VERGLIMIT

Experimental Feature
Final Report

Projects OR 83-04 and OR 83-05

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VERGLIMIT SURFACING ON THE SALMON RIVER AND QUARTZ CREEK BRIDGES

INTRODUCTION

Bridge deck icing is a phenomena that Highway Departments and motorists must contend with each winter. The formation of ice on bridge decks as the temperature falls below 0 C (32 F) creates a particularly treacherous condition. Since much less heat is stored in the deck than in the ground, the deck can ice while the rest of the roadway is clear. When this occurs, unwary drivers may approach these bridges at unsafe speeds.

Verglimit is the proprietary name for a multi-component defroster that is added to the asphalt concrete wearing surface. It is a specifically conserved and activated defroster compound which is released in small quantities by the traffic induced abrasion. Verglimit, which is produced in Germany, has been primarily used in Europe. In view of the favorable reports from Europe, it was decided to test it on two bridges in Oregon that are known to have icing problems.

Test Sites

The Salmon River Bridge in Clackamas County, approximately 12 miles east of Sandy on the Mount Hood Highway and the Quartz Creek Bridge in Clatsop County, approximately 47 miles northwest of Portland on the Sunset Highway were selected to receive Verglimit modified asphalt concrete overlay. It was estimated that the Salmon River Bridge would require 470 tons of Verglimit modified asphalt concrete and the Quartz Creek Bridge would require 270 tons.

CONSTRUCTION

Mix Design

The mix design was the same for both structures and was provided by the Materials Laboratory using aggregate from Baker quarry, #34-80-1, and stockpile gradations supplied by field personnel. The design had 31 percent coarse aggregate (3/4 - 1/4), 58.5 percent fine aggregate (1/4 - 0), 5 percent sand and 5.5 percent Verglimit. The recommended gradation, including the Verglimit was:

TABLE I
MIX DESIGN GRADATION

Sieve Size	Percent Passing
3/4	100
1/2	87
3/8	77
1/4	66
10	32
40	16
200	5.0

The asphalt to be used was AR4000W with a penetration of 79 and 0.5 Pave Bond Special as an additive. The recommended asphalt content was 6.0 percent. The design voids were 1.1 percent at 100 percent compaction.

Placement of Overlays

Prior to placement of the overlays, membrane waterproofing was installed on both structures. The overlay placement was relatively routine with the following points being noted.

	Quartz Creek Br.	Salmon River Br.
Date of paving	9/15/83	9/16/83
Tons placed	220.3	401.32
Mix temp. at placement	275 F (135 C)	260 F (127 C)
Verglimit added *	5.5%	5.3%
Air temperature	58 - 80 F (14 - 27 C)	50 - 60 F (10 - 16 C)

The overlays were compacted with 10-ton rollers until they were smooth in appearance. A standard class "C" mix was used to feather the ends of the overlays. The structures were then sanded, rolled, and opened to traffic.

* Calculated from a sack count at the plant.

Sampling and Test Results

During placement of the overlay, samples were taken and submitted to the Materials Laboratory for testing. On October 28, 1983 both overlays were cored (1 core each) to determine compaction. The nuclear density gage was not used since the overlays were too thin (approximately 1 1/2 inches). A minimum of 2 inches is required for accurate results from the gage. Skid data on both structures was taken on August 12, 1983, before paving, and September 22, 1983 after paving, for comparative purposes. The test results are tabulated in Table II.

Table II

Tests	Quartz Cr.	Salmon Rvr.	Specification
No. of samples	4	6	
Gradation, percent passing			
3/4	99	100	95 - 100
1/2	88	86	81 - 93
1/4	66	64	66 +/- 6
4	55	52	
10	32	31	32 +/- 4
40	13	15	
200	1.8	2.6	5.0 +/- 2
Asphalt, percent	5.85	5.3	5.5 +/- .5
Verglimit, percent (1 test)	5.4	4.5	5.5 +/- .5
Moisture, percent			
sealed samples	0.31 (1 sample)	0.32 (3 samples)	0.70 max
unsealed samples *	1.53	1.48	
No. of passing samples	0 of 4	1 of 6	
Compaction samples - 1 core each side			
thickness	1.5	2.2	1.5 min
percent compaction			
field estimate	87.7	87.4	(see discussion)
lab results	87.5	82.6	
voids, percent **	12.5	17.4	
Skid data			
before overlay (8/12/83)	39	47	
after overlay (9/22/83)	59	58	

* uncompacted samples were hydrophilic when exposed to air

** far in excess of the manufacturer's recommendation of 4 percent max

PERFORMANCE

Approximately one week after placement of the overlays, both bridges were tested to determine the effectiveness of the membranes. The Quartz Creek Bridge had a low electrical resistance reading indicating that the deck was not fully protected from chlorides. The Salmon River Bridge was found to be in excellent condition.

Quartz Creek Bridge

The first inspection was on November 3, 1983, approximately seven weeks after paving. There was some minor raveling in the wheel tracks and spalling had begun at several joints. In January 1984, it was necessary to extensively patch the Verglimit overlay. On February 1, 1984 the bridge was again inspected and it was noted that approximately 20 percent of the eastbound lane had been patched because of raveling. There were many more areas in both the eastbound and westbound lanes where more raveling had occurred after the patches were placed.

The Verglimit appeared to be effective in melting snow and reducing the formation of ice on the deck, however, the extensive raveling exposed much more of the Verglimit additive than would be intended.

In September 1984, a contract was let to remove the remaining Verglimit modified asphalt concrete, replace the membrane and place a new overlay on the deck using a conventional "B" mix.

