BRIDGE DECK WATERPROOF MEMBRANE EVALUATION

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FINAL REPORT

By

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16. Abstract

Bridge deck membranes are used to prevent corrosion of reinforcing steel in bridge structures. Recent failures of the asphalt pavement overlaying these membranes prompted this study to evaluate the performance of waterproofing membranes.

Test results proved inconclusive in this study. Field studies indicate that overlaying the membranes with four inches of asphalt pavement have helped prevent membrane failures.

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EXECUTIVE SUMMARY

Bridge deck waterproofing membranes are used to prevent corrosion of the reinforcing steel in bridge structures. Recent failures of the asphalt pavement overlaying these membranes prompted a study to evaluate the bonds between the waterproofing membranes, the bridge decks, and the pavement. Five preformed waterproofing membranes were tested.

The membranes tested for this research were *Bituthene 5000, Bituthene Highway and Bridge (H & B), Polyguard 665, GeoTac,* and *Petrotac. Bituthene 5000, GeoTac, Polyguard 665* and *Petrotac* were on the 1993 Alaska Approved Products List (APL). *Bituthene Highway and Bridge (H & B)* had been conditionally approved on a project by project basis for the 1993/94 construction season. Although *Protecto Wrap M400A* and *Royston Bridge Membrane* are on the 1993 Alaska Approved Products List (APL), they were not tested since at the time of testing these products had never been used in Alaska.

Bituthene 5000, Bituthene H & B, and *Polyguard 665* are rubberized asphalt with polypropylene geotextile membranes. These three membranes rely on the hot asphalt pavement to melt the rubberized asphalt to bond with the bridge deck and penetrate the geotextile and bond with the pavement. *Bituthene 5000* has a surface tack coat, whereas *Bituthene H & B* and *Polyguard 665* require application of a tack coat prior to

paving. *GeoTac* and *Petrotac* are modified bitumen with non-woven polyester geotextile membranes. Tack coat is required with both of these membranes.

This research project consisted of field evaluations of selected bridges to determine if bonding had occurred between the bridge decks, waterproof membranes, and asphalt pavement overlays. In addition, shear and pull-out tests were developed to attempt to quantify the bond strengths between the membrane and the concrete bridge deck and the asphalt pavement overlay. The shear and pull-out tests were conducted under varying conditions to evaluate the effects that deck preparations (sandblasting vs. powerwashing), temperature of asphalt pavement (225°F, 250°F, and 275°F), and temperature of bridge (35°F, 45°F, and 55°F) has on the bonding characteristics of the membranes.

The results of the shear test developed as part of this research project to simulate the shear stresses placed on the membrane are not conclusive. Using a consistent texture on the surface of the concrete cylinders may yield more consistent and conclusive results.

Recommendations from this research are:

1) The waterproof membrane should be covered with four inches of pavement. This will reduce the shear stresses on the membrane and allows for future pavement surface rehabilitation without damaging the existing membrane.

2) Continue development of the membrane shear test procedure by testing samples

with cylinders with the same surface texture.

3) R*oyston Bridge Deck Membrane No. 10* requires asphalt application temperatures between 290°F and 340°F. The minimum application temperature is greater than the asphalt mix temperature of 280°F to 290°F normally used for AC-5 asphalt binder. Due to the temperature requirements of this membrane it is recommended that it be removed from the 1993 APL. *Royston Bridge Deck Membrane No. 10* revised its minimum asphalt application temperature from 290°F to 250°F for 1996 and it has been approved for the 1996 APL.

4) *Protecto Wrap M-400 A* membrane requires that the maximum aggregate size of the asphalt pavement be ½ inch. This membrane could only be used with Type III asphalt, therefore, it is being recommended that this membrane be removed from the 1993 APL and be used on a conditional basis for projects that would meet these special asphalt mix requirements. *Protecto Wrap M-400 A(R)* is a new membrane. The manufacturer's have revised the maximum aggregate size of the asphalt pavement from ½ inch to ¾ inch. *Protecto Wrap M-400 A(R)* was added to the 1996 APL and is currently being used in by the Department.

