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## *Comparison of three compactors used in pothole repair*

Michael A. Snelling and Robert A. Eaton

*For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.*

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## 20. Abstract (cont'd)

of laboratory density, but that a 200-lb lawn roller could not. Temperature of the hot recycled mix is critical, with 250°F being the cut-off temperature. It was shown that if the mix is not compacted promptly after placement and is allowed to cool below 250°F, proper compaction may not be attained. Single lifts of 3-in., 6-in. and 9-in. depth were compacted to 98% density using the vibratory plate compactor on mix above 250°F in 18-x24-in. holes. In larger 3-x4-ft holes, 98% density was obtained only with the steel wheel vibratory roller on patches placed in two 3-in.-thick lifts. The number of coverages of the compactors influences densities obtained. By doubling coverages of the steel wheel vibratory compactor from 6 to 12, the density increased from 96.9% to 99.0%.

## PREFACE

This report was prepared by Michael A. Snelling, Civil Engineering Co-op Student at the University of New Hampshire, and Robert A. Eaton, Research Civil Engineer, Geotechnical Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

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## COMPARISON OF THREE COMPACTORS USED IN POTHOLE REPAIR

Michael A. Snelling and Robert A. Eaton

### INTRODUCTION

One problem with pothole patching in cold regions is the use of unacceptable materials. Usually, patches are made with low quality cold patching materials that do not meet State or local performance specifications because most potholes occur during winter and spring months when hot mix plants are closed.

One way to provide high quality materials without paying premium prices is to order hot mix asphalt concrete that meets local or State highway specifications in the fall before the hot mix asphalt plants close. This hot mix should be tailgate spread in a layer 6 to 8 in. thick on a relatively clean paved area. After the hot mix has cooled, it can be broken up with a pavement breaker, or front-end loader, and stockpiled under a cover.

With currently available, relatively inexpensive, portable recycling equipment, hot mix asphalt concrete can be supplied year-round. In the winter, the equipment can be used to heat this stockpiled asphalt concrete above 250°F for pothole patching and in the summer the same equipment can be used to keep the asphalt concrete, picked up at the hot mix plant in the morning, hot all day and even overnight. It will eliminate most of the waste caused by a load of asphalt that has cooled below State or local paving or patching specifications by providing a means of reheating and allowing the asphalt to be used in an acceptable manner.

This report is a summary of the results of a compaction study using recycled hot mix asphalt concrete conducted during August 1983 inside the ATCO building at CRREL in Hanover, New Hampshire. This study compared three kinds of compactors for optimum performance, and also considered such factors as temperature of the asphalt concrete mix, number of passes, size and depth of patches, and the number of lifts to fill the holes.



Figure 1. Wacker model VPC-16 vibratory plate compactor.

#### COMPACTORS USED IN TEST

The first compactor evaluated was a Wacker VPG-160 vibratory plate compactor, which has a plate size of 21 x 24 in. and an overall weight of 166 lb (Fig. 1).

The second compactor was a large Wacker 474T vibratory roller (Fig. 2). It has two steel drum rollers with a water tank reservoir for each roller. The gross weight for this self-propelled forward and reverse compactor is approximately 2000 lb.

The last compactor was a Jackson no. 12 lawn roller (Fig. 3). It had a single hollow drum which was filled with water. It had a gross weight of 200 lb.

The recycling machine used for heating the asphalt concrete was a Porta-Patcher model 9286ES (Fig. 4). This machine reheats old or new asphalt chunks to a desired temperature. The reheated mix can be placed in a pothole and recompact. The Porta-Patcher is capable of producing 1-1/4 ton (1 yd<sup>3</sup>)/hr of reheated asphalt when large 15- x 15-in. chunks of asphalt concrete are used.



