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COMPACTION CHARACTERISTICS OF MICROASPHALTS AND SLURRY SEALS BY TRAFFIC SIMULATION WITH THE LOADED WHEEL AND WHEEL TRACKING TESTS

PART III: INITIAL EXPERIMENTS ON TEMPERATURE EFFECTS USING THE TRIPLE TRACK WHEEL TRACKING TEST

BY: C. ROBERT BENEDICT, CONSULTANT
ISSA DIRECTOR OF RESEARCH, EMERITUS
C/O ALPHA LABS
P.O. BOX 74
ALPHA (BY DAYTON), OHIO 45301
PHONE: (513)298-6647
FAX: (513)426-3368

INTRODUCTION

The Loaded Wheel Test (LWT) and British Wheel Tracking Tests (WTT), are accelerated laboratory tests which in a short time may predict field performance. Acceleration of results is achieved by heavy wheel loading, small specimen contact areas (.3-1.5 in^2, .2-9.7 cm^2) and slow speeds (1.6 MPH or 2.5 km/hr) as well as elevated temperatures ranging from ambient to 115°F (45°C). In both test methods the rate of load applications is the equivalent of 126,000 VPD in a single lane.

The LWT suffers the disadvantages of a small wheel, periodic manual loading and unloading for removal of sample for manual measurement and a rocking to and fro motion in which the load varies as much as 30 lbs (13.6 kg) depending upon the up or down crank position.

While the LWT wheel moves over a fixed specimen, the WTT wheel is stationary while the specimen moves to and fro under the wheel and the load is constant in both directions.

Other advantages of the Triple-Track, British-Type WTT are:

1. Productivity; 3 samples may be run simultaneously
2. Load application is by easily regulated air cylinders
3. Load removal by a simple 4-way air valve
4. Sample measurement is accomplished quickly without sample removal
5. Easily adapted to measurement-in-motion, continuous digital read out and computerization
6. Greater accuracy - square, uniform wheel track shape vs. LWT's rounded, concave track
7. Many years reference experience in the U.K. at TRRL

At TRRL, considerable work with the WTT has been published regarding Hot Mix or "Hot Rolled Asphalt" which uses an aggregate similar to ISSA's coarse Type 3 gradation but with hot compaction and consequent higher densities. An example of the TRRL work is the relationship of Ring & Ball Softening Points to the rutting rate at 35, 45 and 60°C (1) Figure a shows an excellent R&B softening point correlation with the rutting rate. Others (2) have suggested that a WTT rutting rate (@ 45°C) of 2.0mm/hour (.76mm/M cycles) would be satisfactory for 6000 commercial vehicles per day in the U.K. climate.

In Parts I and II, we discussed only LWT vertical displacements only at ambient (70°F, 21°C) and 1000, 4000 or 8000 cycles and at applied [and total] loads of 125 lbs [144 lbs, 65.5 kg]; in one instance 75 lbs [103.5 lbs, 47 kg]. Effects of variables reported and discussed were:

1. Relationship of uncompacted and compacted voids to vertical and lateral unconfined LWT displacement (rut or track depth) to bitumen percent and performance qualities of mix components
2. Effect of number of cycles
3. Effect on cement or chemical filler content variation
4. Effect of 0/#4 and 0-5/16" (4.75 and 8.0mm) gradations
5. Effects of different polymers
6. Effect of pH
7. Applied wheel loads 75 and 125 lbs.
8. Effect of number of cycles

In this Part III, we will discuss our initial, experimental WTT results as follows:

1. LWT extended to 20,000 cycles using 4-wheel loads with "Latham" 0/#4 with an SBR modified emulsion at 1.0pc-8-11% emulsion and 13mm samples run at 21°C

With <u>"Plum Run" Dolomite</u>, <u>plain</u> or <u>natural latex</u> modified emulsion (same base bitumen) at 1.0%pc, 8% water and 11% emulsion. Unless noted, all samples were 13mm thick. Polymer contents were all 3.0% on the bitumen:

2. Comparison of LWT and WTT at 21°C using 4 LWT loadings and 2 WTT loadings

3. Effect of layer thickness on 0/#4 and 50% added chips. WTT @ 21°C

4. Effect of temperature and gradation with added 7mm chips. WTT @ 21°C and 45°C

5. Effect of temperature on 2 different aggregates, Latham and Plum Run. WTT @ 21°C and 45°C

With <u>"Latham" Dolomite</u> and <u>Synthetic Latexes</u>: WTT @ 35°C and 45°C (95°F and 115°F):

6. Effect of chemical filler type (Hydrated Lime or Portland Cement). VAE modified emulsion. WTT at 35°C and 45°C.

7. Comparison of SBR and VAE polymer with Latham 0/7mm, 1.0pc-8-11% AE. WTT @ 35°C (95°F)

Troublesome variables and unsolved problems:

8. Effect of density or specific gravity as cast on compacted density, 2 cases.

9. Effect of sample aging.

10. Standardization of wheel properties.

11. Field correlation with lab results.

1 - **EFFECT OF LWT CYCLES EXTENDED TO 20,000** at ambient

In Part II, our final example we supposed that the number of cycles to reach a steady-state rate of compaction as well as the rate of compaction to be significant. But what happens when more than 8000 cycles are run? Will a point be reached where the force of compaction is balanced by the mixes' resistance to compaction?

