EVALUATION OF LIMESTONE COARSE AGGREGATE IN ASPHALT CONCRETE WEARING COURSES

Summary Report
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by

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ABSTRACT

EVALUATION OF LIMESTONE AGGREGATE IN
ASPHALT CONCRETE WEARING COURSES

Limestone is not used in asphalt concrete wearing courses in Alabama because of potential low skid resistance. Limestone is generally suspected to be polish susceptible and hence available sources of limestone are not utilized. This study was conducted to evaluate the performance of limestone when used in the coarse aggregate fraction of asphalt concrete wearing courses.

Three field test sites containing one experimental section each were constructed to study in-situ performance. The surface course mixes in experimental sections had 30 to 40 percent limestone in lieu of gravel in the coarse aggregate fraction. The control sections had 100% gravel as coarse aggregate for comparison. Performance of the surface courses was studied in the field by periodically measuring the skid resistance using the ASTM skid trailer and British Pendulum tester.

The in-situ mixes were replicated in the laboratory by using the same job mix formula and materials. Similar mixes were developed in the laboratory by varying the limestone content. Strength, moisture susceptibility and polishing properties mixes were measured in the laboratory. Acid insoluble tests, petrographic analysis and polish tests were also performed on the coarse aggregates to further understand their frictional and polish resisting properties.

Laboratory results show that the limestone in Fayette and Chilton County mixes are beneficial in increasing mix stability and resistance to moisture damage. However, the limestone in the Hale County mix did not

improve these properties. Laboratory frictional properties of limestone used in Chilton and Fayette Counties was comparable to the gravel aggregate. The limestone used in the Hale County was more polish susceptible. Field test results show that the experimental mixes with limestone had skid resistance comparable to the control gravel mixes in Fayette and Hale Counties. For Chilton County, skid numbers and British Pendulum numbers were higher on the experimental sections.

It appears possible to utilize some limestone in the coarse aggregate fraction without adversely affecting skid resistance. A maximum of 25% limestone coarse aggregate is recommended. Additional research to expand and verify the results from this study is needed.

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I. STUDY DESCRIPTION

Three experimental field projects constructed by the Alabama Highway Department (AHD) were the basis for this study. Each project namely, AL 13 in Fayette County, US 31 in Chilton County and AL 25 in Hale County included a one mile experimental section which had a specified amount of limestone substituted for gravel in the coarse aggregate (plus #4) of the wearing course mix. Coarse aggregate compositions were as follows:

County	Composition of coarse aggregate fraction
Fayette	40% Limestone + 60% Gravel
Chilton	30% Limestone + 70% Gravel
Hale	33% Limestone + 67% Gravel

Pavement surface friction characteristics were measured with the AHD skid trailer and the British pendulum tester. Measurements with the two devices were made at the same location, and at different times of the year to account for seasonal variations.

The field experimental mixes had limestone contents ranging from 30 to 40% which did not provide a range sufficient to effectively evaluate its influence on structural and frictional characteristics. In the laboratory, additional mixes were developed and tested with 20 and 60% limestone coarse aggregate.

Marshall stability and retained tensile strength tests were conducted on laboratory prepared mixes to evaluate the influence of limestone on structural properties. British polish and pendulum tests were conducted on aggregate blends and mixes to assess the influence of limestone on polish and frictional properties.

II. DISCUSSION OF RESULTS

Marshall Stability

Results from Marshall stability tests are summarized in Figure 1. Figure 1 shows Marshall stability plotted versus limestone content for control, experimental and mixes with 20 and 60% limestone coarse aggregate for the Fayette, Chilton and Hale County projects.

The concave upward relationship for Fayette County indicates that there is a slight decrease in stability for 20% limestone coarse aggregate, that the stability for 40% limestone is about the same as the control mix and that the stability for the 60% limestone mix is about 250 pounds larger than the control mix. The curve for Chilton County shows that the Marshall stability increased somewhat with increasing limestone content in the mix. Most of this increase occurred between the control and 20% mix with little if any increase indicated for higher limestone contents. The shape of the curve for Hale County is similar to that for Fayette County but the difference between the control and 20% limestone mix was more pronounced.

