EFFECTS OF DIESEL CONTAMINATION IN HOT MIX ASPHALT CONCRETE

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ABSTRACT

Five different asphalts in molded HMAC samples were tested at 0.2 % and 0.5 % diesel fuel contamination. The purpose of these tests was to determine just how significant the loss of strength might be from diesel contamination. The tests used to measure these losses were the Resilient Modulus Test (ASTM D4123) and The Indirect Tensile Strength Test (TEX-226-F)

The test results showed significant losses in the range of 37 to 61 % at 25 °C, in the Indirect Tensile Strength Test, and 13 to 67 % at 25 °C, in the Resilient Modulus Test. The losses generally were greatest at 5 °C and almost negligible at 40 °C in the Resilient Modulus Tests.

No significant differences were detected between the five asphalts; the diesel contamination appeared to have the same effect regardless of the asphalt used.

KEY WORD: Diesel Contamination, HMAC, Resilient Modulus, Indirect Tensile, Strength Loss

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INTRODUCTION

The effects of diesel contamination in Hot-Mixed Asphalt Concrete (HMAC) have often been discussed; but to the best of the authors' knowledge, no actual quantitative tests have been recorded in the literature. With regard to Truck Loading Procedures NAPA states that, "...the truck bed should be cleaned and coated with a lubricant to prevent sticking. Petroleum based products, such as diesel fuel, should not be used because of environmental problems and potential detrimental effects to the asphalt mixture"(1). The U.S. Corps of Engineers express a similar attitude regarding the use of diesel fuel (2). When asphalt is mixed with diesel fuel the resulting product is called "sludge", which is covered by the Oil Pollution Act of 1990. Nevertheless, it is common practice among some hot-mix workers to "lubricate" their truck beds and tools with diesel fuel to prevent hot-mix asphalt concrete from sticking. It is a time-consuming job to clean off. This practice is condoned or at least allowed in some states.

OBJECTIVES

1. Determine the effect of diesel contamination on the engineering properties of hot-mix asphalt concrete as measured by resilient modulus and indirect tensile strength.
2. Determine if different types of asphalt are affected the same way when contaminated with diesel.

METHODOLOGY

Molded specimens were prepared using Texas Department of Transportation (TXDOT) standard dense-graded mixes conforming to Special Specification Item 3022, Type C (16 mm) or Type D (9.5 mm). The samples were compacted in three equal lifts, to 96% density using the Texas Gyratory Compactor. All samples were molded to 102 mm diameter x 51 mm height. The samples were contaminated by applying a calibrated spray of diesel fuel to each during compaction. The molded samples each weigh 1000 grams, so a diesel contamination of 0.2 % would be 2.0 grams and a contamination of 0.5 % would be 5.0 grams. The diesel spray was adjusted so that it dispensed 1.0 gram per spray. The samples contaminated with 0.2 % diesel fuel received one spray (squirt) application each, on top of the first and and second lifts for a total of 2.0 grams. The samples contaminated with 0.5 % diesel fuel received 5.0 grams distributed as one spray application on top of the loose mix while still in the pan; one spray application in the bottom of the mold; and one spray application each on top of each of three lifts.

The test matrix consisted of samples molded with four different asphalts; and three levels of diesel contamination (0.0%, 0.2% and 0.5% diesel). Each data point in Table 1 is the average of three samples; therefore, there were nine samples per asphalt. These four HMACs are plant mixes from various hot-mix plants. The asphalts used are AC-10, AC-20, PG64-22 and PG76-22.

During the mixing and molding process three samples were left uncontaminated (0.0% diesel); three were contaminated with 0.2% diesel; and three were contaminated with 0.5% diesel. All these samples were molded from a Type D mix. These samples were then tested according to ASTM D4123, for resilient modulus, and TEX-226-F, for indirect tensile strength. The same samples were used for both tests since the resilient modulus test is non-destructive. These samples were tested within two weeks after being molded.

A fifth set of molded samples using the Type C mix and an AC-10 w/ 3% Latex asphalt, was also prepared as above using only two samples per level of contamination. This HMAC is a lab mix. These samples were "aged" for six months at 25 °C before testing. Only the resilient modulus test was performed on these six samples. The purpose of the six-month delay was to see if the contaminated mix regained it's strength after the diesel evaporated.