Field observations in the U.S.(3) and Germany(4), show clearly that a small initial compaction by traffic of perhaps 10% takes place immediately within a day or two, but that no further displacements take place, even after 4 years of heavy traffic.

Again, the LWT and WTT are accelerated tests due to heavy loading and slow speeds far in excess of real world conditions. We wondered what would happen if we reduced LWT more realistic loads and increased the cycles or load applications. Figure 1 graphs results of our first longer-run trials. We note that extended load applications (cycles) did reduce the rate of compaction under ambient conditions as did load reductions. At 49 lbs., a realistic number, total load, the rate of compaction between 8000 and 20,000 cycles is only .003mm/1000 cycles, at ambient. We speculate that at some undetermined additional cycles and load, some types of mixes will eventually completely resist additional compaction so that the rate of compaction becomes zero.

2 - **COMPARISON OF LWT WITH WTT AT 21°C (70°F) AND VARIOUS WHEEL LOADS @ 20,000 CYCLES**

Figure 2 plots our initial comparative LWT and WTT compaction rates of plain and natural latex modified multilayer slurry microsurface. Each set was cast 13mm deep and used 0/#4 Plum Run aggregate, 1% Portland Cement and 11% emulsion. Total average LWT loads were 29,49,97 and 144 lbs. While the WTT total loads were 67 and 155 lbs. The tests were run for 20,000 cycles at 21°C (70°F).

The most obvious variation is in the difference in amount of compaction, vertical displacement, or resistance to compaction between the unmodified and natural latex modified mixes, tabulated as follows:

	Average Compaction Rate mm/1000 cycles	
CYCLES	PLAIN	MODIFIED
0-1000	1.17	.86
4000-8000	.09	.04
8000-20,000	.04	.02
Track Depth	2.38mm	1.27mm
% Compaction	18.3%	9.7%

Latex modification appears to resist compaction by a factor of 2. Note that the plain emulsion specimen failed at 8000 cycles with at 5mm track depth (38.5% displacement and a .80mm/1000 rate) while the latex modified LWT was perfectly intact at 20,000 cycles at 2.3mm track depth (17.7% displacement and .034mm/1000 rate).

However, a most troublesome variation was observed with large differences between the LWT and WTT Track depths at similar loads, the LWT results being much more severe than the WTT. Though each wheel was about the same width (30-32mm), the WTT wheel gave a perfectly flat contact "foot print". While the LWT wheel was rounded at the edges so that the initial contact width was much smaller so that 1 to 2mm track depth was necessary for the wheel to be fully supported by the sample.

Though the trends are comparable, there can be no reasonable equivalencies or correlation here between the LWT and WTT results until the wheels are identical in dimension and properties (see appendix).

3 - EFFECT OF LAYER THICKNESS AND ADDED CHIPS ON THE WTT DISPLACEMENT AT 21°C (70°F) - LATEX MODIFIED EMULSIONS

In this experiment, 2 gradations of the Plum Run aggregate (0/#4 + 50% ¼" or 5/7mm chips) were mixed with a natural latex modified emulsion at 11% and 10% respectively and each gradation cast 3/8"and 3/4" (9.5 and 19mm) thick and WTT compacted at 67 lbs. total load at 21°C. Figure 3 plots our results. Note that after 4000 to 8000 cycles:

1) Specimens with 50% added chips has a slightly deeper wheel penetration (due possibly to emulsion richness).

2) The 3/4" samples compacted about twice as much as the 3/8" samples; i.e., track depth was proportional to layer thickness

3) The rate of compaction of the thicker samples was a little more than twice the thinner samples.

BUT

4) The percent compaction or vertical displacement for all samples, regardless of the thickness or gradation was nearly the same (8.0 to 9.5%) or,

5) The difference between specific gravity as cast and as compacted was nearly the same, .14 to .17; rather low values.

4 - EFFECT OF TEMPERATURE, ADDED CHIPS AND MODIFIED EMULSION ON WTT DISPLACEMENT

Two sets of Plum Run 0/#4 (0/#5mm) aggregate + 50% and 63% added 1/4" (5/7mm) chips at 10% and 8% modified emulsion contents respectively were cast in 5/8" (16mm) molds, cured and WTT compacted at 67 lbs. (30 kg) total load for 8000 cycles at 70°F and 115°F (21°C and 45°C).

Figure 4 shows similar results for both plain and modified systems at 21°C as found in figure 3. At these high temperatures of 115°F (45°C) the displacements are alarmingly high at 62.5% for the plain emulsion and 37.5% for the modified system. In the plain system, it appears that the wheel penetrated so deeply that it became supported by the larger chips which were in direct contact with the rigid substrate. Lateral displacements were 25 to 17%. The latex modified specimen performed much better. Emulsion contents may be excessive but it is quite clear that these mixes would be unstable during the hot summer.