INTRODUCTION

Bridge deck waterproofing membranes are used extensively throughout Alaska in bridge structures. The membranes are used to prevent water and de-icing salts from penetrating the concrete and corroding the embedded reinforcing steel. There are several types of membranes available. Preformed waterproofing membranes are the only type currently used in the State of Alaska. Spray on liquid waterproofing membranes have been used on a limited basis in the past.

On older bridge structures, membranes were the primary form of corrosion protection for the reinforcing steel. On newer structures, epoxy coating of the reinforcing steel now provides additional corrosion protection. Membranes are usually overlaid by a minimum of two inches of asphaltic concrete.

Historically, some of the preformed membranes have failed to bond to either the asphalt overlay or the concrete bridge deck. Pavement and/or membrane failures have become more prevalent in the last several years. The primary objective of this research project was to determine causes of the bond failures of the pavement and membrane, and identify potential measures to prevent future failures. Several factors which may effect the bond of the membranes with the bridge deck and asphalt pavement are:

1. Change in asphalt mix designs (see Table I for Asphalt Mix Design Standards) - Before 1991, Type II (¾ inch minus aggregate) hot asphalt pavement was commonly used for most roads. From 1991 to 1994, the hot asphalt pavement for roads with high ADTs (Average Daily Traffic counts) was changed to Type I (1 inch minus aggregate) asphalt mix which generally has larger voids between the larger aggregate that decreases the bonding surface area between the asphaltic concrete and the membrane

TABLE 1
BROAD BAND GRADATIONS FOR ASPHALT CONCRETE PAVEMENT AGGREGATE
Percent Passing by Weight

Sieve Designation	Gradation Designation		
	Type I	Type II	Type III
1 inch	100	-	-
3/4 inch	75-90	100	-
1/2 inch	60-86	75-90	100
3/8 inch	50-78	60-88	75-90
No. 4	34-62	44-72	50-78
No. 8	24-52	30-58	32-60
No. 16	16-42	20-44	20-45
No. 30	10-32	12-34	12-34
No. 50	8-24	8-24	8-24
No. 100	5-16	5-16	4-15
No. 200	3-8	3-8	3-8

2. The time of year work is performed - Typical construction season in Alaska is May 1 to October 30. Bridge work is done all summer so that bridge decks are usually ready for the membrane placement and pavement in the fall. When colder temperatures (below 40°F) and rain or snow are not uncommon during membrane placement and paving operations.

3. The introduction of new products - For many years the primary preformed membrane used in Alaska was *Bituthene 5000.* Currently there are six different preformed waterproofing membranes listed on the State of Alaska, Department of Transportation and Public Facilities (DOT/PF), 1993 Approved Products List (APL). The membrane section of the 1993 APL can be found in Appendix A. In addition, one membrane produced by W.R. Grace and Company, *Bituthene Highway & Bridge Membrane* was conditionally approved and used during the 1993/94 construction season.

4. Use of membranes only over girder joints - The use of epoxy coated rebar resulted in membranes only being required over the girder joints to protect field welded seams. The difference in the textures of the membrane and the concrete deck, may be creating different horizontal shear strengths in the asphaltic concrete overlay.

5. Significant increases in traffic equivalent axle loads (EALs).

6. The effects of drainage on the bridge deck - Field observations indicate that once the bridge overlay starts to ravel and pothole, water ponding amplifies the effect of potholing and failure spreads more rapidly.

7. Asphalt mix temperatures decreased with the use of AC-5 asphalt cement which is better suited for asphalt pavements in cold climates. Since the mix

temperature is only 280°F to 290°F, the temperature of the asphalt mix when it is placed on the membrane is only 230°F to 270°F. This is significantly cooler than asphalt mix using an AC-20, AC-30, or AC-40 which is more commonly used in the continental United States.