Salmon River Bridge

During the period October 17 - 21, 1983, one month after paving, deck joints were installed and the overlay appeared to be in good condition. The first freezing weather occurred on or about November 1, 1983. On November 23, 1983, deterioration of the overlay was first noted. By November 28, 1983, the pavement was severely deteriorated and there were areas where the membrane waterproofing was exposed.

On December 15, 1983, the entire eastbound lane was covered with a one inch lift of commercial asphalt concrete.

In September 1984, a contract was let to remove the remaining Verglimit modified asphalt concrete, replace the membrane and place a new overlay on the deck using a conventional "B" mix.

DISCUSSION

Even though the two test sections failed prematurely, there is ample evidence that the material did reduce icing and snow on the decks. This is the desired result and bears out the experiences of others with the product. The premature failure of the overlay can be attributed to the failure of the materials to meet the specifications (Appendix A) and the failure of the specifications to adequately address the manufacturer's design and construction criteria (Appendix B).

The laboratory data (Table I) indicates the mix was deficient in passing #200 material and/or asphalt. Either condition increases the design voids at 100 percent compaction and makes placement of a dense overlay such as that required for a Verglimit modified mix, difficult, if not impossible, regardless of the compactive effort expended. The compaction results obtained from the cores indicate that the overlay void content was 3 to 4 times greater than the manufacturer's recommendation, a condition that virtually guarantees ravelling of the overlay.

The skid numbers showed a significant increase after placement of the overlay. The amount of increase could be significantly less if proper void content had been realized.

The project specifications failed to adequately address several of the manufacturer's design and construction guidelines. Failure to note these specific points may have affected the overlay performance.

The Quartz Creek and Salmon River Bridges have an ADT of 4,000 and 6,000, respectively, and are both located in areas of studded tire use during the winter season. The guidelines given for the Verglimit addition level is "as low as 3.5 percent on a site with very heavy traffic and a high percentage of studded tires" (10,000 ADT) or, "as high as 7.5 percent with very little (300 ADT) and slow (30 km/hr, 19 mph) traffic" with "the common addition rate being 5.5 to 6.5 percent". Serious consideration should then be given to using a semi-log approach (see Appendix C) to estimating the Verglimit addition level. If this is done, an addition rate of 4 percent for 6,000 ADT and 4.5 percent for 4,000 ADT would be recommended rather than the 5.5 percent used on both structures.

For many small jobs such as these, the only aggregate available is from commercial stockpiles. Historically, the gradations of these stockpiles is, at best, sketchy. To design a critical mix, such as the Verglimit modified asphaltic concrete, requires extensive sampling from stockpiles that would be reserved for the production of the special mix. Failure to get a representative gradation would result in mix design stockpile proportions that may not be appropriate for the actual material reserved for production. This is a condition that could result in a final product that cannot be compacted to meet the minimum compaction requirements.

Assuming that a mix can be produced that can be compacted to meet the compaction requirements, one further item needs consideration. Compaction is very dependent on temperature. Not only must the mix come from the asphalt plant within the proper temperature range, it must reach the job site and be placed and ready for the breakdown rollers with enough heat remaining in the mix to achieve proper compaction. The haul distance determines to a great extent the amount of heat that will be lost by the mix in transit to the job site. If the haul distance is so great that heat-loss prevention techniques would not allow placement of the mix at the proper temperature, then other alternatives, such as using a portable plant at the job site, should be considered.

The mix design did not meet the manufacturer's guidelines in as much as the recommended asphalt content was not bracketed and the design mix placement temperature was 280 F (138 C) instead of the recommended 284 F (140 C) behind the paver. (The actual placement temperature was much lower.) Bracketing of the mix design asphalt content may result in a more suitable mix with a higher asphalt content thus making it easier to obtain the recommended void content. The manufacturer's guidelines state that "the temperature of the mix behind the paver must be at least 284 F (140 C). The specifications say that the mix temperature at the time it is spread shall be "within the 240 F (115 C) to 300 F (150 C) range" and "be as designated by the engineer". Since temperature is so important to compaction and to the performance of the Verglimit, a value of 284 - 300 F (140 - 149 C) at laydown is recommended to help insure optimum compactability. Failure of any load to meet this condition should result in rejection of the load.

Compaction specifications for these jobs were not adequate. With the extremely critical void content of between 3 and 4 percent, special rolling requirements, placement requirements and density measurement methods should be treated in detail.

The design and construction notes supplied by the manufacturer are very specific about how joints and porous spots are to be handled and should be so addressed in the specifications.

CONCLUSIONS

The Verglimit modified asphalt concrete did provide snow and ice control during the short time it was intact. The premature failure of the overlay can be attributed to the problems previously discussed and in view of these, the probability of getting a successful test was very small. Consequently, Verglimit modified asphalt concrete should not be judged on the basis of this demonstration project.

RECOMMENDATIONS

If a future demonstration project using Verglimit is undertaken, the following recommendations are offered for consideration.

1. Place the overlay on a section of roadway, in a snow zone, so that in the event of a failure, the membrane would not have to be replaced.

2. Place the overlay early in the summer so that the weather conditions are optimum for laydown and so that the overlay has longer to "cure" before the snow season.

3. Pay particular attention to the mix design and stockpile gradations so that the proper amount of asphalt and fines will be obtained in the mix.

4. Provide for expansion joints and pavement dams to be placed immediately after compaction is completed.

5. Specify a 2 inch minimum thickness so that accurate in-place densities can be determined during placement, using a nuclear gage.