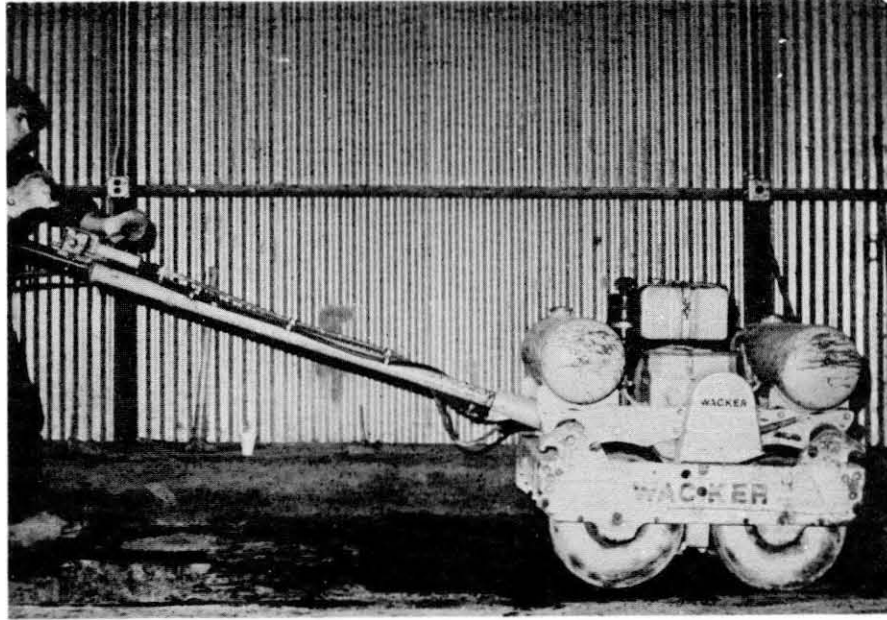


Figure 2. Wacker model 474T vibratory steel wheel roller.

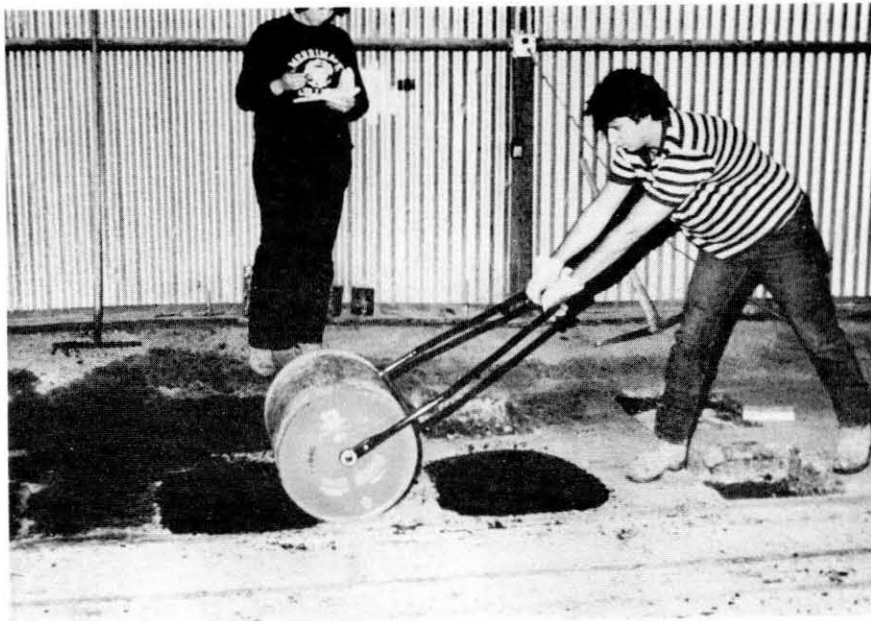


Figure 3. Jackson no. 12 lawn roller.

