REPRESENTATIVE SAMPLING
FOR CONSTRUCTION QUALITY CONTROL
AT THE 2000 NCAT PAVEMENT TEST TRACK

By

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ABSTRACT

A 2.8 kilometer experimental test oval has been constructed near the campus of Auburn University for the purpose of conducting research to extend the life of flexible pavements. Forty-six different experimental sections were installed at the facility, with materials and methods unique to section sponsors imported from all over the United States to maximize the applicability of results. A design lifetime of truck traffic is now being applied over a two-year period of time, with pavement performance documented weekly. Sponsors typically compare the performance of two or more sections constructed with different materials and/or methods to obtain information that can be used to build future pavements with the greatest amount of rut resistance.

In order to generate meaningful results, the Track was built to stringent quality standards. Quality control sampling and testing was utilized on research mixes plant-produced before and during paving operations to protect the research interests of section sponsors. To insure the value of subsequent laboratory test results, samples that were truly representative of the entire production run were needed. Initially, elaborate and time consuming shovel sampling was planned as the primary method of representative sample recovery; however, a robotic sampling device erected by the contractor onsite provided an opportunity to objectively compare subsequent laboratory results using samples that were recovered from production truckloads at the plant using both methods. An Analysis of data collected during construction illustrates the increase in percent within limits that could be expected from the robotic sampling device if similar methods are employed.

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BACKGROUND

An experimental facility has been constructed near the campus of Auburn University that is being used by governmental agencies throughout the United States to conduct research designed to extend the life of flexible pavements. Managed by the National Center for Asphalt Technology (NCAT), the Pavement Test Track (see Figure 1) provides an opportunity for sponsors to answer specific questions related to flexible pavement performance in a full scale, accelerated manner where results do not require laboratory scale extrapolations or lifelong field observations.

Experimental sections on the 2.8 kilometer Pavement Test Track are cooperatively funded by external sponsors, most commonly state DOT's, with subsequent operation and research managed by NCAT. Forty-six different flexible pavements were installed at the facility, each at a length of 61 meters. Materials and methods unique to section sponsors were imported during construction to maximize the applicability of results. A design lifetime of truck traffic is now being applied over a two-year period of time, with subsequent pavement performance documented weekly.

Unlike conventional efforts on public roadways, research at the NCAT Pavement Test Track is conducted in a closed-loop facility where axle loadings are precisely monitored and environmental effects are identical for every mix. An array of surface parameters (smoothness, rutting, cracking, etc.) are monitored weekly as truck traffic accumulates to facilitate objective performance analyses. State DOT's typically have to wait 10 to 15 years to obtain less reliable results in full-scale field studies on public roadways.

Sponsors typically fund research on two or more sections so they can compare life cycle costs of common paving alternatives. In this manner, they can rationally manage the public's investment in flexible pavements by choosing mixes that cost less over the life of the structure. For example, it is unwise to spend less on construction if the cheaper construction alternative results in a substantially higher life cycle cost.

The Pavement Test Track (referred to occasionally hereafter as the Track) is the result of industry and government committing to work together to improve the quality of flexible pavement performance, thus maximizing the taxpayers' investment in America's roadway transportation infrastructure. The facility is expected to clarify the relationship between methods and performance such that design and construction policy in the future can be objectively guided by life cycle costs. Moreover, the broad range of methodologies and materials utilized to build the Track provides a proving ground for laboratory methods intended to predict the performance of pavements in the field as well as those intended for quality control during construction.

INTRODUCTION

In order to generate meaningful results, the Track was built to stringent quality standards. Quality control sampling and testing was utilized on research mixes plant-produced before and during paving operations to protect the research interests of section sponsors. To insure the value of subsequent laboratory test results, samples that were truly representative of the entire production run were needed. Initially, elaborate and time consuming shovel sampling was planned as the primary method of representative sample recovery; however, a robotic sampling device erected by the contractor onsite provided an opportunity to objectively compare subsequent laboratory results using samples that were recovered from production truckloads at the plant using both methods.

This research will be useful to the industry because mix properties can vary greatly within the same truckload, and samples that are representative of the entire truckload are necessary to produce meaningful test results upon which plant adjustments or owner acceptance will be based.

MIX PRODUCTION

Laboratory job-mix formulas were used as a starting point when each mix was trial run through the plant, except that actual stockpile gradations were used to make subtle adjustments to the bin percentages wherever possible. Stockpile moisture contents were measured daily on any mixes that were scheduled for production to minimize the effect on plant operations and resulting final mix proportions. The portable double drum plant presented in Figure 2 was temporarily located onsite to produce mix exclusively for Track construction with minimal haul times.

A sufficient quantity of both coated and uncoated material was wasted on either end of each production run (typically just under a truckload of coated material on either side of the full truck from which the samples were taken during trial mix runs) so that a meaningful sample could be recovered and tested in the onsite laboratory. Representative samples were blended and passed through the mechanical hot-mix sample splitting device shown in

Figure 3 to appropriately reduce the sample size while minimizing heat loss and its effect on the time required to reach compaction temperatures.