6. Use the minimum amount of Verglimit that is practical for the ADT at the site.

7. Pay particular attention to the longitudinal joints and treat them according to the manufacturer's instructions.

APPENDIX A

Specifications

SECTION 403 - ASPHALT CONCRETE PAVEMENT

Asphalt concrete pavement with Verglimit additive shall be constructed in conformance with Section 403 of the Standard Specifications supplemented and/or modified as follows:

Delete subsections 403.11 and 403.12 of the Standard Specifications and add the following new subsections 403.11, 403.12, 403.13, 403.14, 403.15, 403.16 and 403.17.

403.11 Classes of Asphalt Concrete and Proportions of Materials - This specification provides for the following class of asphalt concrete.

Sieve Size Passing	Class "B" Percentages of Total Aggregate (by weight)
1"	100
3/4"	95-100
1/2"	81-93
1/4"	52-72
No. 10	21-41
No. 40	8-24
No. 200	2-7
Asphalt Cement	4-8*
Verglimit	5-6*

*Percent of total mix (by weight).

403.12 Asphalt Cement, Verglimit and Additives - The asphalt cement shall be a viscosity or penetration graded asphalt, with the understanding that any one of the grades is to be used at such times and under such conditions as determined by the engineer.

Antistripping additives required for strength retention shall be added to the mix as determined by the engineer.

Asphalt cement and antistripping additives shall meet the applicable requirements of Section 702 of the Standard Specifications. The use of silicones as an additive to asphalt cement will not be permitted.

Verglimit additive is a chemical multicomponent de-icer available from the following source:

PK Innovations
466 Burlington St. East
Hamilton, Ontario, Canada L8L 4H9
Tel. (416) 528-7023

403.13 Composition of Mixtures and Proportions of Materials - The asphalt concrete mixture shall be composed of aggregate, mineral filler if required, asphalt cement, Verglimit and additives if required, intimately combined in the proportions specified for the type of asphalt concrete mixtures involved as such are given herein. Specified aggregate proportions are given in percentages of the weight of the total aggregates.

At least 15 days prior to producing any of the mixture for use in the asphalt concrete pavement, representative samples of acceptable materials proposed for use in the mix shall be furnished to the engineer for use in determination of the proportions of each of the several constituents to be used in the mixture. The proportions so determined shall be known as the "job mix formula" and shall be changed only upon order of the engineer. No mixture will be accepted for use until the "job mix formula" for the project is determined.

The materials to be used in the work shall be of such nature that a mixture of them, proportioned in accordance with the "job mix formula", will have a retained strength of not less than 70% when tested in accordance with OSHD 308.

403.14 Job Mix Formula and Tolerances - After the job mix formula is determined as prescribed in subsection 403.13, the several constituents of the mixture and the temperature of the mixture at the time it is placed in final position shall conform thereto within the following tolerances, but always within the range of proportions specified in subsection 403.11:

Constituent of Mixture	Tolerance (Plus or minus to job mix formula)
Aggregate passing 1", 3/4", 1/2" and No. 40 sieves specified in subsection 403.11.	Within the range of the proportions specified in subsection 403.11
Aggregate passing 1/4" sieve . . .	6.0%
Aggregate passing No. 10 sieve . .	4.0%
Aggregate passing No. 200 sieve. .	2.0%
Asphalt cement	0.5%
Verglimit	0.5%
Temperature of mixture at time it is placed in final position .	20°F

403.15 Acceptance of Materials:

(a) Aggregates - Aggregates produced according to subsection 403.16 will be subject to acceptance as they are produced and stockpiled.

If the contractor wishes to produce coarse and fine aggregates in sizes other than those stated in subsection 403.16, he shall so request in writing to the engineer. The target value and tolerances for each of the individual sieve sizes of the materials the contractor proposes to produce must be documented by contract change order.

(b) Asphalt concrete mixture - Acceptance of the mixture will be based on job control sampling and testing by State field personnel and by the Division's Engineering Lab as follows:

1. For each 100 tons of mix placed, State field personnel will determine asphalt cement content from tank stickings, weighings or metering and determine Verglimit content by weighing or counting empty sacks.

2. Field personnel will provide the Lab with 15-20 lb. samples of mixture taken randomly from the road or trucks for each 100 tons of mixture placed. The Lab will determine aggregate gradation compliance and run check tests on asphalt cement and Verglimit content.

403.16 Aggregates - Delete the provisions of subsection 703.08 of the Standard Specifications and substitute the following:

Aggregates for the asphalt concrete pavement shall conform to the following:

(a) General - During production of aggregates, samples of each size shall be provided as frequently as the engineer may consider expedient to determine conformance to requirements. On the basis of testing, the contractor shall modify or adjust his crushing and screening operations as necessary to bring the materials within quality requirements, gradings, proportions and quantities of each separate size as specified herein.

The determination of sizes and gradings shall be as set forth in OSHD 204.

(a-1) Fracture of gravel (OSHD 213) - If crushed gravel is furnished, 60 percent (by weight) of the material retained on each designated sieve 1/4" or larger and 50 percent (by weight) of the material retained on the #10 sieve shall have at least one fractured face produced by mechanical crushing.

(a-2) Plasticity (OSHD 103) - Aggregates passing the 1/4-inch sieve shall meet the plasticity index requirements set forth in subsection 703.07(d) of the Standard Specifications.

(a-3) Soundness - The crushed aggregates shall not have a weighted percentage of loss of more than 18% when subjected to five alternations of the sodium sulfate soundness test (OSHD 206).