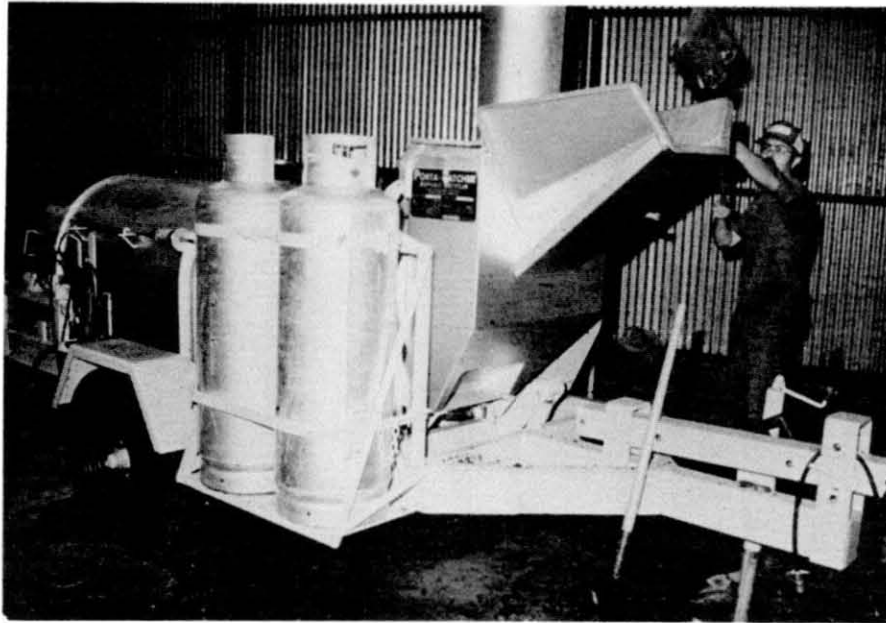


Figure 4. Porta-Patcher model 9286 ES recycling machine.

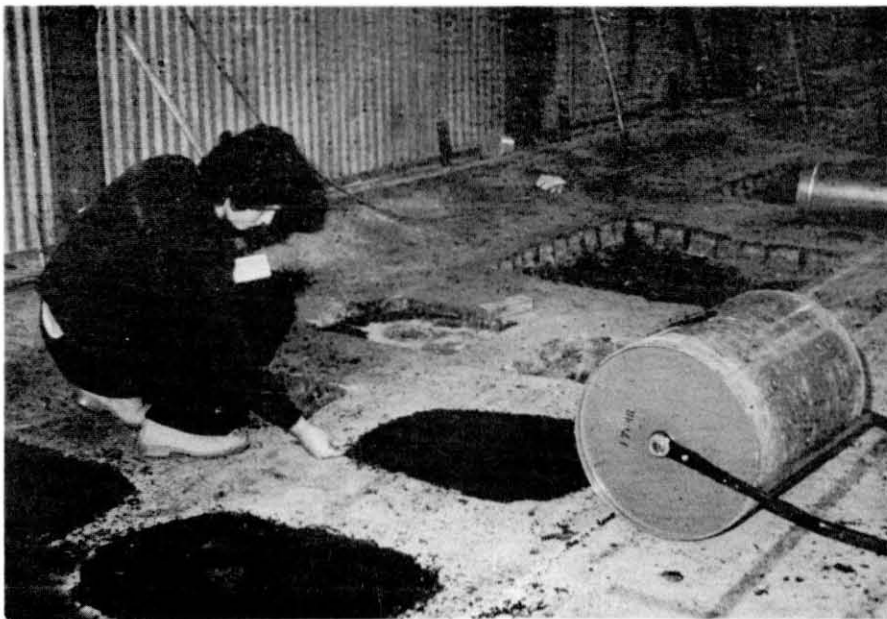


Figure 5. Smaller (18- x 24-in.) test holes in foreground.

#### ASPHALT CONCRETE MIX

The asphalt concrete mix used in this study was obtained from a local asphalt plant and it met State of New Hampshire requirements for 3/8-in. bituminous concrete leveling course. The asphalt cement penetration\*

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\* In accordance with ASTM D5-73

dropped from 80 to 40 mm after passing through the asphalt recycler, which is considered acceptable. Appendix A contains the gradation and job mix of the asphalt concrete used (Table A1).

Laboratory tests were conducted on the asphalt concrete mix before and after going through the Porta-Patcher recycling machine. These tests were conducted to quantify any changes in characteristics of the asphalt, i.e. in kinematic viscosity and penetration (Table A2):

#### TEST PROCEDURE

Simulated potholes were made by jackhammering 18- x 24-in. holes to depths of 3, 6 and 9 in. in an existing pavement inside the test building (Fig. 5). Figure 6 shows 3- x 4-ft x 6-in. holes made to measure differences in compaction of the larger patches. Also, two 3-in.-thick layers were compacted in the 3- x 4-ft x 6-in. holes to measure the effect of layering on compaction.



Figure 6. Larger (3- x 4-ft) test holes.



Figure 7. Coring sample being extracted.

Figure 7 shows a 2-in.-diam core sample being removed from a compacted patch (two cores were obtained from each patch). The samples were then taken to the asphalt lab where density measurements were made. These measurements were then compared to a lab sample of the same material, which was prepared in accordance with Military Standard 620A, Section 3.3 (i.e. it was heated to 250°F and then put into a heated mold on a compaction pedestal, where each side received 50 blows from the compaction hammer). The lab control sample was then used to determine the degree of compaction from the field tests. Technical Manual 5-822-8, Section 7.8 (U.S. Army 1971) states that all field samples must meet or exceed 98% of the density of the lab sample. The density obtained from the lab sample was 148.1 lb/ft<sup>3</sup>.