ASTM D4123. STANDARD TEST METHOD FOR INDIRECT TENSION TEST FOR RESILIENT MODULUS OF BITUMINOUS MIXTURES: This procedure uses an indirect tension test to determine resilient modulus by the application of repeated compressive loading in a haversine or other wave form. The loads are applied vertically in a vertical diametrical plane of a molded cylindrical sample. Loads were controlled by load cells, and the corresponding displacements were recorded via linear variable differential transducers (LVDT). The loading wave form used was a repeated haversine having a duration of 0.2 seconds at all frequencies. Molded samples were tested at 5 °C, 25 °C and 40° C and at 0.33 Hz, 0.5 Hz and 1.0 Hz. The compressive loads generated stresses amounting to only 10% to 25% of the indirect tensile strength. These tests are non-destructive so the same samples could be used for both the resilient modulus tests, and the indirect tensile tests. The equations for resilient modulus of elasticity and Poisson's ratio are as follows:

$$E_{RI} = P(\nu_{RI} + 0.27)/t\ \Delta H_I$$

$$E_{RT} = P(\nu_{RT} + 0.27)/t\ \Delta H_T$$

$$\nu_{RI} = 3.59\ \Delta H_I/\Delta V_I - 0.27$$

$$\nu_{RT} = 3.59\ \Delta H_T/\Delta V_T - 0.27$$

where

E_{RI} = instantaneous resilient modulus of elasticity, psi (or MPa)

E_{RT} = total resilient modulus of elasticity, psi (or Mpa)

ν_{RI} = instantaneous resilient Poisson's ratio

ν_{RT} = total resilient Poisson's ratio

p = repeated load, lbf (or N)

t = thickness of specimen, in (or mm)

ΔH_I = instantaneous recoverable horizontal deformation, in (or mm)

ΔV_I = instantaneous recoverable verticle deformation, in (or mm)

ΔH_T = total recoverable horizontal deformation, in (or mm)

ΔV_T = total recoverable vertical deformation, in (or mm)

TEX-226-F. INDIRECT TENSILE STRENGTH TEST (3): This test is performed on the same apparatus as required for the resilient modulus test (above), except that cyclic loading is not used. A load is applied so as to obtain a strain rate of 51 mm per minute at a termperature of 25 °C, and allowed to increase to failure. The peak load at failure is recorded. The equations (1) for indirect tensile stress and strain at failure are as follows:

$\alpha_x = 2P/\pi dt$ $\varepsilon_f = 0.52x_t$

$\alpha_y = 6P/\pi dt$

where:

α_x = horizontal tensile stress at center of specimen, psi

α_y = vertical compressive stress at center of specimen, psi

ε_f = tensile strain at failure, inches/inch

P = applied load, lbs

d = diameter of specimen, inches

t = thickness of specimen, inches

x_t = horizontal deformation across specimen, inches

π = 3.14159 (a constant)

TEX-204-F. DESIGN OF BITUMINOUS MIXTURES (3): This procedure is used to determine the proper proportions of aggregate and asphalt which will produce a mixture that will satisfy the specification requirements. The method utilizes a motorized gyratory-shear compactor commonly referred to as the "Texas Gyratory Compactor". The desired characteristics for these mixes were 96.0 % density, minimum VMA of 14 % (Type C mix) or 15 % (Type D mix), and an asphalt content around 4.8 to 5.0 %.

The aggregates used in these hot mixes were graded according to Table 1:

Table 1: Aggregate Gradations for HMAC

SIEVE SIZE, mm	TYPE C	TYPE D
25.0		
22.4	98.0 - 100.0	
16.0		
12.5		98.0 - 100.0
9.5	70.0 - 85.0	85.0 - 100.0
6.3		
4.75	43.0 - 63.0	50.0 - 70.0
2.00	30.0 - 40.0	32.0 - 42.0
0.425	10.0 - 25.0	11.0 - 26.0
0.180	3.0 - 13.0	4.0 - 14.0
0.075	1.0 - 6.0	1.0 - 6.0
MIN. VMA, %	14.0	15.0
MIN. HVEEM STABILITY	35	35

The asphalts used in these hot mixes have the characteristics shown in Table 2.

Table 2: Visco-Elastic Properties of Selected Asphalts

PROPERTY	AC-10	AC-10 w/3% Latex	AC-20	PG 64-22	PG 76-22
VISCOSITY 60 C, Pa·s 135 C, Pa·s	 80 - 120 >0.19	 >160.0 <1.20	 160.0 - 240.0 >0.25		
PENETRATION 100g, 5s, 25 C, (0.1mm)	85	75	55		
Viscosity D4402 3 Pa·s Max, at Test Temp. C				135	135

PROPERTY	AC-10	AC-10 w/3% Latex	AC-20	PG 64-22	PG 76-22
Dynamic Shear, TP5: G*/sinδ, 1.00 kPa min. Test Temp @ 10 rad/s, C				64	76
Dynamic Shear, TP5: G*/sinδ, 2.20 kPa min. Test Temp @ 10 rad/s, C				64	76

DISCUSSION OF TEST RESULTS

Although the scope of testing is somewhat limited, both Resilient Modulus and Indirect Tensile Tests confirm significant loss of strength from low levels of diesel contamination. The losses may be characterized as approximately 37 to 42% at 0.2% diesel contamination, and approximately 50 to 61% at the 0.5% level in the Indirect Tensile Tests (Figure 6) for all asphalts tested. The Resilient Modulus Tests resulted in greater variability than the Indirect Tensile Tests, but still fell in approximately the same percentage loss categories as the latter.