Plant settings were then adjusted based upon laboratory test data and either another trial run was deemed necessary or the final plant-run job-mix formula was established. Whenever practical, trial mix was placed on Lee Road 151 (the local, previously unpaved road leading into the facility) so that sponsor representatives could weigh placement and compaction into their decision-making process. Following the determination of the final job-mix formula, production of mix for placement on the Track surface was authorized.

TRUCK LOADING PROCEDURE

End-dump trucks were used to haul mix on the majority of experimental sections; however, live-bottom trucks (also known as flow-boys or horizontal discharge trucks) were used to haul mix during the construction of sections located on curves. This difference was intended to avoid the possibility of tipping lifted beds while paving on super-elevation (which transitions to a full 15 percent within the curves). Regardless of the type of haul vehicle used, trucks were consistently loaded in a manner intended to minimize within-load segregation (see Figure 4). This procedure involved 3 separate dumps in the end-dump trucks and 4 to 5 separate dumps in the flow-boys.

CONVENTIONAL SHOVEL SAMPLING

The standard practice for conventional shovel sampling at the Track consisted of removing the top of each accessible dump in the back of the haul truck to a depth of approximately 1 foot. In most instances, this was accomplished by standing on the sampling platform at the plant and leaning out over the side of the truck (as in Figure 5); however, in many cases it was necessary to actually climb over into the bed of the truck to get into a position that would accommodate recovering representative material (see Figure 6). In either case, a 5 gallon metal bucket was filled by removing and combining material from near the mid-portion of each accessible mound of hot material.

Shovel sampling was initially considered the primary method of representative sample recovery; however, early experiences with obtaining unexpected laboratory results in consideration of plant adjustments (presented in Table 1) necessitated a field review of alternative sampling methods. To test the suspicion that shovel samples were less representative of the entire production run than robotic samples, a simple experiment was designed in which a truckload of hot production mix was sampled numerous times. Laboratory results from a single robotic sample were compared to results from 3 different shovel samples, all taken with care in the hopes of generating representative test results.

Based upon the results presented in Table 2, it was observed that the robotic sampling device apparently produced more meaningful results. Based upon this limited information, a change in practice was quickly initiated in which robotic sampling became the primary method of representative sample recovery. Shovel samples would continue to be obtained in a manner that would facilitate a more thorough statistical analysis some time after the completion of construction. Most importantly, construction on the Track could continue with confidence that accurate laboratory test results would be obtained.

ROBOTIC SAMPLING

A standardized method for robotic sample recovery (see Figure 7) was developed to complement the methods already being utilized to load haul trucks. The probe was inserted at approximate third points in each exposed dump for loads contained within end-dump trucks. The two largest mid-load dumps (determined visually) were sampled in this same manner any time flow-boys were in use. Robotic sample depth is completely controlled by the operator; consequently, every effort was made to extract third point material from each dump at the greatest possible depth of penetration. In this manner, the objective was to remove material from the “core” of the dumped mass (see Figure 8). Four probes typically produced two 5-gallon buckets of sample material that could be taken to the laboratory, combined, split, and tested.

The aforementioned experiences at the Track illustrate the difficulty in obtaining high quality representative samples from a loaded truck using a shovel. Without scaffolding to provide access to hard-to-reach areas of the bed, in many cases it is necessary to literally climb into the back of the truck to obtain samples in a dangerous and time consuming manner. The advantages of the robotic sampler in the area of safety are obvious by comparison, where samples can be retrieved from the middle of the truck while the operator stands safely on the platform completely outside the bed of hot material. Track technicians generally found the remote control panel easy to learn and operate, and adapted well to its use. The biggest problem encountered was in selecting the location to insert the probe when sampling mix from flow-boy trucks. Care had to be taken to avoid the numerous metal components that run in both directions of the bed (see Figure 9). Flow-boy beds were eventually marked so that operators would know what areas to avoid (Figure 10).

RESEARCH SUMMARY

Based upon a field review of the initial test results presented in Tables 1 and 2, it was decided that the robotic sampler could potentially obtain material more representative of the entire load than could be obtained using the conventional shovel method; consequently, robotic samples were utilized for quality control and acceptance testing. Since the construction of the Track presented an opportunity to evaluate the comparability of the two methods for numerous mixes imported from many different states, an effort was made to obtain comparison data at least once for each new mix placed on the Track's surface.

When the last section had been paved on July 14, 2000, a total of 145 robotic sample extracted aggregate gradations had been run to potentially compare to 38 shovel sample gradations. Robotic samples are not available for each of the 54 different mixes used to build the Track due to an electrical problem that prevented the heated use of the device for a short period of time (if the probe is too cool, it quickly becomes clogged with mix). In many instances, shovel samples could not be obtained because construction logistics made it difficult given the level of effort and time required to insure quality without the benefit of scaffolding.