On the basis of standard repair procedures, we arbitrarily chose to make six coverages with the steel wheel compactor, 20 coverages with the vibratory plate compactor and 40 coverages with the lawn roller for each patch. A coverage was defined as one passage of the compactor (in one direction) over the hole. In a separate test series, we varied the number of coverages to determine whether an increase would be beneficial to increasing compaction.

Table 1. Effect of temperature on compaction of single 3-in. lift (18- x 24-in. holes).

Compactor	Recycled temperature (°F)	Actual compaction temperature (°F)	Number of coverages†	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	175	160	6	143.1	96.6
	250	250	6	143.1	96.6
	300	210	6	144.6	97.6
Vibratory plate	175	160	20	136.5	92.2
	250	230	20	144.3	97.5
	300	225	20	142.5	96.2
Lawn roller	175	150	40	132.4	89.3
	250	245	40	144.5	97.6
	300	230	40	142.5	96.2

† The number of coverages was arbitrarily chosen at the beginning of the test (see Table 7 for effects of number of coverages).

Table 2. Effect of temperature on compaction of single 6-in. lift (18- x 24-in. holes).

Compactor	Recycled temperature (°F)	Actual compaction temperature (°F)	Number of coverages	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	175	170	6	141.7	95.7
	250	250	6	146.9	99.2
	300	270	6	145.9	98.5
Vibratory plate	175	170	20	140.9	95.2
	250	230	20	145.6	98.3
	300	250	20	145.6	98.3
Lawn roller	175	170	40	133.9	90.4
	250	255	40	141.0	95.2
	300	285	40	138.7	93.7

## FIELD RESULTS

All temperatures were measured with a hand-held bi-metallic thermometer. Tables 1-3 show that the temperature of the asphalt concrete mix at the time of compaction plays a very important part in the compaction achieved. The asphalt concrete mix that had been heated up to 300°F in the Porta-Patcher recycling machine lost up to 30% of its heat through ambient heat loss. This was caused by the reduced rate of production (1 yd<sup>3</sup>/hr) obtainable when large (up to 15- x 10-in.) chunks of asphalt concrete were used. Higher production rates can be obtained by using smaller chunks (i.e. 2 yd<sup>3</sup>/hr with 3- x 3-in. pieces).

At 175°F, compaction of 98% lab density was not reached for any compactor at any thickness of patch.

When recycling at 250°F, we were able to get at least 97.5% compaction with the vibrating steel wheel, lawn roller, and vibrating plate in the single 3-in. lift patch. Over 98% compaction was achieved in the single 6-in. lift patch with both the vibrating steel wheel and vibrating plate compactors. In the single 9-in. lift patch, over 98% compaction was achieved with only the vibrating plate.

Problems with cooling were experienced when recycling at 300°F in the 3-in. single lift patches. The steel wheel roller was able to get 97.6% compaction in the 3-in. patch even though the mix had cooled. The vibrating plate and lawn roller were able to obtain 96.2% compaction.

The 6-in. single lift patches using 300°F recycled mix yielded 98.5% compaction for the steel wheel roller, 98.3% for the vibrating plate and 93.7% for the lawn roller. Use of 300°F recycled material in the 9-in. single lift resulted in 96.0% for the steel wheel, 95.9% for the vibrating plate, and 9.15% for the lawn roller.

Tables 4 and 5 contain data for single lift thicknesses compacted at 175°F and 250°F, respectively. As shown in Table 4, 98% compaction could not be obtained at 175°F with any of the compactors.

As shown in Table 5, the vibrating steel wheel roller obtained 97.6% compaction in the 3-in. single lift, 99.2% in the 6-in. single lift, and 96.8% in the 9-in. single lift. The vibrating plate compactor achieved 97.5% in the 3-in. single lift patch, 98.3% in the 6-in. single lift, and 95.7% in the 9-in. single lift patch. The lawn roller achieved 97.6% on



Table 3. Effect of temperature on compaction of single 9-in. lift (18- x 24-in. holes).