This research project examines the effects of ambient temperatures, climatic conditions (snow and rain), asphalt laydown temperatures, and deck preparations on membranes; and the actual performance of different membranes. This information will be used to help determine acceptable products for the 1997 APL, and establish construction procedures.

MEMBRANE DESCRIPTIONS

The preformed waterproofing membranes considered for this research project initially consisted of the six membranes listed on the 1993 Approved Products List and *Bituthene H & B Membrane* that was conditionally approved for the 1993/94 construction season. Only five of the seven membranes were selected for testing.

1. *Protecto Wrap M-400 A* - Cold applied bridge deck waterproofing membrane manufactured by Protecto Wrap Company is a rubberized asphalt with fiberglass mesh membrane. This membrane requires an ambient temperature above 40°F

or the use of a cold weather primer, a maximum aggregate size of the asphalt pavement of ½ inch, asphalt application temperatures between 275°F and 300°F, and that no tack-coat is used for paving. Since this membrane requires a maximum aggregate size of the asphalt mix of ½ inch, it could only be used with Type III asphalt. This membrane was not tested because at the time of testing it had never been used in Alaska and the relatively high application temperature makes it unfeasible to use with AC-5 asphalt cement. It is being recommended that this membrane be removed from the 1993 APL. *Protecto Wrap M-400 A(R)* is a new membrane that has been approved for the 1996 APL. The manufacturer has revised the maximum aggregate size of the asphalt pavement from ½ inch to ¾ inch for this membrane.

2. *Bituthene 5000 Waterproofing System* manufactured by Grace Construction Products is a rubberized asphalt with polypropylene mesh membrane coated with an asphalt tack. This membrane requires an ambient temperature of 40°F, the use of *Bituthene P-3000* primer, minimum 1 ½ inch asphalt overlay, asphalt mix temperatures between 250°F to 300°F in the "hopper" and no tack-coat prior to paving. This membrane was tested.

3. *Royston Bridge Deck Membrane No. 10* manufactured by Royston Laboratories, Inc. is a modified bitumen with non-woven polyester geotextile membrane. This membrane requires the use of *Royston 713A* primer with an ambient temperature above 45°F and the use of *Royston 740* low temperature primer with an ambient temperature between 25°F and 45°F, minimum 1 ½ inch

asphalt overlay, and asphalt application temperatures between 290°F and 340°F. Since the minimum application temperature is greater than the asphalt mix temperature of 280°F to 290°F normally used for AC-5 asphalt binder, this membrane was not tested and removal from the 1993 APL is being recommended. This membrane has not been used for the last six years. *Royston Bridge Deck Membrane No. 10* revised its minimum asphalt application temperature from 290°F to 250°F for 1996 construction season and it has been approved for the 1996 APL.

4. *Petrotac* manufactured by Phillips Fiber Corporation is a modified bitumen with non-woven polyester geotextile membrane. This membrane requires an ambient temperature of 70°F if no primer is used. If the temperature is below 70°F, *Henry's Petrotac Primer* or *Fields 400 Asphalt Primer* should be used; a minimum overlay thickness of 1 ½ inches; a maximum asphalt application temperature of 300°F, no minimum asphalt application temperature is indicated in the product literature; and a tack-coat prior to paving. This membrane was selected for testing. There is no record of this product being used for the six years prior to the testing, but it has been used since this testing.

5. *GeoTac* manufactured by Contech Construction Products, Inc. is a modified bitumen with non-woven polyester geotextile membrane. This membrane requires an ambient temperature of 50°F; has no minimum asphalt pavement temperature requirements; a minimum 1 ½ inch overlay; and no tack-coat is required prior to paving. This membrane was selected for testing.

6. *Polyguard 665 Membrane* manufactured by Polyguard Products, Inc. rubberized asphalt with polypropylene mesh membranes this membrane requires an ambient temperature of 40°F or above, has no minimum asphalt pavement temperature requirements and a maximum asphalt pavement application temperature of 300°F, a minimum 2 inch overlay, and a tack-coat prior to paving. This product was selected for testing.