Gradations were run on both solvent and furnace extracted aggregate blends; however, it was decided to only include furnace method data in the statistical analysis because the solvent method used at the Track is not a uniformly accepted standard. Additionally, two solvent extractions were run for each sublot of production, and the effect of the splitter quadrant on results would be unknown. Since interpreting robotic sample results played a large part in the overall quality control plan for Track construction, theoretical blends using plant settings and stockpile gradations were used as the basis of comparison for this analysis. Unfortunately, there is no way to consider breakdown in the plant when this method is used. The resulting difference in mix fines is further complicated by the slight increase in dust due to the effect of combustion in ignition furnace extraction. Regardless, it was decided that the most unbiased way to compare the performance of the two sample methods was to use the theoretical blend as the baseline.

A review of the data revealed 14 instances where both robotic and shovel sample furnace extracted gradations could be objectively compared to theoretically blended gradation results in an independent and unbiased manner. Three qualifying mixes were designed with gradations blended on the fine side of the maximum density line (referred to in Table 4 as "ARZ" ("fine") gradations), 2 were blended very near the maximum density line (referred to in Table 4 as "TRZ" (dense") gradations), 8 were blended on the coarse side of the maximum density line (referred to in Table 4 as "BRZ" ("coarse") gradations), and 2 blends were gap-graded (referred to in Table 4 as "SMA" ("gap") gradations).

Four mixes were comprised primarily of crushed stone and 10 mixes were primarily processed gravel. One mix had a nominal maximum aggregate (NMA) size of 9.5 mm, 9 mixes had an NMA of 12.5 mm, and 4 mixes had an NMA of 19.0 mm. Consequently, the statistical approach described herein represented a broad sampling of the 54 mixes utilized to build the entire Track (see Table 3).

For each sieve, the average and standard deviation were calculated over the entire population of comparison samples (see Table 5, with n = 14 for results generated with each sampling method). Using typical values for specification sieve tolerances during hot-mix asphalt production, the average and standard deviation were used to compute the percent within limits (PWL) that would be thus be expected for each method on every sieve. As seen in Table 6, the "advantage" can then be calculated for the robotic sampling device as the difference in PWL for each method (plotted in Figure 11).

Although the smaller sieves are presented, it should be pointed out that aggregate breakdown during production creates uncertainties in the analysis that make it impossible to weigh the value of one method over the other. If one assumes there is no breakdown, the shovel method produces a PWL "advantage" on these smaller sieves; however, quality control test data indicate that breakdown on the order observed in the robotic results actually occurred. Figure 12 illustrates the potential for segregated samples centered near the 1.18 mm (#16) sieve with shovel samples, with the entire average gradation rotated to the coarse side.

CONCLUSIONS

A statistical analysis of gradation test data collected during construction of the 2000 NCAT Pavement Test Track as described herein leads to the following conclusions:

1) Gradations run on extracted hot-mix asphalt aggregate blends were always finer than those calculated in the theoretical blend based on plant settings and known stockpile gradations. This is expected due to aggregate breakdown during production. Shovel samples were generally coarser than robotic samples;

2) Robotic sampling resulted in quality control gradations with a higher probability of falling within the limits of typical state DOT specifications for sieves larger than 1.18 mm (#16). There was no appreciable difference on the 0.60 mm (#30) sieve, and shovel sampling produced an apparent PWL advantage on smaller sieves (if the known effect of aggregate breakdown on the results is ignored); and

3) Shovel samples do not contain as much fine material (in this case, material smaller than the 1.18 mm (#16) sieve) as robotic samples. Since this investigation uses theoretical blends (which do not account for aggregate breakdown during production) as the basis of comparison, it is not possible to determine which method more accurately characterizes material on the finer side of the gradation curves.

RECOMMENDATIONS

This research resulted from an informal testing program during construction of the 2000 NCAT Pavement Test Track, and was intended to generally compare the performance of a robotic sampling device to conventional shovel sampling. With the experience gained in building the initial Track, it will be possible to accommodate a designed experiment for the 2003 reconstruction effort that fully compares the suitability of each method. It is recommended that this comparison be broadened to encompass the array of materials and mixes that will be used to rebuild the Track in 2003. In this manner, any increase in PWL and decrease in segregation centered about the 1.18 mm sieve can be quantified.

ACKNOWLEDGEMENT

This research study is being managed by NCAT, who is responsible for the daily operation of the Pavement Test Track and the completion of associated research. Funding has been provided under a cooperative agreement by numerous State DOTs and FHWA. The author would like to express his appreciation to the many pavement professionals from across the country who endorsed the concept of a research test oval, without whose courteous cooperation and support this research would not have been possible.

The author is solely responsible for the contents of this paper, and the views expressed do not necessarily reflect the views of the researchers or the research sponsors.

REFERENCES

1. Powell, B. *As-Built Properties of Experimental Mixes on the 2000 NCAT Pavement Test Track*, NCAT Report Number 01-02, April, 2001.