Compactor	Recycled temperature (°F)	Actual compaction temperature (°F)	Number of coverages	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	175	160	6	139.9	94.5
	250	240	6	143.3	96.8
	300	260	6	142.1	96.0
Vibratory plate	175	155	20	137.6	92.9
	250	230	20	145.2	98.9
	300	250	20	142.0	95.9
Lawn roller	175	---	---	--	--
	250	230	40	138.2	93.3
	300	270	40	135.5	91.5

Table 4. Comparison of single lift thickness compaction at 175°F (18- x 24-in. holes).

Compactor	Lift thickness (in.)	Number of coverages	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	3	6	143.1	96.6
	6	6	141.7	95.7
	9	6	139.8	94.4
Vibratory plate	3	20	136.5	92.2
	6	20	140.9	95.2
	9	20	137.6	92.3
Lawn roller	3	40	132.4	89.4
	6	40	133.9	90.4
	9	--	--	--

the 3-in. single lift patch but was unacceptable on the 6- and 9-in. single lift patches.

Table 5 shows that the required 98% compaction can be achieved in 3- and 6-in. single lifts by using vibrating steel wheel or vibrating plate compactors, but only at the proper temperature at the time of compaction (250°F).

Table 6 shows the comparison of a single lift 6-in. patch vs two 3-in. lifts. When the steel wheel compactor was used on the single 6-in.

Table 5. Comparison of single lift thickness compaction at 250°F (18- x 24-in. holes).

Compactor	Lift thickness (in.)	Number of coverages	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	3	6	144.5	97.6
	6	6	146.9	99.2
	9	6	143.3	96.8
Vibratory plate	3	20	144.3	97.5
	6	20	145.6	98.3
	9	20	142.0	95.9
Lawn roller	3	40	144.5	97.6
	6	40	141.0	95.2
	9	40	138.2	93.3

Table 6. One 6-in. lift vs two 3-in. lifts (3- x 4-ft holes).

Compactor	Number of lifts and thickness (in.)	Number of coverages	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	1-6	6	143.5	96.9
	2-3	6	147.2	99.4
Vibratory plate	1-6	10	139.9	94.5
	1-6	30	142.7	96.4
	2-3	20	142.7	96.4
Lawn roller	2-3	40	141.2	95.4
	1-6	40	136.4	92.1
	1-6	80	139.3	94.1
	1-6	120	138.2	93.3
	1-6	160	137.2	92.7

lift, only 96.9% compaction was obtained compared to 99.4% compaction on the 6-in. patch placed in two lifts. Note that these patches were in a 3- x 4-ft hole in order to permit layer compaction by putting the compactors down into the hole. These densities compare with 99.2% of lab density for the single 6-in. patch in the 18 in. x 24 in. hole. An explanation of the higher density in the smaller hole is that the smaller hole confines the mix and gives the compactor resistance to push against. Compaction with the vibratory plate and lawn roller resulted in higher patch densities when placed in two 3-in. lifts vs the single 6-in. lift, although 98% of lab density was not attained.

Table 7. Comparison of number of coverages on compaction (3- x 4-ft x 6-in. patch size). All lifts were made at approximately 250°F.

Compactor	Lift thickness (in.)	Number of coverages	Density (lb/ft <sup>3</sup> )	% lab density*
Steel wheel	6	6	143.5	96.9
	6	12	146.6	99.0
Vibratory plate	6	10	139.9	94.5
	6	30	142.7	96.4
Lawn roller	6	40	136.4	92.1
	6	80	139.3	94.5

Table 8. Influence of hole size on compaction at 250°F.

Compactor	Lift thickness (in.)	Number of coverages	Temp. (°C)	Size	Density (lb/ft <sup>3</sup> )	% lab density
Steel wheel	6	6	240	A*	143.5	96.9
	6	6	250	B†	146.9	99.2
Vibratory plate*	6	30	225	A	142.7	96.4
	6	20	230	B	145.6	98.3
Lawn roller	6	40	225	A	136.4	92.1
	6	40	255	B	141.0	95.2

\* 3- x 4-ft

† 18- x 24-in.

Table 7 shows the density when the number of coverages was varied. By doubling the coverages of the steel wheel vibratory compactor from 6 to 12 on the single 6-in. lift, density increased from 96.9% to 99.0%. The vibratory plate compaction increased from 94.5% at 10 coverages to 96.4% at 30 coverages. The lawn roller densities increased from 92.1% at 40 coverages to 94.5% at 80 coverages. These results show that increases in density do indeed occur with increased coverages, and that with minimal testing using readily available equipment, the number of coverages at specified temperatures can be determined.