In summary the effects of limestone on stability are not well established by this series of tests. This is partially due to inconsistencies in the composition (aggregate and asphalt content) and voids in the mixes. The mixes with limestone generally show that stability increases as percent limestone increases, but for lower limestone contents, structural benefits are not clearly demonstrated.

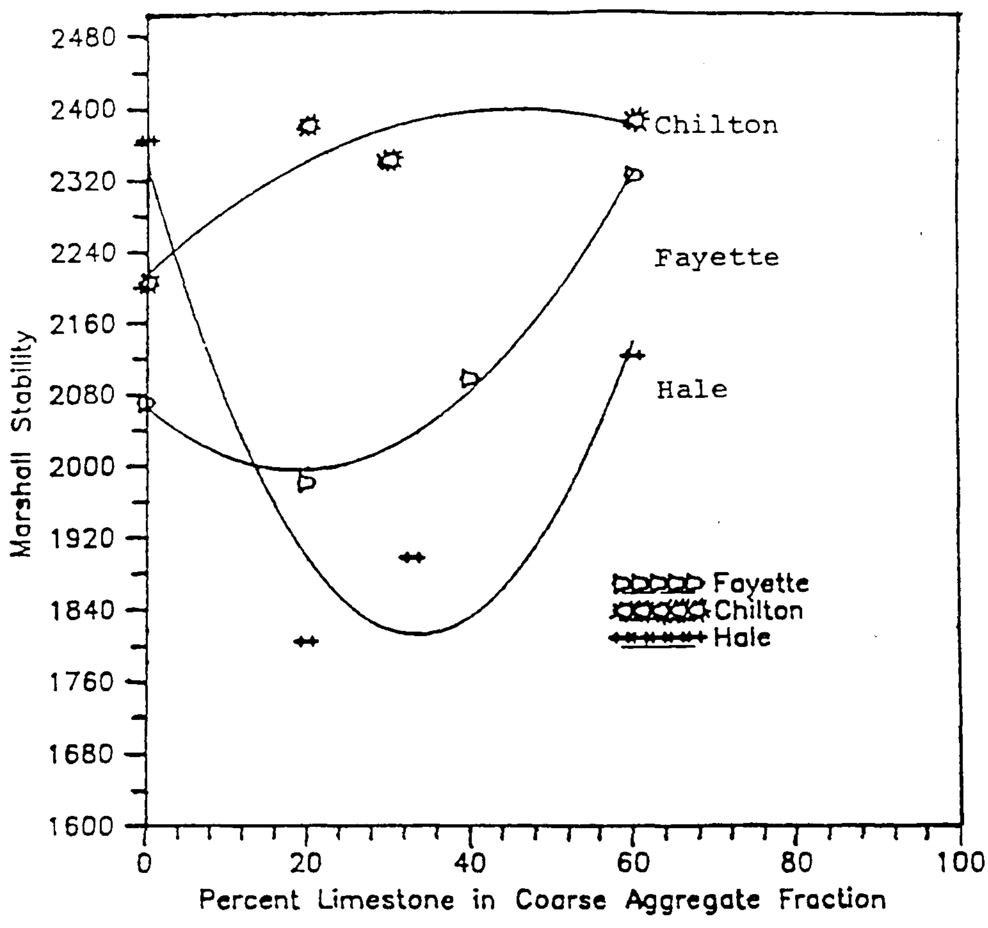

Figure 1. Marshall stability versus percent limestone in the coarse aggregate fraction.

Retained Tensile Strength

Results from retained indirect tensile tests and summarized in Figure 2. Figure 2 shows tensile strength ratio (TSR) plotted versus limestone content for control, experimental, and mixes with 20 and 60% limestone coarse aggregate for the Fayette, Chilton and Hale County projects.