FIGURES

Figure 1 – Aerial View of the 2000 NCAT Pavement Test Track

Figure 2 – Onsite Plant at Track (Robotic Sampling Device in Foreground

Figure 3 – Mechanical Splitter Used to Minimize Heat Loss

Figure 4 – Multi-Drop Flow-Boy Truck Loading Procedure to Minimize Within-Load Segregation

Figure 5 – Removing a Shovel Sample from Flow-Boy Truck at Plant

Figure 6 – Removing a Shovel Sample from Flow-Boy Truck on Roadway

Figure 7 – Removing a Robotic Sample from Flow-Boy Truck at Plant

Figure 8 – Typical Third Point Probing Pattern Used in Robotic Sampling

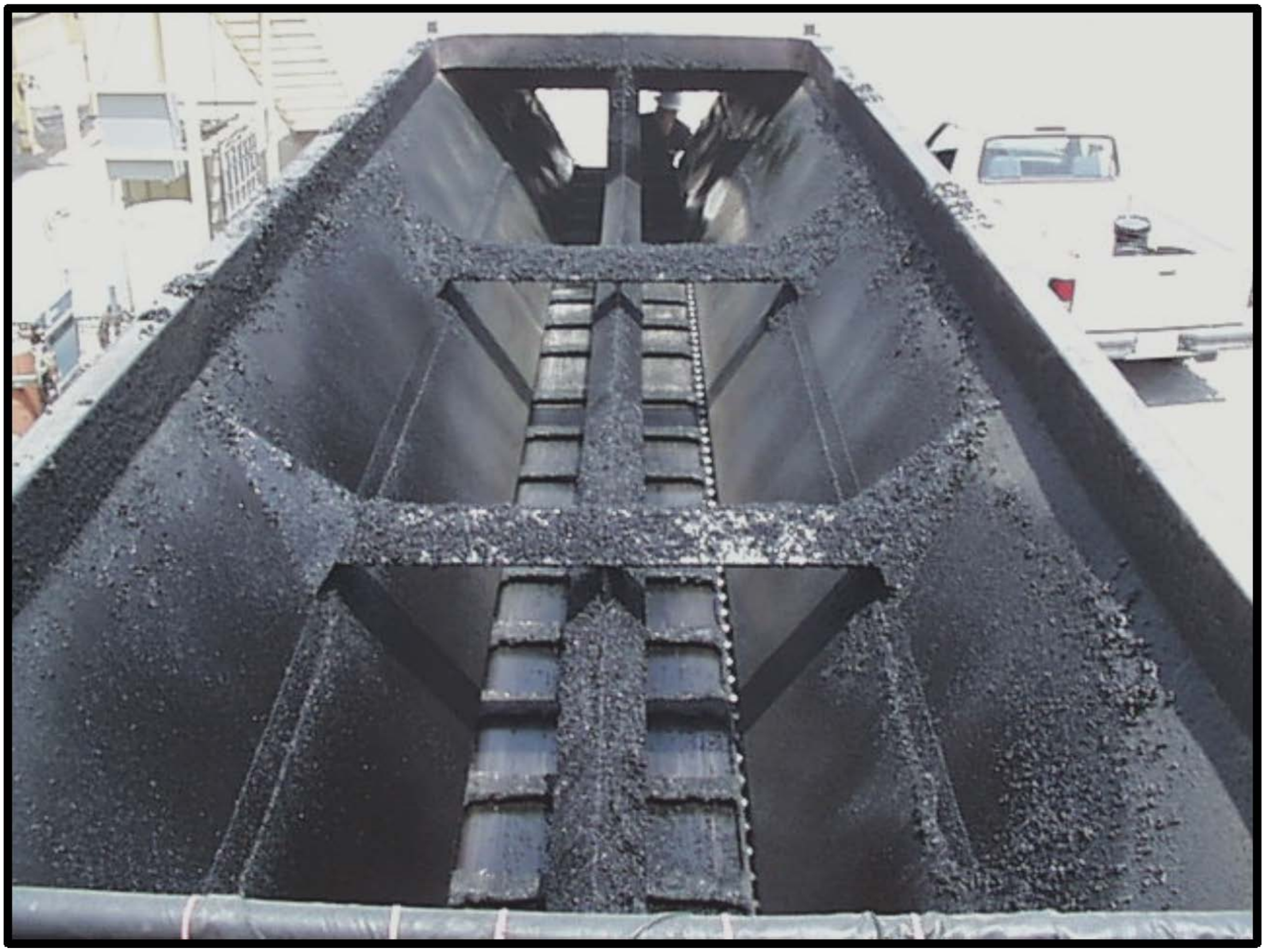

Figure 9 – Potentially Problematic Components in Flow-Boy Truck Bed

Figure 10 – Robotic Sample Head Penetrating Load Dump