(a-4) Durability - The crushed aggregates shall meet the following test requirements:

Test	Test Method	Requirements
Coarse Aggregates		
Degradation		
Passing No. 20 Sieve	OSHD 208	30% Max.
Sediment Height	OSHD 208	3" Max.
Abrasion	OSHD 211	30% Max.
Fine Aggregate		
Degradation		
Passing No. 20 Sieve	OSHD 208	30% Max.
Sediment Height	OSHD 208	4" Max.

(a-5) Deleterious substances - The amount of deleterious substances in each test fraction of the crushed aggregate material shall not exceed the following:

Test	Test Method	Percentages (by weight)
Lightweight Pieces	OSHD 222	1.0 Max.
Wood Particles	OSHD 225	0.1 Max.
Friable Particles (Coarse Aggregate)	OSHD 221	2.0 Max.
Friable Particles (Fine Aggregate)	OSHD 221	3.0 Max.

The aggregates shall be reasonably free from all other deleterious substances such as soft or disintegrated pieces, clay, loam or vegetative matter, either in a free state or as a coating on the stone.

(b) Coarse aggregate - That portion of the aggregate retained on a 1/4-inch sieve will be known as coarse aggregate and shall be crushed rock or crushed gravel. The coarse aggregate shall contain not more than 5 percent (by weight) of flat elongated pieces having a dimension greater than twice the maximum screen size for the specified grading.

(b-1) Separated sizes - Coarse aggregate for the asphalt concrete mixture shall be produced and stockpiled in either the 3/4" - 1/4" size or the 3/4" - 1/2" and 1/2" - 1/4" sizes at the contractor's option.

(c) Fine aggregate - That portion of the aggregate passing the 1/4-inch sieve shall be known as fine aggregate and shall consist of finely crushed rock or finely crushed gravel, fine sand and other finely divided mineral matter.

Fine aggregates for the asphalt concrete mixtures shall be produced and stockpiled in either the 1/4" - 0 size or the 1/4" - #10 and #10 - 0 sizes at the contractor's option.

403.17 Mineral Filler - Mineral filler shall meet the requirements of subsection 703.15.

403.31 Weather Limitations - Delete subsection 401.31 of the Standard Specifications and substitute the following:

403.31 Weather Limitations - Asphalt concrete mixtures shall be placed on dry prepared surfaces when the air temperature in the shade and the surface temperature is 50°F or above. However, the engineer may permit the contractor to begin paving work if the temperature is 45°F or above and rising and in the judgment of the engineer will be 50°F in a reasonable period of time. Placing of any mixture during rain or other adverse weather conditions normally will not be permitted, except that mix in transit at the time these adverse conditions occur may be laid if of proper temperature, if the mix has been covered during transit, if placed on a foundation free from pools or flow of water and if all other requirements of these specifications are met.

403.33 Bituminous Mixing Plant - Delete 401.33(c) of the Standard Specifications. The mixing plant used on the project shall be a batch type plant.

The mixing plant used shall conform to the requirements of subsection 401.33 of the Standard Specifications and the following modifications thereto:

Truck Scales - Delete subsection 401.33 (a-10) of the Standard Specifications and substitute the following:

(a-10) Truck Scales - Each pay load of bituminous mixture shall be weighed on vehicle scales meeting the requirements of subsection 109.02 except as follows:

When vehicle scales meeting the requirements of subsection 109.02 are available for check weighing, the contractor, upon written approval of the engineer, will be permitted to use either an approved automatic printer system as provided in subsection 401.33 (a-1) or an approved weigh hopper that is accurate to 0.5 percent. Use of these methods of determining pay weights will be discontinued when random check weighings indicate that the quantities are not accurate to 0.5 percent. Each load of mixture shall have a weigh ticket provided by the automatic printer system or by a Division provided weighperson. The Division provided weighperson will not be involved in any way in the production of materials or the loading of contractor's vehicles. The contractor shall be responsible for any additional costs resulting from the use of these weigh methods.

403.34 Hauling Equipment - After each application of an approved coating material, and prior to loading, the vehicle bed shall be drained of all excess coating material by raising the truck bed, opening belly dump gates or operating the conveyor belt as appropriate for the type of equipment being used.

403.40 Heating Bituminous Cement - Delete the last paragraph of this subsection in the Standard Specifications and substitute the following:

The temperature of the asphalt cement upon entry into the mixture shall be not less than 250°F nor more than 350°F.

403.43 Hauling, Spreading, Finishing and Temperature Control - Contrary to the provisions of subsection 401.43 the temperature of the mixture at the time it is spread into final position shall be as designated by the engineer within the 240°F to 300°F range.

The moisture content of the mixture at the time it is spread into final position shall not exceed 0.7 percent.

When placing asphalt concrete pavement in layers of 2 inches or less in thickness is being performed under traffic, work shall be scheduled in a manner such that at the end of each working shift one strip of new travel lane pavement shall not extend ahead of the adjoining strip of travel lane pavement more than the distance normally covered by each shift.

Prior to any suspension of operations for a period of one day or more, the full width of the pavement shall be completed to the same elevation with no longitudinal dropoffs within this width. The transverse dropoff at the end of each strip shall be feathered out as directed by the engineer.

Where abrupt dropoffs occur within or at the edge of the paved surface the contractor shall provide suitable warning signs as required under "Temporary Protection and Direction of Traffic".

Transverse construction joints shall be cut back to good material and squared up prior to proceeding with paving operations.

The intermingling of asphalt concrete mixtures produced from more than one job mix formula is prohibited.