For Fayette County, TSR decreased slightly for 20 and 40% mixes and only increased for 60% mix. This indicates that limestone had little effect on the resistance of the mix to moisture damage. However, it should be noted that the asphalt content of the control mix was 5.5% and the asphalt contents of the mixes with limestone were, respectively, 5.1, 5.2 and 5.0 for the 20, 40 and 60% limestone mixes. These smaller asphalt contents may have influenced the moisture resistance. For Chilton County TSR increased as limestone percentage increased.

For Hale County TSR decreased as limestone content in the coarse aggregate fraction increased. For the particular limestone source used in Hale County similar reductions in apparent resistance to moisture damage have been observed in other mixes.

In summary the Chilton County limestone improved mix resistance to moisture damage, the Fayette County limestone seemed to have little or no effect, and the Hale County limestone seemed to have an adverse effect on mix resistance to moisture damage. However, variable asphalt contents may also have affected the resistances of the mixes to moisture damage.

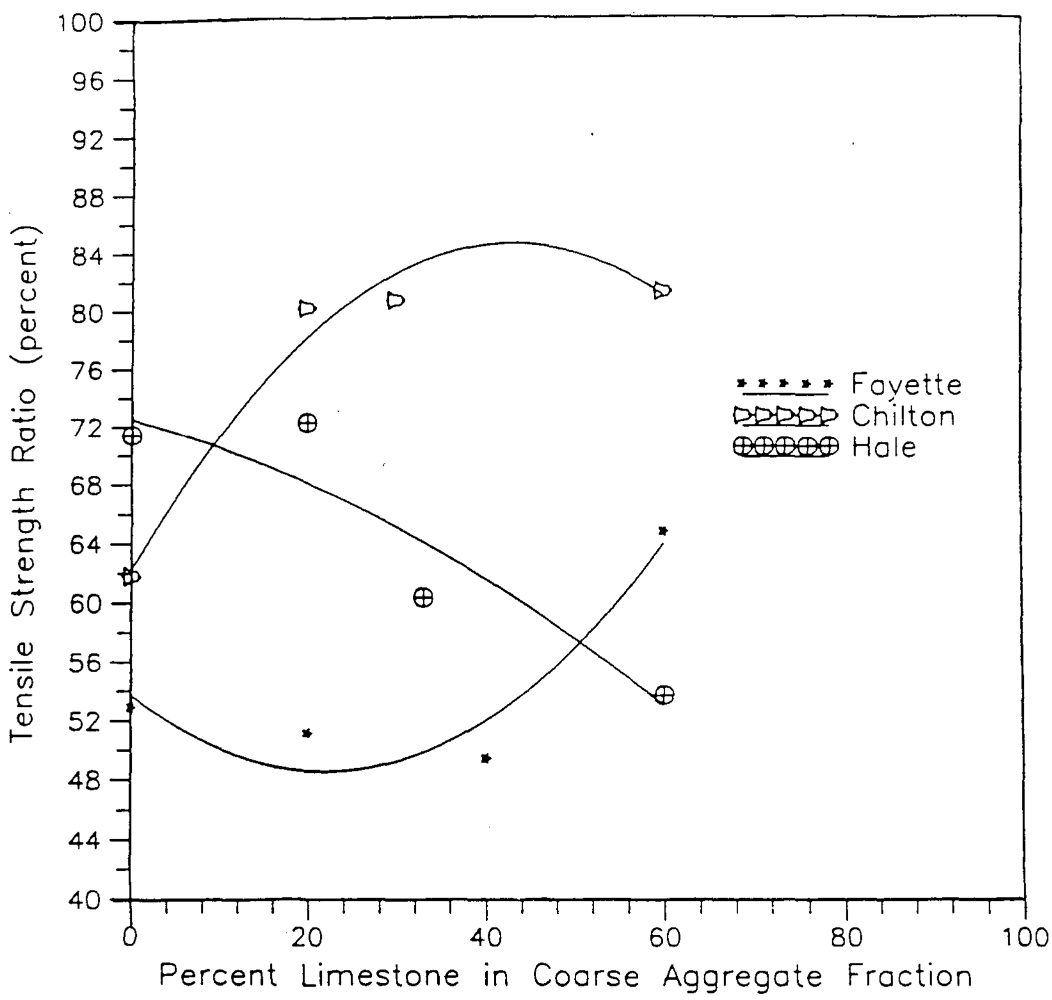

Figure 2. Summary of modified Lottman test results for all three counties.

Polishing of Aggregate

Results of polish and frictional tests are summarized in Table 1. British Pendulum Numbers (BPN) are included for 0, 3, 6 and 9 hours polish. Values shown represent averages from 3 to 10 specimens. The data indicates that the largest reduction in frictional resistance occurs during the first 3 hours polishing. Hyperbolic relationships were fit to the data with curves approaching horizontal asymptotes as polish times increases.

The data for Fayette County shows that BPN increases as limestone content increases indicating a small improvement in microtextural properties. Changes in BPN from 0 to 9 hours were about the same for all mixes. For Chilton County, the data is similar to Fayette County indicating small improvements in microtextural properties and relatively constant polish resistance as limestone content increases. For Hale County, frictional resistance and polish resistance generally decrease as limestone content increases.

In summary, the limestone used in Fayette and Chilton Counties were somewhat better than corresponding gravel aggregates. In Hale County the opposite was true with the gravel exhibiting better frictional and polish resistance characteristics.