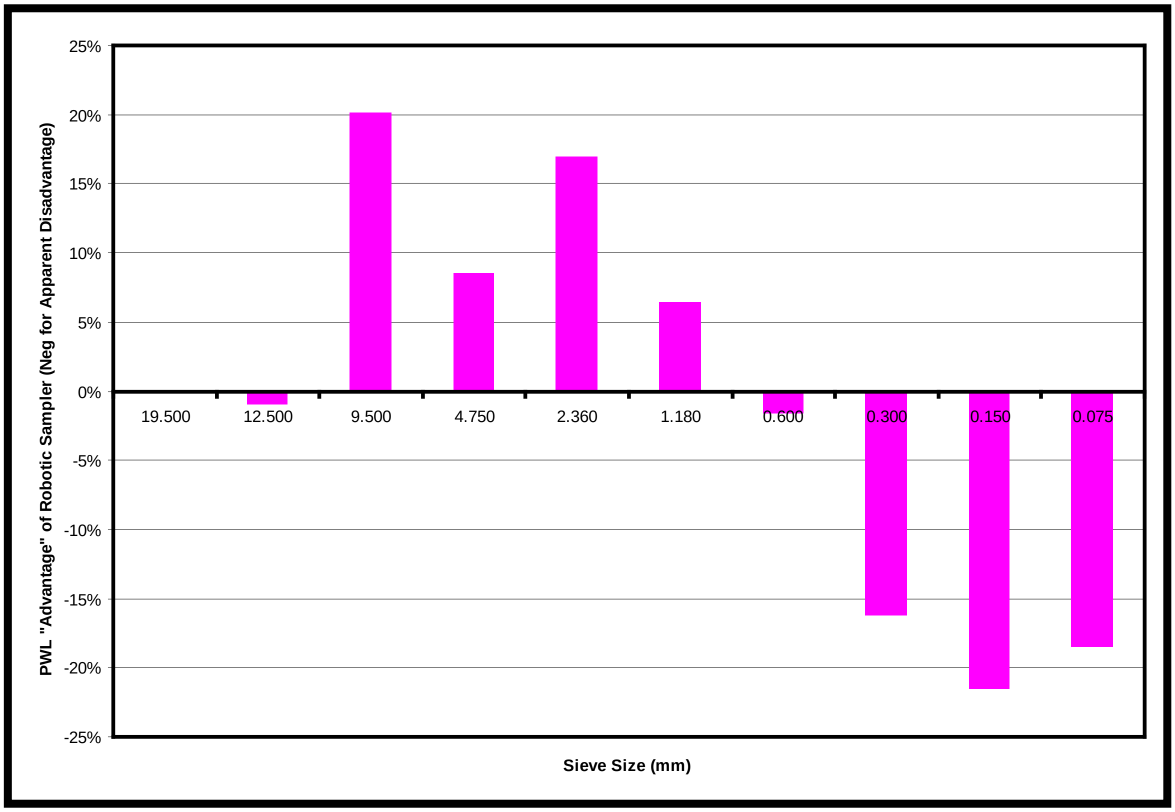

Figure 11 – Difference in PWL with Alternate Sampling Methods

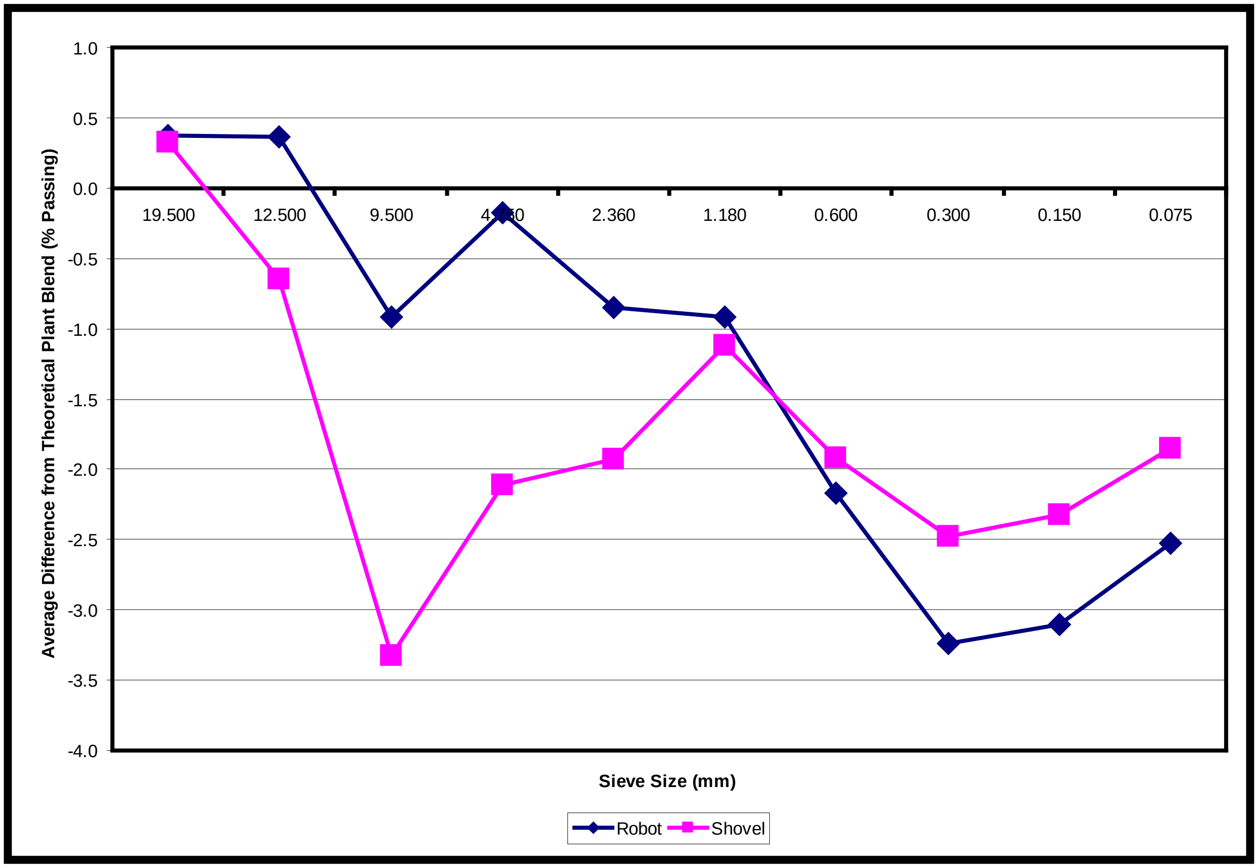

Figure 12 – Comparison of Average Differences of Alternate Sampling Methods

TABLES

Exp Section	Sublot Mix	Plant AC	Shovel AC	Robot AC
E2	1	5.2	5.06	5.38
E2	2	5.2	5.04	5.34
E3	1	5.0	5.39	5.14
E3	2	5.0	5.11	4.87
Expected Results in Lab:			No	Yes

Notes: 1 - Data from the first two research mix placements on 2000 Track
2 - Sublots 1 & 2 refer to inside then outside bottom lane lifts

Table 1 – Early Experiences Comparing Track Sampling Methods

Sample	Method	AC	VTM
1	Shovel	5.1	4.8%
2	Shovel	5.9	3.5%
3	Shovel	5.3	4.3%
4	Robotic	5.1	4.9%
Plant Setting:		4.8	