Inspection of data in Table 3 indicates that all five of the hot mixes lost more resilient modulus strength at 5 °C than at 40° C, as compared to their respective uncontaminated condition. This probably indicates that an increased sensitivity to cold cracking is caused by low levels of diesel contamination.

Cutback asphalt is a liquid asphalt which is manufactured by adding petroleum solvents so as to reduce the viscosity of the asphalt. When applied to an aggregate, the the solvent evaporates and leaves a coating of asphalt on the aggregate. The conventional view is that as the solvent evaporates, the asphalt regains it's original viscosity (and presumably) it's strength.

If the contamination of asphalt with small percentages (< 1%) of diesel can be compared to the solvent dilution of asphalt in the manufacture of cutback asphalt, then it appears that the conventional view that the asphalt regains its strength as the solvent evaporates may not be correct. The fifth HMAC (AC-10 w/3% Latex) tested for this paper was aged for six months on an open shelf in the lab before it was tested for Resilient Modulus only. The losses were of the same general magnitude as those which were tested within two weeks after molding. These losses for 0.2% and 0.5%diesel, amount, respectively, to30% to 46% at 5 °C and 47% and 62% at 25 °C compared to the uncontaminated samples of the same HMAC. Loss at 40 °C is practically 0 %. On the basis of this admittedly limited testing, further testing on cutback asphalts may be justified to determine the recoverability of the viscosity and strength of the cutback asphalt as the solvent evaporates.

The work done on this paper has supported the development of test procedures and specifications for asphalt release agents which do not contaminate hot-mixed asphalt concrete. The release agents are sprayed on the truck beds or equipment before coming in contact with hot-mixed asphalt concrete. The release agents are replacing the use of diesel in Texas.

Table 3: Results of Resilient Modulus and Indirect Tensile Tests of Diesel-Contaminated Samples

Sample ID: Asphalt Percent Diesel	Resilient Modulus @ Temperature, psi x 10^3			Indirect Tensile Strength, psi
	5 °C	25 °C	40 °C	25 °C
AC-10*				
0.0% Diesel	1322.8+	292.9	118.7	119.1
0.2% Diesel	998.1	176.7	90.1	70.8
0.5% Diesel	998.7	123.8	70.8	46.2
AC-20*				
0.0% Diesel	1763.5	573.9	267.0	178.7
0.2% Diesel	776.4	405.6	108.1	105.9
0.5% Diesel	414.2	247.0	141.7	89.4
PG64-22*				
0.0% Diesel	842.6	327.0	227.8	149.0
0.2% Diesel	569.2	236.0	94.1	86.4
0.5% Diesel	639.7	105.6	82.2	61.5
+Data entries represent the average of three replicate samples.				

Sample ID: Asphalt Percent Diesel	Resilient Modulus @ Temperature, psi x 10^3			Indirect Tensile Strength, psi
	5 °C	25 °C	40 °C	25 °C
PG76-22*				
0.0% Diesel	1016.4	327.5	155.0	138.0
0.2% Diesel	779.8	283.2	83.4	86.7
0.5% Diesel	377.4	139.8	136.1	60.8
AC-10 w/3% Latex**				
0.0% Diesel	1013.2	179.8	27.2	Not tested for this mix
0.2% Diesel	703.3	94.9	23.8	"
0.5% Diesel	536.9	67.5	24.5	"