403.44 Compaction - Compaction shall be performed in conformance with the requirements of subsection 401.44 of the Standard Specifications except:

403.44 Compaction - Compaction to the specified density requirements will not be required on this project. In lieu thereof, compacting of the asphalt concrete mixture shall conform to the following:

The asphalt concrete mixture in the base course and leveling course shall be compacted with rollers conforming to the requirements set forth under subsection 401.36 of the Standard Specifications and having a minimum gross weight of 10 tons. The rolling shall continue until the entire surface has been compacted by at least four coverages of the roller and, unless otherwise directed by the engineer, shall be completed within 15 minutes after the mixture has been spread and struck off by the paver. Additional rolling shall be performed as necessary to attain thorough consolidation of the mixture.

403.81 Measurement - The quantities of asphalt concrete mixtures shown in the Bid Schedule were computed on the basis of aggregates having a specific gravity of 2.75. When the contractor notifies the engineer what source is to be used in production of aggregates for asphalt concrete mixture the engineer will recompute the quantities of the mixtures required based on the specific gravity of the aggregates to be used. The pay quantities of the various classes of asphalt concrete mixtures may be adjusted accordingly with no adjustment in contract unit prices.

403.91 Payment - Add the following new pay item:

Pay Item	Unit of Measurement
Verglimit Additive	Ton

Antistripping additives will be paid for at the contractor's actual documented costs with no percentage allowance or mark-up allowed.

SECTION 407 - ASPHALT TACK COAT

The asphalt tack coat shall be constructed in conformance with Section 407 of the Standard Specifications supplemented and/or modified as follows:

407.32 Application Method and Rates - Normally, the asphalt shall be applied to the prepared surface at a rate within the range of 0.06 - 0.10 gallons per square yard, the actual rate to be as directed by the engineer.

APPENDIX B

Construction Criteria

Appendix B

DESIGN AND CONSTRUCTION NOTES FOR ANTI-ICING PAVEMENTS CONTAINING VERGLIMIT

In general, the locally prevailing design, specifications and procedures are used for the mix design and construction of VERGLIMIT pavements. The details given below cover those aspects requiring special attention. Any questions concerning these notes should be directed to Verglimit SA or their local representative.

I. COMPOSITION AND DESIGN OF MIX

1. Basic Mix Without VERGLIMIT

The mix design starting point is always the usual design for dense-graded surface mixes, which is based on local experience and specifications. The most suitable mix which would be specified for the site if no VERGLIMIT was incorporated should be selected. Recommended is a dense-graded asphaltic concrete with a high content of coarse aggregate which provides a high macro texture (10 mm to 18 mm. minus 7/16" - 3/4"). For the selection of aggregates and asphalt cement (bitumen) and the composition of the mix (gradation, asphalt cement content) the conditions of the site and the local climatic conditions (alignment, gradient, elevation, exposure, traffic density, traffic speed, number of trucks, studded tires, etc.) must be considered.

2. Modification of Basic Mix: VERGLIMIT Addition Level

VERGLIMIT additions are typically given in terms of total weight of mix (aggregate + asphalt cement + VERGLIMIT = 100%). The most common addition rate is 5.5-6.5%. It can be as low as 3.5% on a site with very heavy traffic and a high percentage of studded tires (10,000 vehicles with 100% studded tires) or as high as 7.5% on a small site with very little (300 cars) and slow 30 km/h (18 mph) traffic. The size of the particles ranges from minus 0.1 mm to plus 5.0 mm. The specific weight is 1.8 g/cm^3, i.e. 5% of VERGLIMIT has a volume of about 7% in the mix. During incorporation of VERGLIMIT and during the construction of the pavement a portion of the VERGLIMIT particles is crushed, which results in a somewhat higher content of the finer aggregate. This makes the following modifications of the basic mix necessary.

3. Gradation

To compensate for VERGLIMIT addition, the sand and screenings content up to 5 mm (#4) in size has to be reduced by weight, in accordance with the VERGLIMIT addition rate.

4. Filler Content (Fines)

In order to avoid an unwanted hardening of the binder ratio of filler to asphalt cement in the VERGLIMIT mix should not exceed 1.7 to 1 by weight.

5. Asphalt Cement Content

It should be noticed, that VERGLIMIT has a higher volume than the aggregate and that it is a little porous. Therefore, the asphalt cement content of the usual mix (basic mix) must be raised by 0.1 to 0.3% by weight. It remains unchanged for any mix which is high in asphalt cement content.

6. Method for Mix Design

The mix design test methods normally adopted should be followed. The Marshall method has been found to be appropriate when VERGLIMIT is incorporated. The VERGLIMIT must be added cold, as the last item (i.e. after asphalt cement mixed in) during the preparation of the mix prior to compaction. Addition of the VERGLIMIT about 15 seconds before the end of mixing has been found suitable with satisfactory coating being achieved. Marshall briquettes and any mix should be cooled and stored in a desiccator with a drying agent to avoid the absorption of moisture. The weighing under water for density estimation and the 60 degree C. (140 degree F.) water storage, which is done before the actual Marshall stability test, do not cause any problems. During vacuum saturation of mix for maximum density determination, testing times must be kept as short as possible. (Leaching of VERGLIMIT during this test does not appear to influence the results.) It is recommended that different compaction efforts (2 x 50 blows (low) as well as 2 x 75 blows (high)) be used. By this method the potential compaction induced by high traffic volumes can be estimated. VERGLIMIT favors the compaction characteristics of the mix. The density is increased and the Marshall stability changes accordingly. The results of these tests should be discussed with Verglimit SA or representative.