Table 2 – Summary of Simple Field Experiment

Track Quad	Section Num	Aggregate Blend Type	Design Method	Design NMA	Grad Type	Binder Grade	Binder Modifier	Approx Length	Lift Type	Design Thick	Survey Thick	Std Dev Thick
E	**2**	Granite	Super	12.5	BRZ	67-22	NA	213	Dual	4.0	4.2	0.2
E	**3**	Granite	Super	12.5	BRZ	76-22	SBR	189	Dual	4.0	4.1	0.3
E	**4**	Granite	Super	12.5	BRZ	76-22	SBS	204	Dual	4.0	4.1	0.1
E	**5**	Granite	Super	12.5	TRZ	76-22	SBS	201	Dual	4.0	4.2	0.2
E	**6**	Granite	Super	12.5	TRZ	67-22	NA	211	Dual	4.0	4.2	0.1
E	**7**	Granite	Super	12.5	TRZ	76-22	SBR	193	Dual	4.0	4.2	0.2
E	**8**	Granite	Super	12.5	ARZ	67-22	NA	208	Dual	4.0	4.2	0.1
E	**9**	Granite	Super	12.5	ARZ	76-22	SBS	198	Dual	4.0	4.1	0.1
E	**10**	Granite	Super	12.5	ARZ	76-22	SBR	99	Dual	4.0	4.4	0.3
N	**1**	Slag/Lms	Super	12.5	ARZ	76-22	SBS	201	Dual	4.0	3.9	0.3
N	**2**	Slag/Lms	Super	12.5	ARZ	76-22+	SBS	200	Dual	4.0	4.3	0.3
N	**3**	Slag/Lms	Super	12.5	ARZ	67-22+	NA	200	Dual	4.0	4.2	0.1
N	**4**	Slag/Lms	Super	12.5	ARZ	67-22	NA	199	Dual	4.0	4.2	0.1
N	**5**	Slag/Lms	Super	12.5	BRZ	67-22+	NA	201	Dual	4.0	4.4	0.3
N	**6**	Slag/Lms	Super	12.5	BRZ	67-22	NA	197	Dual	4.0	4.1	0.2
N	**7**	Slag/Lms	Super	12.5	BRZ	76-22+	SBR	203	Dual	4.0	3.9	0.1
N	**8**	Slag/Lms	Super	12.5	BRZ	76-22	SBR	203	Dual	4.0	3.9	0.2
N	**9**	Slag/Lms	Super	12.5	BRZ	76-22	SBS	197	Dual	4.0	3.9	0.2
N	**10**	Slag/Lms	Super	12.5	BRZ	76-22+	SBS	206	Dual	4.0	4.2	0.3
N	**11**	Granite	Super	19.0	BRZ	67-22	NA	195	Lower	2.5	NA	NA
		Granite	Super	12.5	TRZ	76-22	SBS	195	Upper	1.5	4.1	0.1
N	**12**	Granite	Super	19.0	BRZ	67-22	NA	201	Lower	2.5	NA	NA
		Granite	SMA	12.5	SMA	76-22	SBS	201	Upper	1.5	3.9	0.2
N	**13**	Gravel	Super	19.0	BRZ	76-22	SBS	199	Lower	2.5	NA	NA
		Gravel	SMA	12.5	SMA	76-22	SBS	199	Upper	1.5	4.0	0.2
W	**1**	Granite	SMA	12.5	SMA	76-22	SBR	202	Dual	4.0	3.9	0.1
W	**2**	Slag/Lms	SMA	12.5	SMA	76-22	SBR	200	Dual	4.0	4.0	0.1
W	**3**	Granite	Super	12.5	BRZ	76-22	SBR	205	Lower	3.3	NA	NA
		Slag/Lms	OGFC	12.5	OGFC	76-22	SBR	205	Upper	0.7	4.0	0.1
W	**4**	Limestone	SMA	12.5	SMA	76-22	SBR	199	Lower	3.3	NA	NA
		Granite	OGFC	12.5	OGFC	76-22	SBR	199	Upper	0.7	4.1	0.1
W	**5**	Limestone	SMA	12.5	SMA	76-22	SBS	203	Lower	3.3	NA	NA