Polishing of Mix

British Polish Wheel and Pendulum tests were conducted on mix from Chilton and Hale Counties. The results from these tests are summarized in Table 2. As was the case for bare aggregates, the largest reductions in BPN occurred after 3 hours polish and followed a hyperbolic relationship with time.

Table 1

British pendulum numbers for testing of bare aggregates.

Fayette County

% Lmst	0 hrs polish	3 hrs polish	6 hrs polish	9 hrs polish
0	33	24	20	19
20	36	26	24	22
40	35	25	23	22
60	37	24	23	22

Chilton County

% Lmst	0 hrs polish	3 hrs polish	6 hrs polish	9 hrs polish
0	36	26	25	23
20	37	26	24	25
30	37	27	28	26
60	38	28	29	26

Hale County

% Lmst	0 hrs polish	3 hrs polish	6 hrs polish	9 hrs polish
0	38	29	28	27
20	38	27	25	23
33	37	28	26	26
60	38	26	26	22

For Chilton County, the data indicates that limestone has basically no influence on frictional or polish resistance of the mixes. This is contrary to the data for bare aggregates where small improvements were noted. For Hale County, the data indicates slightly higher BPN's as limestone content increases. Again this is contrary to results from bare aggregate where limestone tended to decrease microtextural properties.

Field Friction Measurements

Results from AHD skid trailer tests (SN) and British Pendulum tests (BPN) on the Chilton County project are summarized on Figure 3. Figure 3 shows that SN and BPN on the experimental mix are higher than values on the control mix and that there is no evidence to indicate serious loss of skid resistance as traffic is applied. Similar figures were prepared for Fayette and Hale Counties, but traffic volumes are insufficient to draw definitive conclusions. However, initial data suggests almost equal performance for control and experimental sections. For Hale County, all four curves slope downward to the right indicating that loss of frictional resistance may be greater than Chilton or Fayette Counties.

Statistical analyses ("t-test") to determine the significance of differences between control and experimental section readings (SN and BPN) were conducted for all three counties with 95% confidence level. Results from these analyses are summarized in Table 3. The computed "t-statistics" are consistently larger than tabular values (in parentheses) only for Chilton County SN values. This indicates that only SN values for control and experimental sections of Chilton County are significantly

Table 2

British pendulum numbers of asphalt concrete mixes.