5 - EFFECT OF TEMPERATURE AND 2 DIFFERENT AGGREGATE SOURCES ON WTT TRACK DEPTH

Two similar aggregates, Latham (12%, 0/#200) and Plum Run (8%, 0/#200) were each mixed with 1% Portland Cement, 11% plain and latex modified emulsion, cast in 13mm molds, cured and WTT tested for 8000 cycles at 67 lbs. (30kg) and 21°C and 45°C. The results in figure 5 again shows the latex modified systems outperforming the unmodified system by a factor of 2.

It is particularly interesting to note that in the unmodified system, Plum Run aggregate performs much better than the Latham. With latex modification, the reverse is true! Perhaps the Latham's 4% additional 0/#200 helps the increase in displacement or the aggregate latex compatibilities or aggregate chemistry is more favorable for the Latham aggregate.

6 - EFFECT OF CHEMICAL FILLER TYPE (HYDRATED LIME OR PORTLAND CEMENT) PERCENT EMULSION AND TEMPERATURE ON WTT RESULTS. LATHAM 0/#4 AGGREGATE 1% pc - 11% VAE MODIFIED EMULSION

In this experiment, (figure 6) the effectiveness of hydrated lime is less than when Portland Cement is used; i.e., displacements or wheel track depths are greater with lime than with cement. The effect is especially noticeable at higher temperatures. Table 2 tabulates our results. Of special interest is the marked reduction in the 4000-8000 cycles track depth rate.

7 - **<u>EFFECT OF SYNTHETIC POLYMER TYPE ON COMPACTION RATES. SBR AND VAE COMPARED AT 35°C. LATHAM 0/8, 1pc - 11% AE.</u>**

In this experiment comparing two polymers, SBR and VAE, the steady state rate of compaction is reached at 4000 and 1000, 67 lb. (30kg) cycles at 35°C (95°F) and the track depth rates are .11 and .07mm/1000 respectively. Compare figure 9 in Part II, the curves are very similar though the Part II LWT curves were with Latham 0/#4 aggregate with a LWT total load of 97 lbs (44kg) at 21°C.

TROUBLESOME VARIABLES AND UNSOLVED PROBLEMS

Four main problems with both the LWT and WTT traffic simulator remain:

1) Accounting for the large variations in specific gravity of the specimens and field samples as-cast and its effect on mix stability and compaction rates. Figure 8 is a schematic graph of two general cases where high and low specific gravities as cast may affect the compaction rates. Case I shows relatively high, as-cast, specific gravities but may or may not compact to the same density as in Case II where there are low specific gravities as-cast. Low as-cast specific gravities may cause shear failures; skewer the results under the abnormally high loads in these accelerated tests.

2) Sample curing conditions have been found to affect LWT displacements by a factor as much as a 2 when the curing time was 5 days (as shown in figure 9). Georgia DOT's GDT-115, "Method of Test for Determining Rutting Susceptibility Using the Loaded Wheel Tester" (1) requires curing for 7 days at room temperature and for one additional day at test temperature.

   A modest research should be undertaken to determine the best curing method.

3) Standardization of the LWT wheel and tire properties and dimensions to eliminate possible distortion of high initial compaction rates due to roundness of the tread and consequent high initial contact pressures.

4) Correlation of laboratory results with field results so that meaningful test results may be established.

CONCLUSIONS AND SUMMARY

1. In all three parts of this paper it is rather clearly shown that compaction behavior is dramatically affected by varying, even by small amounts, the various mix components. Once again, we find that **"EACH SYSTEM IS ITS OWN THING"**.

Among the variables tested, all of which affect compaction rates are:

(a) AGGREGATE GRADATION, either continuous or gap graded
(b) chemical filler (cement) content
(c) aggregate voids
(d) slurry voids as-cast and compacted
(e) emulsion pH
(f) bitumen quality or source
(g) aggregate quality or source
(h) wheel loading
(i) number of cycles run
(j) type of test machine: LWT or WTT
(k) wheel contact area
(l) TEMPERATURE
(m) percent emulsion or bitumen
(n) layer thickness
(o) POLYMER PRESENCE, TYPE

2. In all cases of these accelerated tests, there is an initial high rate of displacement or compaction followed by a stabilized or constant rate of compaction.

3. The number of cycles run to reach a steady-state rate of compaction and the ensuing steady-state-rate under the given conditions are important compaction characterization factors.

4. High temperatures have the greatest affect on compaction rates.

5. Polymer systems outperform plain, non-polymer systems by a factor of at least 2.

6. Aggregate gradation and fines contents and qualities have a large influence on compaction rates.

7. Future experiments are planned to:
   (a) Standardize the test methods
   (b) Investigate effects of aggregate gradation
   (c) Correlate the accelerated tests with real world axle loads and contact areas
   (d) Investigate affects of type and quantity of emulsifier, additives, and polymer at high temperatures.
   (e) Investigate mastic properties and their influence on compaction characteristics.
   (f) Instrumentation to include unattended automatic operation, measurement, recording and computer aided plotting.
   (g) The Triple-Track Wheel Tracking Test machine is preferred because of greater precision, ease of operation and productivity.
   (h) Investigate effects of water saturation and soaking periods.