavement and Patches for IH410Fr.

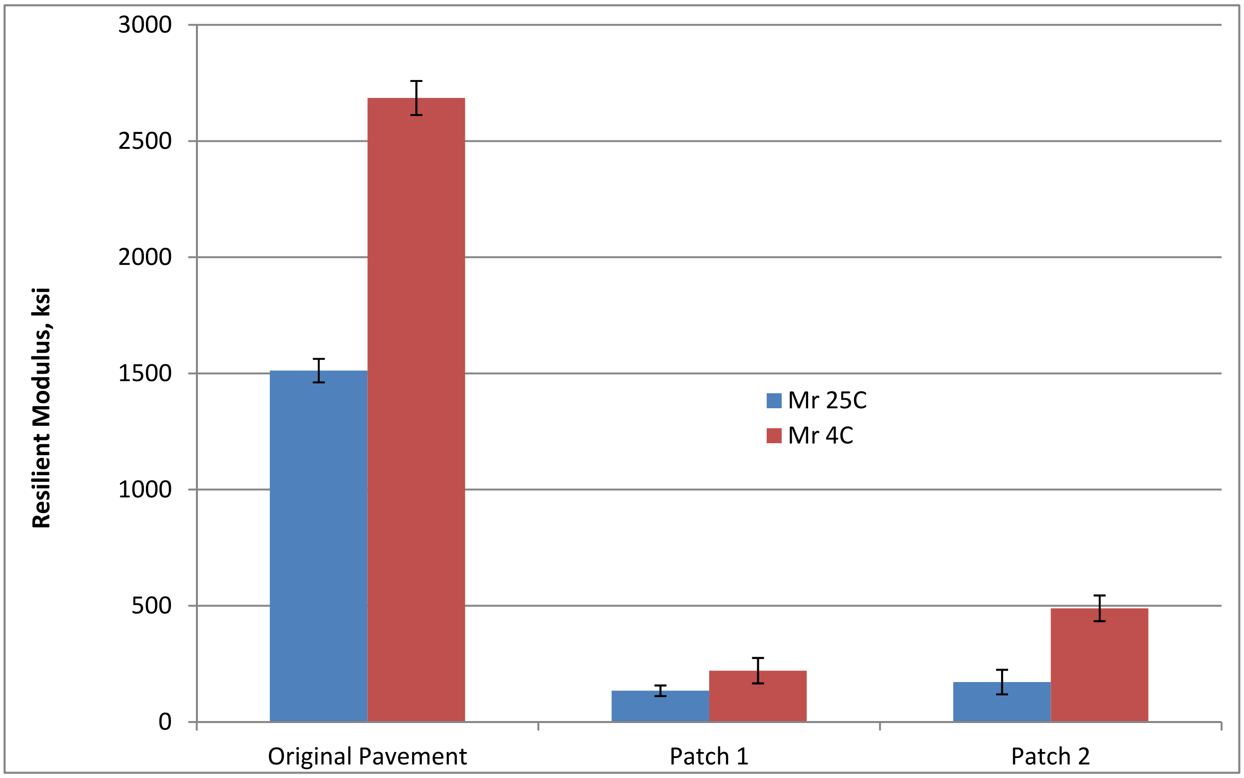

Figure 67. Resilient Modulus of the Original Pavement and Patches for IH410Fr.

CHAPTER 6. SUMMARY AND CONCLUSIONS

The HeatWurx system of patching was brought to the San Antonio District for evaluation. District personnel were trained in its use and a total of 83 patches were placed. The results, described previously and below, lead to the conclusion that while this system might be a good alternative for asphalt pavement in remote areas, it is not well suited to the urban areas where other options are available.

6.1 BENEFITS OF PROCESS

The HeatWurx process provides a patch that is well-bonded, uses a minimum of new materials, can be done in cold weather, and completes the patch process with a single lane closure. The area to be repaired can be located within the 3.5 by 8 ft heating unit. The equipment is well designed and rugged.

If the location was far from a place where hot-mix asphalt pavement was available, this method would solve the transportation and problems associated with the material cooling on the way to the job site.

6.2 CONCERNS

The HeatWurx process requires that in addition to the lane being worked on, an adjacent lane be used for maneuvering and transporting the heating unit and roller. The milling/scarifying unit usually stays within the closure.

TxDOT employees working with the process felt that the production rate was low for a patching operation. This process requires considerable judgment to initiate when the pavement has been heated enough, the amount of additional millings to be added, the amount of rejuvenator to be added, and when the material is sufficiently mixed for rolling to begin.

The depth that could be treated by this process was less than two inches. Deeper than two inches, the pavement was insufficiently heated to allow milling and scarifying by the APX-40 unit. In addition, the temperature of the mix at the time of compaction was low. At the time of rolling, the temperature of the material was less than 150°F. For a PG64-22 asphalt mix, the compaction temperature is usually 250°F.

There was a failure of many of the patches at site IH10Fr, probably due to an excess of rejuvenator and possibly low air voids. Figures 68 and 69 document these problems.

Figure 68. Shoving Failure at Site IH10Fr.

Figure 69. Shoving and Rutting Failure on Site IH10Fr.

6.3 PRODUCTION RATE

The best production rates are achieved when there are multiple areas needing repair within a small area. IH10Fr on the eastbound frontage road of IH10 presented this type of situation. The HeatWurx operation at this site was consistently able to produce 18 patches per day, each covering an area of approximately 0.33 yd^2. For TxDOT Item 211-Leveling or Overlay with Laydown Machine, typical production was 3520 yd^2. The milling and replacement at site IH10Fr (two lanes by more than 167 yd) was accomplished in one day.

6.4 COST COMPARISON

Cost data comparing the unit price for the various patching techniques used in Maintenance Section 17-West Bexar County, is shown in Table 5. Data were extracted for the various function codes pertaining to patching and, where necessary, converted from cubic yards to square yards using an average depth of 7 inches. As expected, localized repairs of small areas is significantly more expensive than repair techniques where large quantities are repaired. The HeatWurx technique was significantly more expensive than all other methods where significant quantities were repaired. The west Bexar County maintenance section is highly urbanized and there are no remote sections of asphalt pavement.

Table 5. Cost Comparison.

Function Code	Description	Cost	Work Units	Cost/Unit
110	Base Remove/Replace	$1,610,337.50	8074	$199.45/CY $38.78/SY
211	Leveling or Overlay with Laydown Machine	$2,029,622.59	187849	$10.80/SY
213	Leveling by Hand	$33136.6	431	$76.88/SY
241	Potholes, Semi-Permanent	$51473.12	1413	$36.43 Each (1 SY)
242	Potholes, Permanent	$2643.52	8*	$330.44* Each (1 SY)
HeatWurx	Patching on IH10Fr	$14315.67	75	$190.88/SY

*- Very few were done in 2011

The following are the costs of the equipment. To improve production, two heating units (HWX-30) and one HWX-AP-40 would be needed.

HWX-30	$49,500
HWX-AP-40 (Processor/Tiller)	$11,500
ReHab Rejuvenator 55 Gallon	$330

6.5 FUTURE USE

The HeatWurx system has potential to be effective when the problem is a localized material problem in a remote location where hot-mix asphalt is not readily available. Unfortunately for Texas, few, if any, of these remote locations have HMAC. In areas where HMAC is available, the traditional techniques will be more cost-effective.

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