Chilton County

% Lmst	0 hrs polish	3 hrs polish	6 hrs polish	9 hrs polish
0	46	39	35	33
20	46	37	32	32
30	45	35	33	32
60	48	38	34	33

Hale County

% Lmst	0 hrs polish	3 hrs polish	6 hrs polish	9 hrs polish
0	47	40	38	35
20	48	41	39	38
33	45	39	38	37
60	49	42	38	37

different. Numerically SN values for the Chilton County experimental section were larger than the control section implying statistically significant higher frictional resistance.

When computed "t-statistics" are lower than tabular values, differences between experimental and control SN and BPN values are not significantly different at a 95% confidence level. This is most often the case in Table 19, except as noted above. The five other instances where the computed "t-statistic" indicates significant differences (2-BPN's for Chilton County, 2-BPN's for Hale County and 1-SN for Hale County), values on the experimental section are larger implying higher frictional resistance.

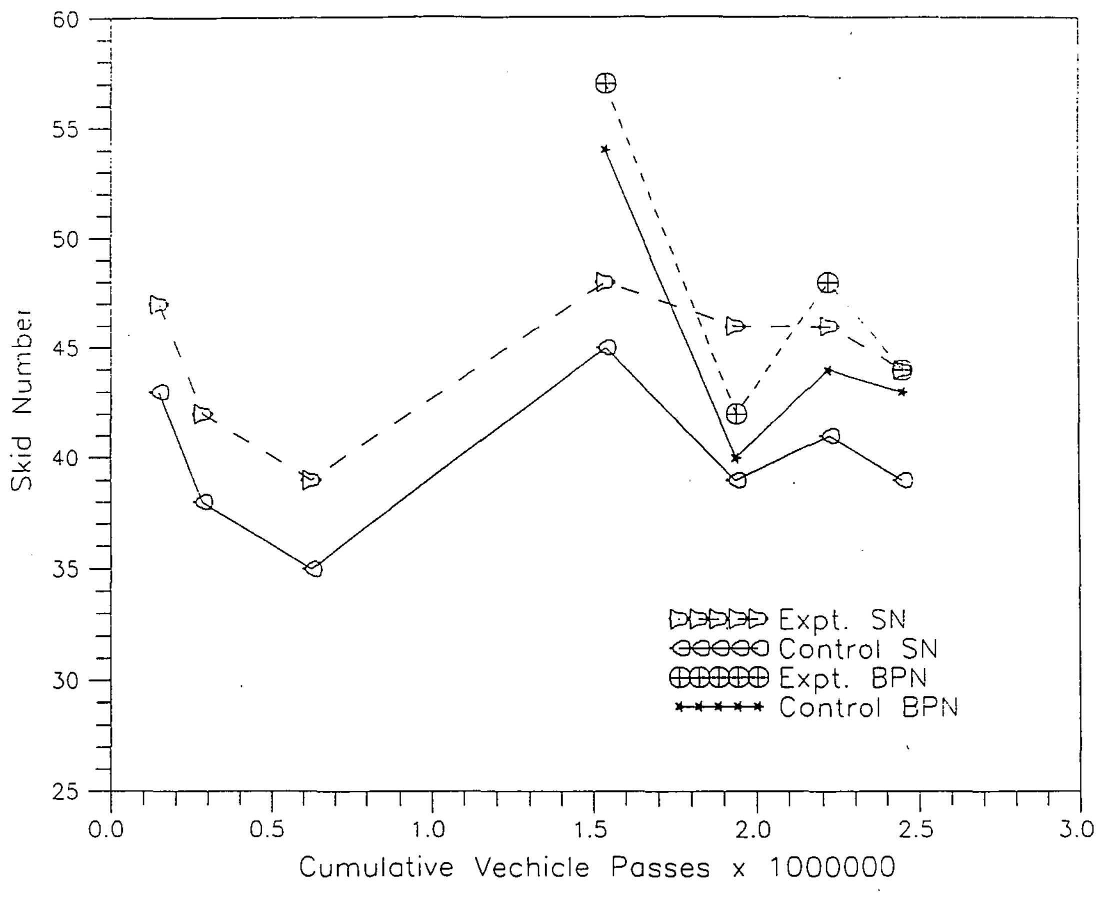

Figure 3. SN versus cumulative vehicle passes (Chilton County)