1.0 psi = 6.89 kPa
*Plant mix
**Lab mix

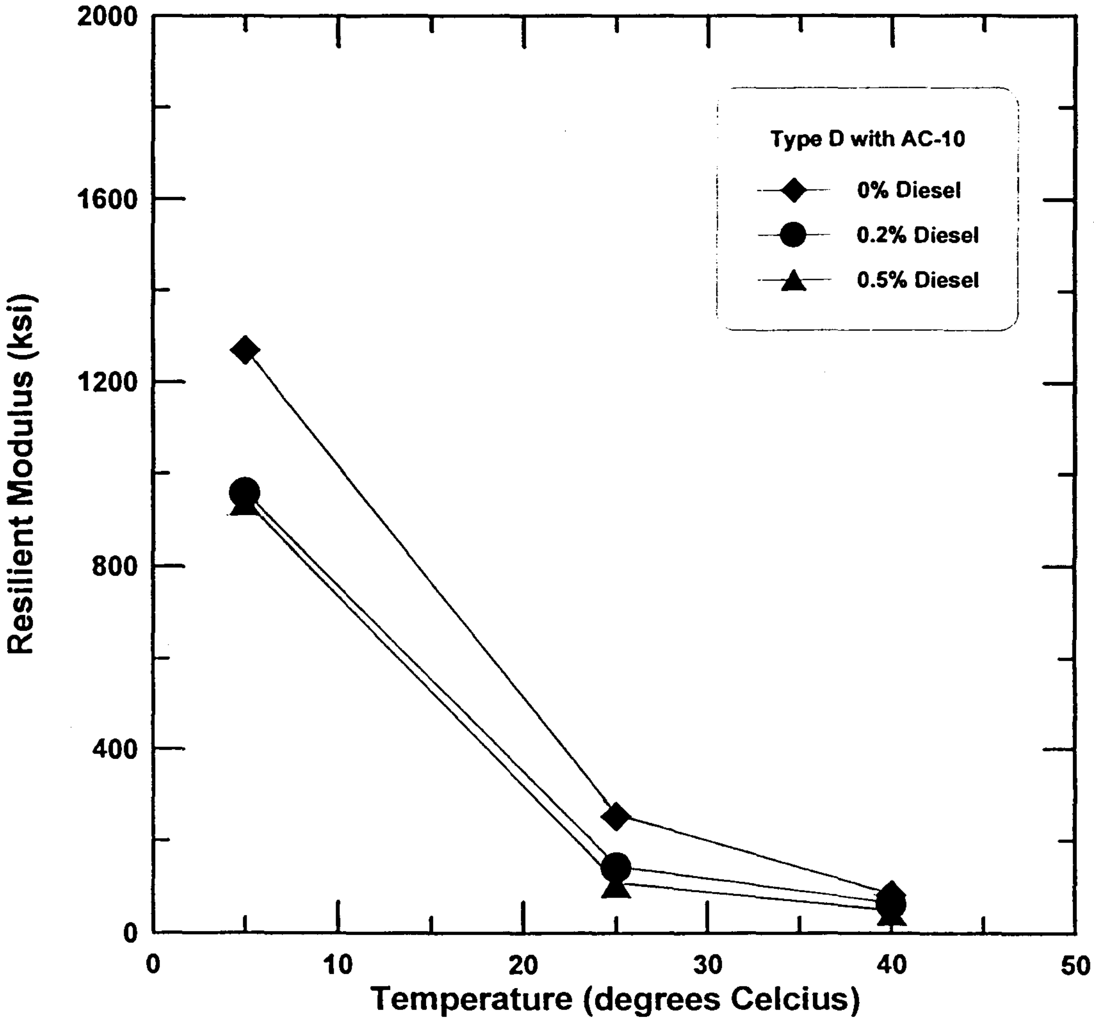

Figure 1: Resilient Modulus for AC-10.