		Granite	OGFC	12.5	OGFC	76-22	SBS	203	Upper	0.7	4.3	0.1
W	**6**	Slag/Lms	Super	12.5	TRZ	67-22	NA	203	Dual	4.0	4.1	0.1
W	**7**	Limestone	SMA	12.5	SMA	76-22	SBR	207	Dual	4.0	4.2	0.1
W	**8**	Sandstn/Slg/Lms	SMA	12.5	SMA	76-22	SBR	197	Dual	4.0	4.0	0.1
W	**9**	Gravel	Super	12.5	BRZ	67-22	NA	203	Dual	4.0	4.0	0.1
W	**10**	Gravel	Super	12.5	BRZ	76-22	SBR	102	Dual	4.0	3.9	0.1
S	**1**	Granite	Super	19.0	BRZ	76-22	SBS	200	Lower	2.5	NA	NA
		Granite	Super	12.5	BRZ	76-22	SBS	200	Upper	1.5	3.9	0.0
S	**2**	Gravel	Super	19.0	BRZ	76-22	SBS	200	Lower	2.5	NA	NA
		Gravel	Super	9.5	BRZ	76-22	SBS	200	Upper	1.5	3.9	0.0
S	**3**	Limestone	Super	19.0	BRZ	76-22	SBS	201	Lower	2.5	NA	NA
		Lms/Gravel	Super	9.5	BRZ	76-22	SBS	201	Upper	1.5	4.0	0.1
S	**4**	Lms/RAP	Super	19.0	ARZ	76-22	SBS	198	Lower	2.5	NA	NA
		Limestone	Super	12.5	ARZ	76-22	SBS	198	Upper	1.5	4.0	0.1
S	**5**	Lms/Grv/RAP	Super	19.0	BRZ	76-22	SBS	203	Lower	2.5	NA	NA
		Gravel	Super	12.5	TRZ	76-22	SBS	203	Upper	1.5	4.1	0.1
S	**6**	Lms/RAP	Super	12.5	ARZ	67-22	NA	198	Dual	4.0	4.1	0.1
S	**7**	Lms/RAP	Super	12.5	BRZ	67-22	NA	202	Dual	4.0	4.0	0.1
S	**8**	Marble-Schist	Super	19.0	BRZ	67-22	NA	197	Lower	2.1	NA	NA
		Marble-Schist	Super	12.5	BRZ	76-22	SBS	197	Upper	1.5	3.8	0.1
S	**9**	Granite	Super	12.5	BRZ	67-22	NA	206	Dual	3.0	3.0	0.1
S	**10**	Granite	Super	12.5	ARZ	67-22	NA	195	Dual	3.0	3.1	0.1
S	**11**	Marble-Schist	Super	19.0	BRZ	67-22	NA	202	Lower	2.1	NA	NA
		Marble-Schist	Super	9.5	BRZ	76-22	SBS	202	Upper	1.5	3.6	0.1
S	**12**	Limestone	Hveem	12.5	TRZ	70-28	SB	199	Dual	4.0	3.8	0.1
S	**13**	Granite	Super	12.5	ARZ	70-28	SB	201	Dual	4.0	4.0	0.1
E	**1**	Gravel	Super	12.5	ARZ	67-22	NA	199	Dual	4.0	4.1	0.1
Average of Thickness Survey Data Excluding Sections with Other than 4 Inch Designs (S8-S11):											4.1	0.1

Notes: - Mixes are listed chronologically in order of completion dates (which are presented in Appendix A).
- "dual" lift type indicates that the upper and lower lifts were constructed with the same experimental mix.
- ARZ, TRZ, and BRZ refer to gradations intended to pass above, through, and below the restricted zone, respectively.
- SMA and OGFC refer to stone matrix asphalt and open-graded friction course mixes, respectively.