Table 8 shows the influence of hole size on densities obtained. By using a single 6-in. lift in the small hole, the vibrating steel wheel roller attained 99.2% density. On the larger hole with less confining pressure, the density dropped to 96.9%. Using the vibrating plate compact-

or on the large hole resulted in 96.4% density. When used on the smaller hole, density increased to 98.3%. Results using the lawn roller showed the same trends, with an increase from 92.1% density on the larger hole to 95.2% for the small hole density.

## CONCLUSIONS

The recycling machine produced acceptable mix, but at a slow rate of 1-1/4 ton (1 yd<sup>3</sup>) per hour with the large chunks we chose for this study. Larger production rates are possible with this machine.

The large Wacker Model 474T vibratory roller and Wacker Model VPG-160 vibratory plate compactor performed satisfactorily for the purposes of this study. The lawn roller was unacceptable for attaining the desired 98% lab density.

Temperature of the recycled asphalt concrete mix as used in this study is critical, with 250°F being the cutoff temperature. It was shown that proper compaction (98% of lab density) may not be attained if the mix is not compacted promptly after placement and is allowed to cool below 250°F.

Single lifts of 3-, 6- and 9-in. depth were compacted to 98% density by using the vibratory plate compactor and mix recycled to at least 250°F in 18- x 24-in. holes. In the larger 3- x 4-ft holes, 98% density was obtained only with the steel wheel vibratory roller on patches placed in two 3-in.-thick lifts.

The number of coverages influences the densities obtained. By doubling coverages of the steel wheel vibratory compactor from 6 to 12, the density increased from 96.9 to 99.0%. This emphasizes the need to run control tests with the equipment, by using the locally available hot asphalt concrete mix at temperatures above 250°F, to determine the number of coverages required for various patch sizes and depths. It is well worth the time and effort to determine proper pothole patching practices with locally available materials and equipment.

## LITERATURE CITED

- U.S. Department of the Army (1970) Bituminous pavements -- Standard practice, Technical Manual 5-822-8.
- U.S. Department of Defense (1966) Test method for bituminous paving materials. Military Standard 620A.

# APPENDIX A: ASPHALT CONCRETE PROPERTIES

Table A1. Job mix formula.

Mix Type	State of N.H.	<u>3/8" leveling</u>	Bitumen	<u>AC 85-100</u>
Permissible variations			Blend specific gravity	<u>2.74</u>
Asphalt	±	0.4	Percent of L.A. Wear	<u>25.9</u>
Agg. #4 & larger	±	7.0		
Agg. #10 & smaller	±	4.0		
Agg. passing 200	±	2.0		
Temperature	±	20.0		

Materials	Spec. req.	Approved job mix
% used		
Sieve		
1-1/4"		
1"		
3/4"		
1/2"		
3/8"	100	100
#4	75-100	78
#10	55-65	60
#20	30-50	43
#40	14-26	24
#80	6-14	9
#200	2-6	4
Asphalt	6.25-7.25	6.7

Table A2. Lab test results.

Mix	ASTM D-2170	ASTM D-5	Pen-Vis Number***
	Kin. Vis. at 275°F (cSt)	Penetration at 77°F 100 g at 5 s	
New Asphalt* Before Porta-Patcher	338.2	80	-0.72
New Asphalt After Porta-Patcher	633.3	40	-0.57
Old Asphalt** Before Porta-Patcher	647.9	37	-0.64
Old Asphalt After Porta-Patcher	751.1	34	-0.57

\* New asphalt is new mix purchased for this test.

\*\* Old asphalt is mix that had been purchased 3-4 years ago and had been stockpiled since receipt.

\*\*\* Pen-Vis Number:

$$PVN = \frac{(L - X)}{(L - M)} (-1.5)$$

where X = log viscosity in centistokes at 275°F for the penetration at 77°F of asphalt cement represented by X.

L = log viscosity in centistokes at 275°F for a PVN of 0.0 for the penetration at 77°F of the asphalt cement represented by X.

M = log viscosity in centistokes at 275°F for a PVN of -1.5 for the penetration at 77°F of the asphalt cement represented by X.

NOTE: Only the new asphalt was used in this compaction study.