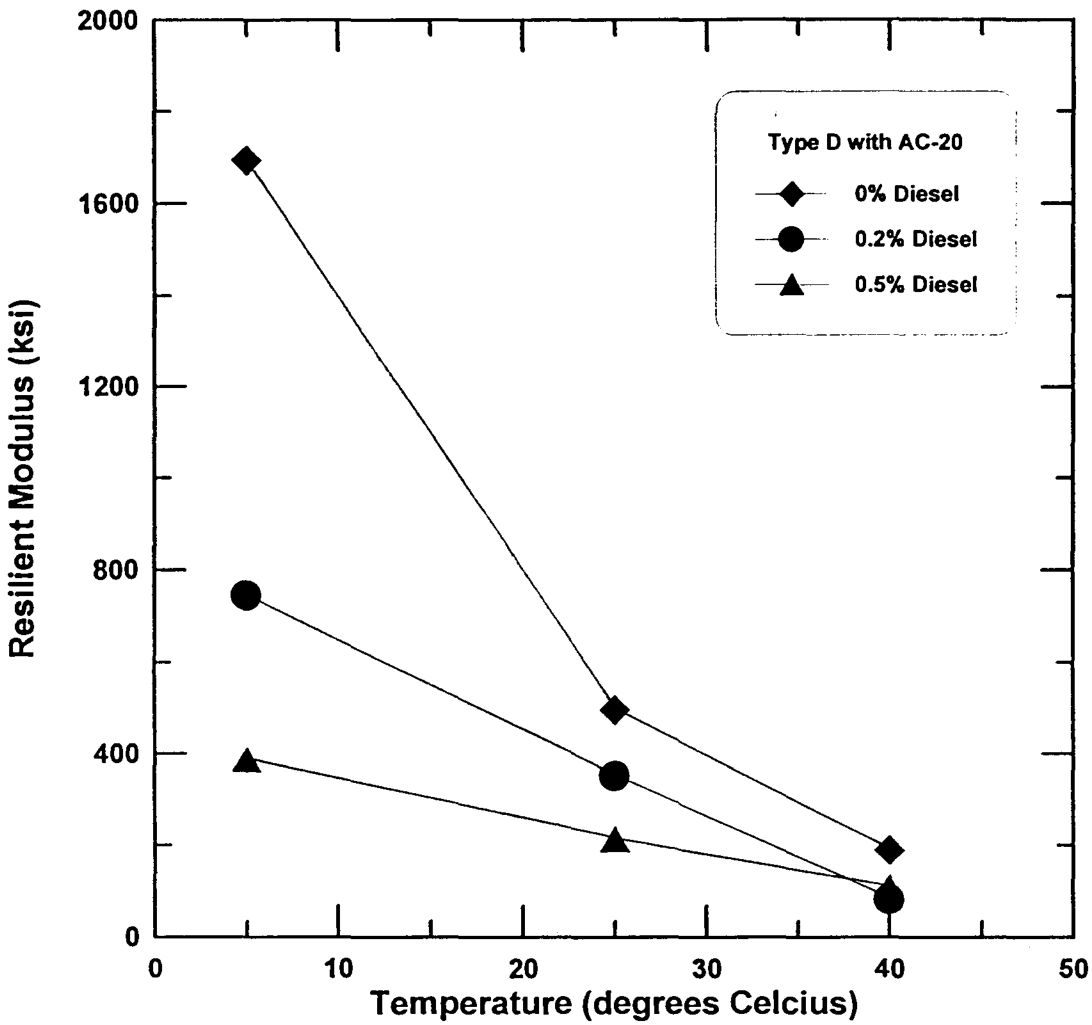

Figure 2: Resilient Modulus for AC-20.