7. Air Voids of the Test Briquettes

- The air voids of the Marshall test briquettes should be adjusted according to the placement site and should be within the following limits:

- 1.5 2.5% for pavements with little traffic, located considerably above sea level, in the shade or other extreme conditions or if they carry traffic with studded tires.

- 2.0 - 3% for pavements with a high traffic volume and exposed to the direct influence of sunshine.

The control tests done with the mix taken from the plant should show only very little difference to this data.

II. MIX PREPARATION AT PLANT

1. Careful Mixing

The design composition of the mix (gradation, filler, asphalt cement and VERGLIMIT content) has to be followed very carefully.

2. Handling of VERGLIMIT

It is equally important to a) handle VERGLIMIT with care in order to keep the crushing of the VERGLIMIT particles as low as possible; b) use the least mixing necessary to ensure that all VERGLIMIT particles are totally covered with asphalt cement.

3. Storage of VERGLIMIT

VERGLIMIT is delivered in 25 kg (55 lb.) polyethylene bags and must be stored in a dry place. To avoid undesirable absorption of moisture, the sacks should not be opened before they are emptied into the mix.

4. Screening -- Important: Sacks must not be thrown into mix.

To eliminate occasional lumps, the sacks must be emptied over a sieve with openings of approximately 20 mm by 20 mm (3/4 in. x 3/4 in.). The openings of the (screen) sieve should not be too small or the flow of material is interfered with.

5. Protection of Personnel

The workers that are in direct contact with the VERGLIMIT particles must wear goggles and gloves. Depending on the working conditions, it is recommended that the workers wear protective breathing masks. (See remarks on the sacks). Contact with the skin must be avoided.

6. VERGLIMIT Addition

VERGLIMIT must be added continuously and loosely into the pug-mill. The apparatus for the addition must be constructed in such a way that each batch can be added in no less than 5 (to ensure homogeneous distribution in the mix) and no more than 10 (to avoid cracking) seconds. If a batch mixer is used the following systems have been proven successful:

a) addition directly into the pug-mill through a hopper or via a conveyer belt. Whenever possible VERGLIMIT should be added in complete sack units only, which means that the batch weight must be adjusted accordingly. When using a hopper a lock-gate is appropriate because that way the hopper can always be filled again while the mixing process takes place.

b) addition directly over the filler scale. This method is favorable if there are 2 filler scales at the pug-mill. When using this process it is particularly important to make sure that VERGLIMIT is added gradually (not all at once, minimum 5 seconds) and is not exposed to the air for a long period of time.

*auger systems are to be avoided because they might lead to a considerable amount of cracking of the VERGLIMIT particles. If they have to be used the auger should not be longer than 2 m (2.2 yds) and should only be used for horizontal transportation. Under no circumstances it may be heated with the aggregate.

7. Time for VERGLIMIT Addition

All aggregates, including the fines, must be in the pug-mill first. Then the addition of the asphalt cement is started. After a minimum of 1/3 of the asphalt cement is added, the VERGLIMIT addition can be started and it should be finished at approximately the same time as the asphalt cement addition is completed.

8. Final Mixing Time

The mixing time after all components including VERGLIMIT have been added should only be long enough that the VERGLIMIT particles are adequately coated with asphalt cement. This can be easily checked by looking at the mixed batch. No white particles should be visible after mixing. It has been found that the total mixing time usually remains unchanged from normal procedures. If due to plant constraints the asphalt cement and VERGLIMIT cannot be added at the same time, the basic mix including the asphalt cement is mixed properly first. Then the VERGLIMIT is in the mix, the additional mixing time should not exceed 15 seconds.

9. Mixing and Storage Temperatures

The mixing temperature depends on the type of asphalt cement. The respective norms must be observed. A mixing temperature of 165 to 170 degrees C (329 to 338 degrees F) must not be exceeded at any time since the mix might otherwise become like a mastic asphalt (Bituminous mastic concrete) in character. If the mix is stored in heated/insulated silos this temperature must not be exceeded either. (It should be noted that the temperature in silos with a capacity above 50 tons can increase by some degree due to exothermic oxidation processes without supplying any further heat to the mix from the outside.)

III. PLACING AND COMPACTION

1. Basic Rules

Placing and compaction characteristics are not significantly different between a mix with or without VERGLIMIT, but the influence of placing and compaction defects are more severe since

the VERGLIMIT particles can absorb moisture in a badly compacted surface course. To obtain good wearing results for the VERGLIMIT surface, and to avoid defects due to water penetrating into the pavement, the notes given below should be observed. The following 3 points are of particular importance:

-in order to avoid water penetration into the uncompacted surface placing must not be done during rain and rollers must be used without water.

- the supporting pavement surface should be free of cracks, smooth and as dense and closed as possible. The air voids content of the compacted VERGLIMIT surface must be between 3 and 4%

- longitudinal joints, construction joints and porous spots are very critical to performance and must be treated as follows:

a. Supporting Pavement Surface

Surfaces being paved over must fulfill the usual requirements for smoothness, freedom from cracks and impermeability. Wide cracks will reflect through when a thin overlay of 3 to 4 cm (1 in. - 1.5 in.) thickness is applied as they do when normal mixes are used. Therefore, the surface being paved over should be given a proper cleaning and preparation, or even a new profile if necessary. The supporting pavement surface must be dry and free of dirt and dust. The surface being paved over should be pre-coated with 300 to 500 g per square meter (10 oz to 1 lb per square yard) of suitable cationic emulsion or 150 g to 300 g per square meter (5 oz to 10 oz per square yard) of a water-free tack coat in order to obtain a proper bond between the old and the new layer.