Table 3

Statistical comparison of control and experimental friction

Fayette County

Test Date	BPN		SN	
	NBL	SBL	NBL	SBL
1/90	1.07(2.09)	0.79(2.09)	0.44(2.09)	0.14(2.09)
8/90	1.96(2.07)	0.10(2.07)	0.54(2.09)	0.03(2.09)
1/91	0.01(2.09)	1.76(2.09)	0.88(2.09)	0.05(2.09)
5/91	0.42(2.09)	1.48(2.09)	0.04(2.09)	0.01(2.09)

Chilton County

Test Date	BPN		SN	
	NBL	SBL	NBL	SBL
1/90	0.24(2.20)	2.17(2.20)	2.74(2.20)	2.87(2.20)
8/90	2.71(2.26)	0.19(2.26)	3.94(2.26)	5.74(2.26)
1/91	1.71(2.36)	2.71(2.36)	5.43(2.31)	7.08(2.31)
5/91	0.03(2.31)	0.39(2.31)	1.57(2.26)	6.86(2.26)

Hale County

Test Date	BPN		SN	
	NBL	SBL	NBL	SBL
1/90	-	-	-	-
8/90	2.22(2.09)	0.51(2.09)	4.53(2.11)	0.15(2.11)
1/91	2.13(2.11)	0.71(2.11)	2.09(2.12)	0.08(2.12)
5/91	0.03(2.12)	0.10(2.12)	0.34(2.11)	0.03(2.11)

III. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

In this study, tests were conducted to study the effects of limestone coarse aggregate (substituted partially for gravel coarse aggregate) on structural, moisture resistance and skid properties of asphalt concrete wearing mixes. On the basis of these tests Table 4 was prepared and, the following conclusions inferred :

1) The effects limestone coarse aggregate on mix stability was not well defined. This was partially due to inconsistences in mix composition and voids. The limestone mixes generally had increased stability as percent limestone increased, but increased stability was not demonstrated at lower limestone contents.
2) Resistance to moisture damage increased for the Chilton County mix, remained relatively unchanged for the Fayette County mix and decreased for the Hale County mix as percent limestone increased.
3) Laboratory polish tests on aggregate and mix indicated positive or no effects of limestone with the exception of the aggregate tests for the Hale County aggregates which indicated that limestone had a detrimental effect on polish resistance.

Table 4

Summary of effects of limestone.

County	Stability	TSR	Agg. BPN	Mix BPN	Pavt. BPN	Pavt. SN
Fayette	0	0	+	NR	0	0
Chilton	0	+	+	0	+	+
Hale	0	-	-	+	0	0

+ = Positive effect
- = Adverse effect
0 = Negligible or conflicting effect
NR = Not run

4) BPN and SN field tests on the pavement surfaces indicated that limestone did not adversely affect skid resistance. For Chilton County there were indications that limestone improved skid resistance.

RECOMMENDATIONS

It appears possible to use limited amounts of limestone coarse aggregate in surface course mixes without adversely affecting skid resistance properties. Based on this study, a maximum of 25% coarse aggregate is recommended.

Additional research is needed to expand and verify results from this study. Specifically, test sections should be designed, constructed and skid resistance monitored with limestone included as coarse and fine aggregate. The test sections should be designed to establish limits for amount and size of limestone aggregates. Polish characteristics of the limestone should be considered and sources with a range of BPN and acid insoluble residues should be included to begin establishing criteria for limestone quality.