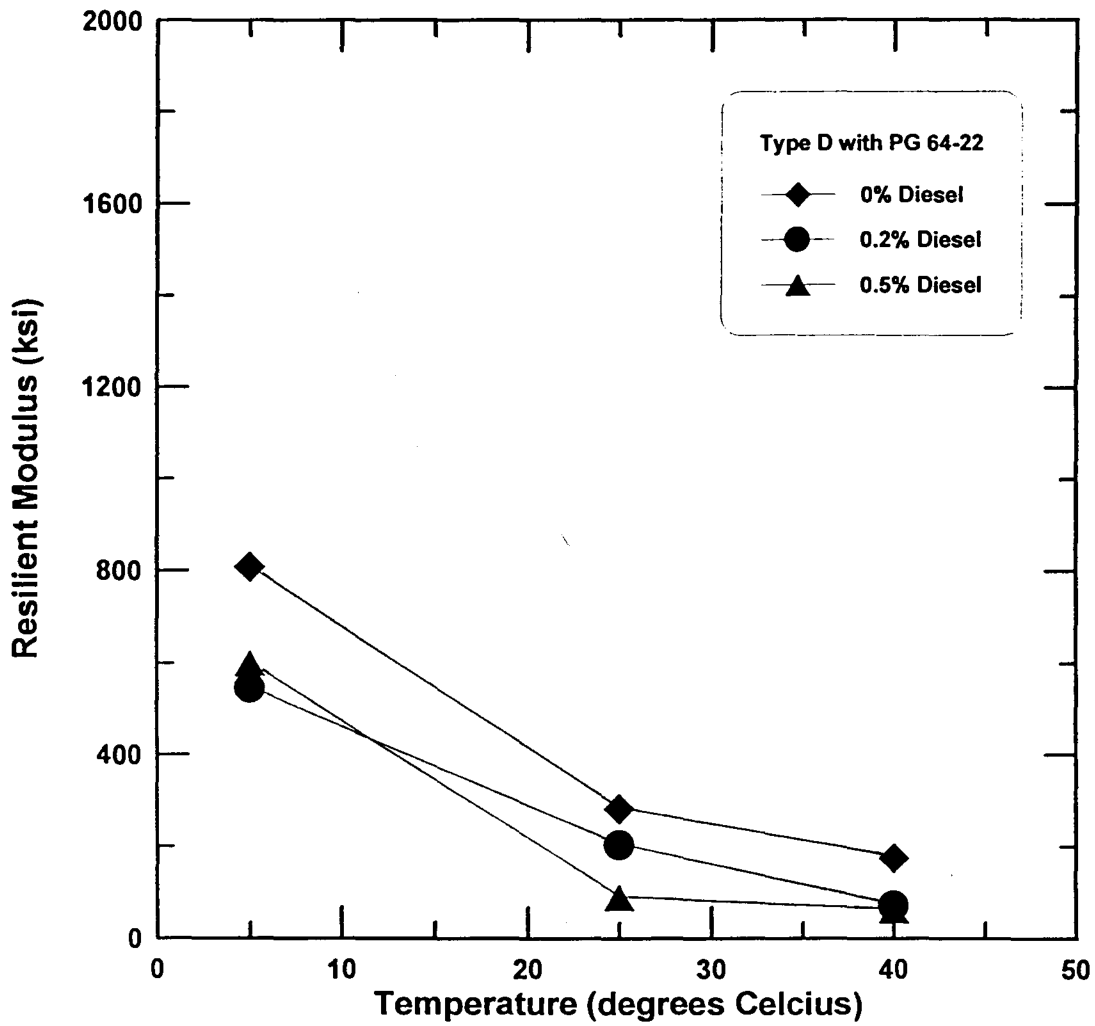

Figure 3: Resilient Modulus for PG 64-22.

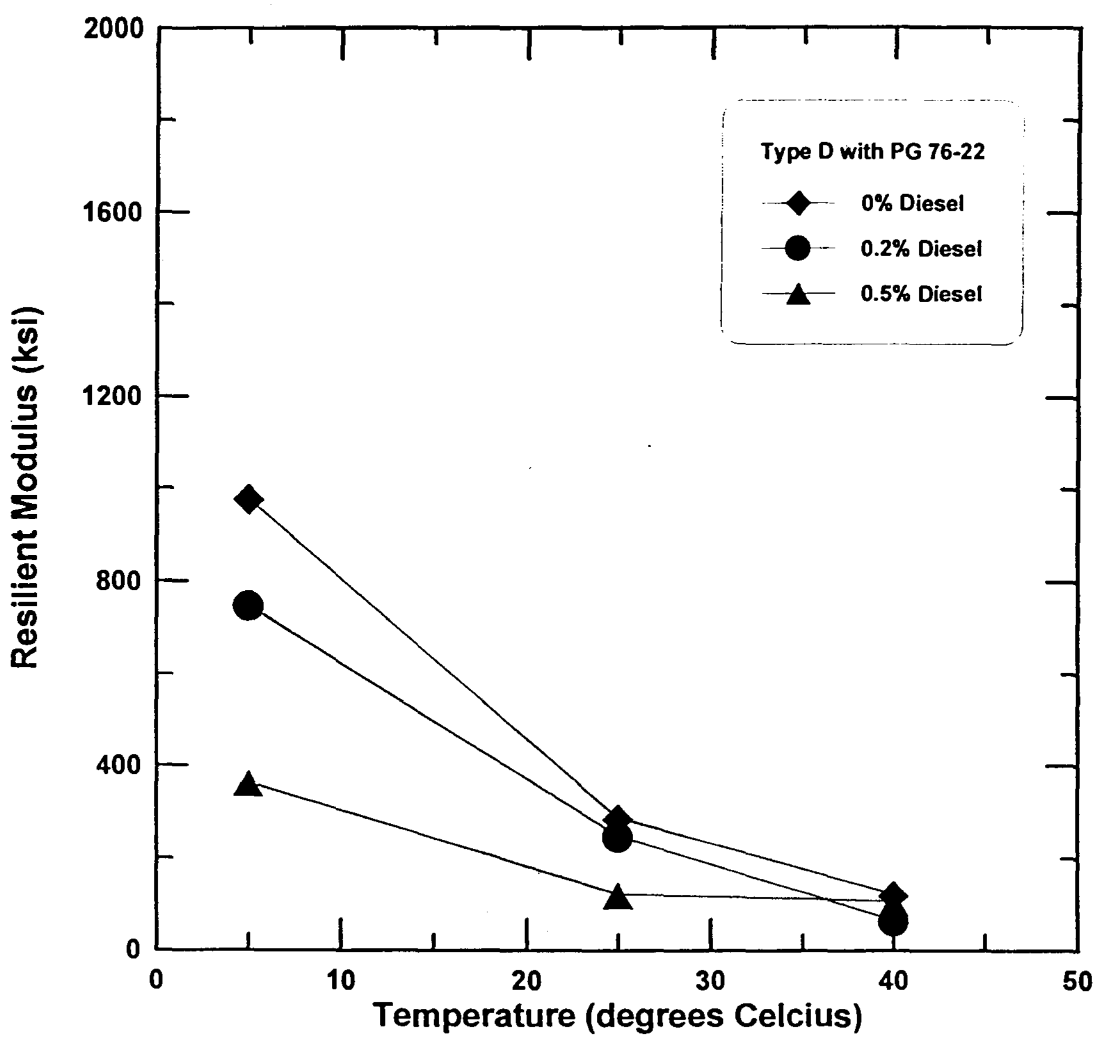

Figure 4: Resilient Modulus for PG 76-22.