2. Weather

VERGLIMIT surfaces should be placed in dry and warm weather only. The air temperature should not be lower than 10 degrees C (50 degrees F) and the supporting pavement surface should be dry. All placing has to be avoided during rain.

3. Pavers.

The same general conditions and specifications for placing a regular mix are applicable. Use only pavers with high pre-compaction screed capabilities operated at the highest compaction settings in order to obtain a smooth, closed surface. If there are still some porous spots visible behind the paver, they have to be filled with some additional mix before the first roller passes. Inclines should always be paved uphill. If the width of the road varies, the use of pavers with hydraulically movable extensions is recommended.

4. Hand Work

Hand work must be kept to an absolute minimum, and must be avoided in the wheel paths. Porous areas and those being placed by hand must be sealed with a suitable emulsion-filler sealant before they are opened to traffic.

5. Longitudinal Joints

If possible, the whole width of the road should be placed in one pass with a single paver. Otherwise two pavers should be operated in tandem to avoid cold longitudinal joints. When this is impossible, careful longitudinal joint compaction is necessary. If the longitudinal joint is placed cold (edge of first paver path cold, new path hot), the necessary uncompacted height of the mix has to be calculated (screed must be elevated sufficiently above the surface of the first paver path). A tack coat and/or infra-red heating of the cold joint is required. (Alternatively, a melting joint tape can be used.) It is strongly recommended that the joint be sealed to a width of 15 cm (6 in.) th same day. This is mandatory if the joint is a little porous.

6. Construction Joints and Edges

VERGLIMIT pavements must not be feathered down during construction. A full, sawn joint is required. The edges and the sawn joint must be clean and treated with tack coat. (If feathering must be adopted due to construction constraints, this must be done with regular mix). The most suitable working method is to start and end placing with plain mix (minimum of one truckload) and to continue with VERGLIMIT-mix without a transition. This way not only the construction joints are safe but also a possibility is provided to run the pneumatic-tired roller hot before it is operated (as the first roller) on the VERGLIMIT-mix.

7. Sealing of Critical Parts

All construction joints, contacts, porous parts, sides and edges are to be sealed the same day in order to keep water from penetrating into the surface. This will prevent potential ravelling of those areas.

8. Pavement Thickness

The thickness of a VERGLIMIT pavement should at no point be less than 2.5 times the minimum size of the coarsest aggregate in the mix.

9. Placement Over Concrete

If VERGLIMIT pavement is placed over concrete without a sufficient asphaltic concrete base course in between, the joint location for the concrete has to be carefully referenced to permit necessary surface cuts later on.

10. Air Voids

Compaction of the mix is the governing performance factor for the pavement, in terms of stability and durability (Suitable calibrated nuclear gauges can be used for overall compaction control.) The voids content of the pavement of drilled cores must under no circumstances exceed:

- average of 4%
- individual value of 5%

A desirable voids content between 3 and 4% should be the goal (while water can be used during core drilling, the use of special, denatured alcohol minimizes any water influences). For any VERGLIMIT-addition rate lower than 5.5%, the voids content of the pavement should not be very much lower than 3% since otherwise the effectiveness during winter might be affected. On the other hand the voids content of the pavement must not exceed 4% since otherwise water may penetrate into the pavement which can result in damage to the pavement. Local destruction always indicates an insufficient compaction in that area. The later in the year the pavement is placed, the more important the strict observation of this rule becomes, because in cold weather the pavement cannot be benefitted from the traffic induced compaction.

11. Compaction Techniques

To avoid unwanted cooling of the mix, but more importantly to keep water from penetrating into the uncompacted surface, no water should be used at rollers (i.e. rolling to be hot and dry). If unavoidable, steel-wheeled rollers may be moistened but not wetted. Pneumatic-tired rollers have to be driven dry, or if absolutely necessary to avoid sticking, a very light oiling can be used.

12. Placing Temperature

The placing temperature depends on the type of asphalt cement used as required by local specifications. The temperature of the mix behind the paver must be at least 140 degrees C (284 degrees F) when using an asphalt cement with a penetration of 80, for instance.

13. Recommended Rollers

The contractor is free to select and combine the proper rollers as long as he achieves the required compaction in terms of specified air voids (3 to 4%; section III-10). Experience indicates that a sufficient compaction can be achieved if the following rollers are operated directly behind the paver:

- pneumatic-tired roller (minimum of 2 ton wheel load; hot and

dry) to obtain a quick closing of the surface, then steel-wheeled roller (minimum 12 tons).

- if a vibratory roller is used the surface should be closed by a static steel-wheeled/pneumatic-tired roller afterwards.

14. Maintenance of the Pavement after Placing

To improve the skid resistance properties of the new pavement clean crushed sand or screening free of fine (0 to 3 mm size) should be rolled in during the last roller passes on the warm surface (minimum of 90 degrees C (194 degrees F) at a rate of approximately 1 kg/m^2. (2 lbs/sq yard). During compaction, the VERGLIMIT particles in the upper 1 to 3 mm of the surface have been crushed, which results in increased VERGLIMIT activity at the beginning and a rich surface appearance. This effect can occur until the asphalt cement on the exposed coarse aggregate is worn off by traffic, which might take - depending on the traffic volume and speed - from 2 to 6 weeks. This surplus of VERGLIMIT should be washed off with a large surplus of water for several days using high pressure units. This way the carryover of the VERGLIMIT to the adjoining pavement can be stopped. If during dry days the VERGLIMIT activity is too high, washing should happen again. Once the pavement is worn in, washing is no longer necessary. Treatment will normally only be required in high speed or traffic conflict situations where year round high skid resistance is required. Verglimit SA or representative should be contacted for advice if there are any questions concerning these procedures. Temporary speed reduction signs are also advised. Generally speaking VERGLIMIT surfaces do not need any maintenance. During the winter period they are integrated into the normal ice control program. Any extra runs can normally be saved. If the surface at the beginning of the winter is still closed by oil or rubber residues, it can be treated with rotating steel brushes. After the VERGLIMIT in the upper mm of the pavement has dissolved, most surfaces look rough. The appearance is similar to that of a ravelling surface. By inspecting the pavement edges it is easy to find whether it is actually a loss of aggregate or the normal appearance. If there is a loss of aggregate this is due to insufficient asphalt cement quality or content or due to insufficient compaction as on any normal pavement. This rough appearance is slowly compensated for a great deal by the traffic. But it always remains a bit rougher to a comparable normal pavement, which is beneficial for the long term skid resistance properties.