Table 3 – Research Plan for the 2000 NCAT Pavement Test Track (1)

Track Placement			Descriptive Information for Mix & Constituents						Sample	Diff Between Indicated Method and Theor Blend by Sieve (%)									
Quad	**Section**	**Lift**	**Agg Type**	**Design**	**NMA**	**Grad**	**Binder**	**Mod**	**Method**	**19.500**	**12.500**	**9.500**	**4.750**	**2.360**	**1.180**	**0.600**	**0.300**	**0.150**	**0.075**
N	10	Surface	Slag/Lms	Super	12.5	BRZ	76-22+	SBS	Robo	0	2	-2	-4	0	3	2	0	-1	-1.0
									Shovel	0	0	-4	-4	1	3	2	0	-1	-1.0
N	11	Surface	Granite	Super	12.5	TRZ	76-22	SBS	Robo	0	-2	-3	-3	-5	-5	-5	-5	-4	-2.3
									Shovel	-1	-1	-1	0	-3	-4	-5	-5	-4	-2.6
N	4	Surface	Slag/Lms	Super	12.5	ARZ	67-22	NA	Robo	0	0	-6	-2	1	2	1	-2	-3	-3.0
									Shovel	0	0	-5	-5	-2	1	1	-2	-2	-2.6
N	7	Surface	Slag/Lms	Super	12.5	BRZ	76-22+	SBR	Robo	0	1	-1	-1	0	2	1	-1	-2	-2.4
									Shovel	0	2	3	4	2	3	1	-2	-3	-3.1
S	11	Surface	Mrbl-Schs	Super	9.5	BRZ	76-22	SBS	Robo	0	0	2	5	0	0	-2	-4	-5	-1.9
									Shovel	0	0	-1	4	1	3	2	0	0	3.3
S	12	Surface	Lms	Hveem	12.5	TRZ	70-28	SB	Robo	0	0	3	1	-4	-3	-4	-4	-2	-2.1
									Shovel	0	1	1	-3	-7	-4	-4	-4	-2	-2.3
S	1	Binder	Granite	Super	19.0	BRZ	76-22	SBS	Robo	0	0	1	2	1	0	-2	-1	-3	-2.7
									Shovel	2	-8	-12	-9	-4	-2	-3	-1	-3	-2.9
S	2	Binder	Gravel	Super	19.0	BRZ	76-22	SBS	Robo	1	1	-1	7	5	2	1	-1	-1	-0.6
									Shovel	0	-4	-13	-5	-1	-2	-3	-3	-2	-2.0
S	4	Binder	Lms/RAP	Super	19.0	ARZ	76-22	SBS	Robo	0	-3	-2	-2	0	-4	-5	-6	-4	-3.1
									Shovel	3	1	1	1	2	-1	-3	-5	-3	-2.2
S	5	Surface	Gravel	Super	12.5	TRZ	76-22	SBS	Robo	4	9	1	-1	-2	-2	-4	-9	-8	-6.0
									Shovel	0	1	-6	-7	-9	-6	-4	-2	-2	-1.8
S	6	Surface	Lms/RAP	Super	12.5	ARZ	67-22	NA	Robo	0	0	-2	-1	-3	-4	-5	-5	-4	-2.9
									Shovel	0	0	-2	-1	-4	-5	-6	-6	-5	-3.5
W	10	Surface	Gravel	Super	12.5	BRZ	76-22	SBR	Robo	0	2	-5	-4	-4	-1	0	-1	-1	-1.7
									Shovel	0	2	-3	-4	-2	0	1	-1	0	-1.3
W	7	Surface	Lms	SMA	12.5	SMA	76-22	SBR	Robo	0	-3	4	2	-1	-1	-3	-4	-4	-3.4
									Shovel	0	-2	0	3	-1	-1	-3	-3	-3	-3.0
W	8	Surface	Sndstn/Slg/Lms	SMA	12.5	SMA	76-22	SBR	Robo	0	-1	-1	-3	-2	-2	-3	-4	-3	-2.3
									Shovel	0	-1	-5	-2	-1	-1	-2	-2	-1	-0.9

Table 4 – Summary of Mix Types with Differences for Each Method from Theoretical Blends

Typical DOT Spec:		7	7	7	7	4	4	4	4	4	2
Sample	**Overall**	**Statistics for Differences in Percent Passing Each Sieve Size (mm)**									
Method	**Statistic**	**19.500**	**12.500**	**9.500**	**4.750**	**2.360**	**1.180**	**0.600**	**0.300**	**0.150**	**0.075**
Robo	Avg Diff	0.4	0.4	-0.9	-0.2	-0.9	-0.9	-2.2	-3.2	-3.1	-2.5
	Std Dev	1.05	2.98	2.85	3.21	2.53	2.47	2.49	2.40	2.00	1.27
	PWL	100%	98%	98%	97%	87%	87%	76%	62%	67%	34%
Shovel	Avg Diff	0.3	-0.7	-3.3	-2.1	-1.9	-1.1	-1.9	-2.5	-2.3	-1.9
	Std Dev	0.94	2.66	4.55	3.91	3.32	2.87	2.58	1.92	1.37	1.68
	PWL	100%	99%	78%	88%	70%	81%	78%	79%	89%	52%
"Advantage" of Robo:		0%	-1%	20%	9%	17%	6%	-2%	-16%	-22%	-19%

View small sieves with caution, "Avg Diff" is compared to theoretical blend which does not account for aggregate breakdown

Table 5 – Summary of Difference in PWL Computations for Each Sampling Method