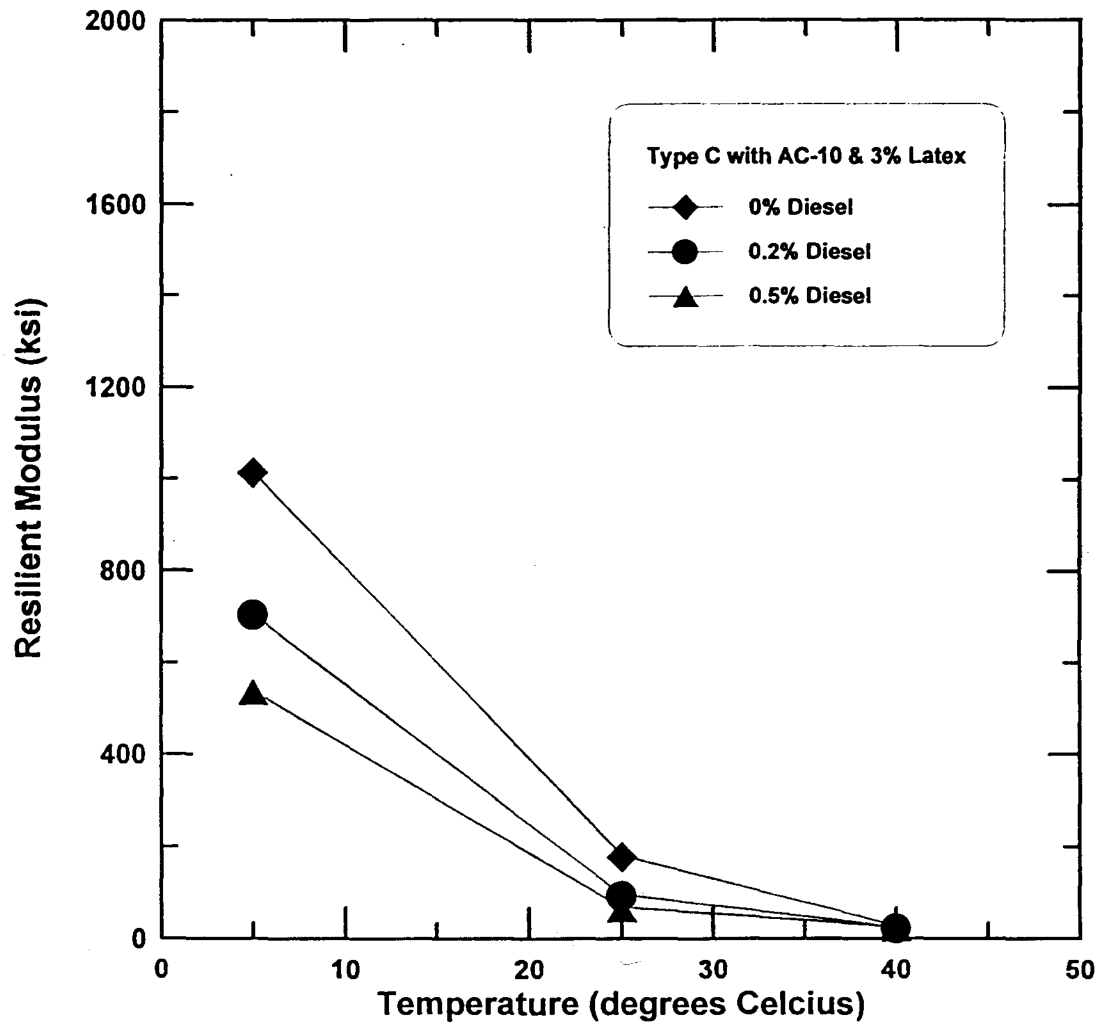

Figure 5: Resilient Modulus for AC-10 with 3 % Latex.