IV. CONTROLS

General quality controls are to be completed by the contractor and/or owner. The use of a desiccator to store any samples containing VERGLIMIT (cores and mix before and after extrusion for example) should be noted again. Care must be taken at all times to avoid moisture absorption.

Mix samples and drilled cores are to be supplied to Verglimit SA or representative for supplementary analyses and control (all to be hermetically sealed:

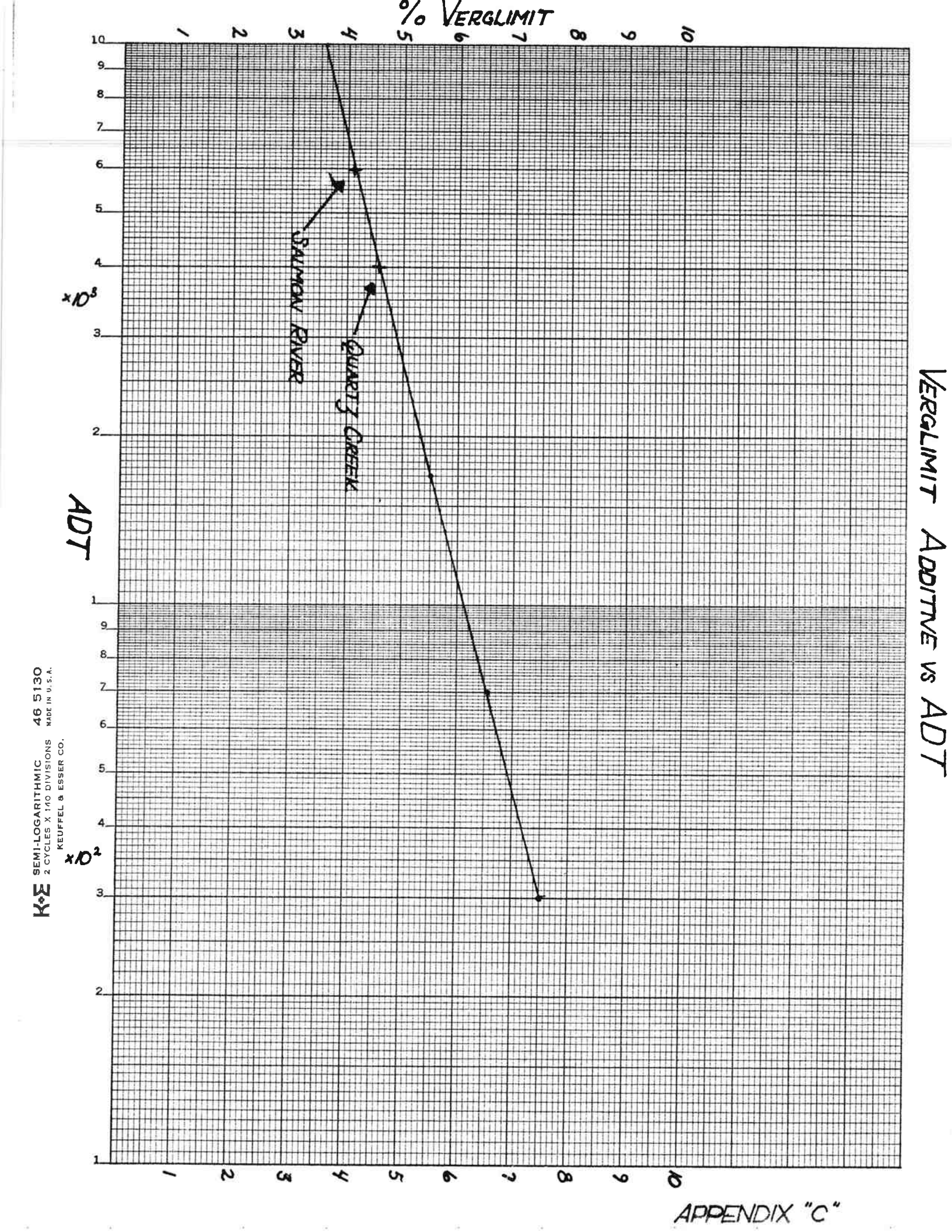
- one 15 kg. (30 lb) sample of normal mix without VERGLIMIT
- one 15 kg. (30 lb) sample per 200 tons of VERGLIMIT containing mix
- at least three cores per VERGLIMIT site.

VERGLIMIT SA, GENEVA

APPENDIX C

Semi-log Plot

Verglimit Additive vs ADT


% VERGLIMIT
ADT
SALMON RIVER
QUARTZ CREEK
VERGLIMIT ADDITVE VS ADT
APPENDIX "C"
SEMI-LOGARITHMIC 46 5130
2 CYCLES X 140 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.