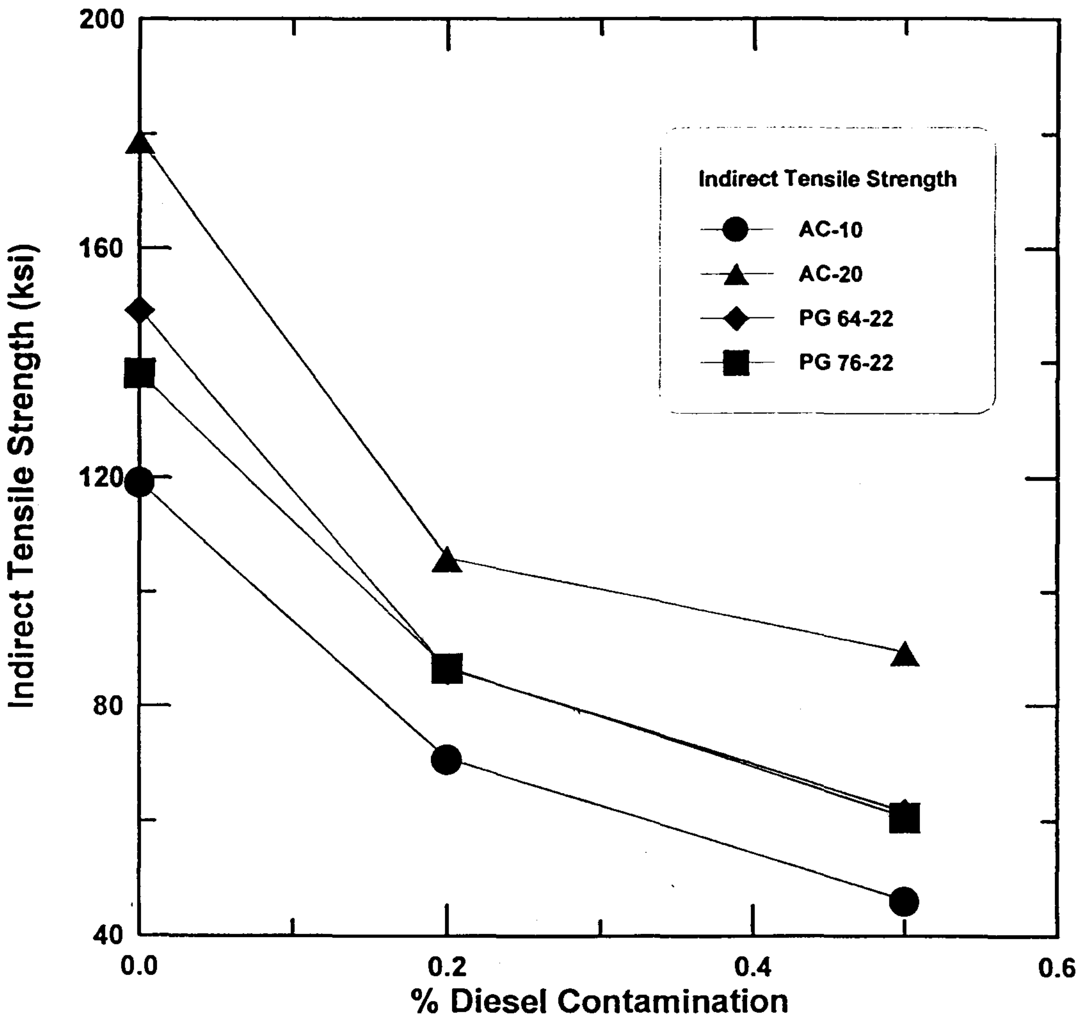

Figure 6: Indirect Tensile Strength for Various Asphalts and Degrees of Contamination.

CONCLUSIONS

1. Diesel fuel in even small amounts has a significant weakening effect on HMAC properties of Resilient Modulus and Indirect Tensile Strength. The most consistant results showed in the Indirect Tensile Strength Test where loss of strength was 37 to 42 % at 0.2 % diesel contamination, and 50 to 61 % at a contamination level of 0.5 %, when compared to their corresponding uncontaminated samples. The data for loss of strength in the Resilient Modulus Test are consistant with the data for Indirect Tensile Strength, though with somewhat more variability. Looking only at Resilient Modulus Strength taken at 25 °C, and Indirect Tensile Strength also taken at 25 °C, the losses may be summarized as shown in Table 4.

Table 4: Loss of Strength in Diesel Contaminated Molded HMAC Samples at 25 °C.

ASPHALT	RESILIENT MODULUS @ 25 C		INDIRECT TENSILE @ 25 C	
	0.2 % Diesel	0.5 % Diesel	0.2 % Diesel	0.5 % Diesel
AC-10	43.6 %	57.6 %	40.6 %	61.2 %
AC-20	29.0	56.8	40.7	50.0
PG 64-22	27.8	67.7	42.0	58.7
PG 76-22	13.5	57.3	37.2	55.9
AC-10 w/ 3 % Latex	47.2	62.5	-----	-----

2. Based primarily on the Indirect Tensile Strength losses there seems to be no significant difference as between the five different asphalts tested. Admittedly, this is a small sampling.

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