7. *Bituthene Highway & Bridge (H&B) Membrane* manufactured by Grace Construction Products is a rubberized asphalt with polypropylene woven membrane. This membrane requires a minimum ambient temperature of 40°F; use of *Bituthene P-3000* primer or concrete conditioner; minimum 1 ½ inch asphalt overlay; asphalt application temperatures between 250°F to 325°F in the "hopper"; and tack-coat prior to paving. According to the manufacturer this membrane is the same as the *Bituthene 5000* with the exception that the woven geotextile is not coated with tack. This membrane was selected for testing.

FIELD APPLICATIONS

Membranes have been installed in Alaska for more than twenty years. Table II summarizes some recent field applications of bridge deck waterproofing membrane, and the problems and construction procedures associated with them.

Table II
Preformed Waterproof Membrane Installations

Year	Brdg. No.	Project No. & Name	Type of Const. (new or rehab)	Membrane Used	Pavement Thickness (in)	Pavement Type	Remarks	Contact
1993	1711	Little Su Brdg@ Schrock	rehab	Bituthene 5000	2"	Type II	Joints only, No tack, Concrete primer used	Niemic
1993	255	Chulitna R4 Bridge	rehab	Bituthene H & B	2.5"	Type II	Joints only, Tacked full width	Sorenson
1993	672	Moose River, Sterling	rehab	GeoTac	2"	Type I	Joints only, No tack on membrane	Henderson
1993	1121	Glenn 1-C	rehab	none				D. Falldorf
1993	1885	Glenn 1-C	new	Bituthene H & B	2"	Type I	Failing at expansion joints	D. Falldorf
1993	1888	Glenn 1-C	new	Geo-Tac	1" + 2"	Type III/I	Joints only, Tacked full width	D. Falldorf
1993	1887	Glenn 1-C	new	Geo-Tac	1" + 2"	Type III/I	Joints only, Tacked full width	D. Falldorf
1993	1124	Glenn 1-C	rehab	none	2"	Type II	Tacked full width	D. Falldorf
1993	1889	Glenn 1-C	new	Bituthene H & B	2"	Type II	Failed, rotomilled off & repaved	D. Falldorf
1993	1327	Hiland 3R	new lane	Bituthene H & B	2"	Type IA	Tacked full width	Crohgan
1992	1739	Hiland PhII ER Brid	new	Bituthene 5000	2"	Type II		Wittrock
1991	1600	NERI	new	Geo-Tac	2"	Type II		Henderson
1991	1323	Tudor Rd @ Sew Hwy	rehab	Polyguard 665	2"	Type I	failed within 1 year, replaced 1992	Martinelli
1993	1323	Tudor Rd @ Sew Hwy	rehab	Bituthene 5000	4"	Type I	Several rolls of Bituthene H & B were used	Gault
*	*	Rich Hwy M 288 N	*	Geo-Tac	2"	Type II		
*	496	Little Su Brdg	rehab	Polyguard 665	2"	Type II		Sorenson
1991	*	Rasp. Rd Inter	new	Bituthene 5000	2"	Type II		Wegener
*	*	Nash Rd Repair	rehab	Bituthene 5000	2"	Type II		K. Sun
1976	1161	Chena River	rehab	*	2"	Type II	full width membrane, paver made hole in membrane	Doore
1990	514	Berry Creek	rehab	Polyguard 665	2"	Type II	Joints only, no problems	Pfeffer
1984	558	Lowe River Upper Crossing	rehab	*	2"	Type II	Membrane glued down, no tack	Rasmussen
1984	559	Sheep Creek	rehab	*	2"	Type II	Full width, glued down, no tack	Rasmussen
1993	526	Banner Creek	rehab	Geo-Tac	2"	Type II	Full width, no problems	Pfeffer
1986	1767	Badger Loop UC	new	Vulkem 927	2"	Type II	Joints only, Membrane blistered in hot weather	Shanley
1993	1705	Cushman Street OC	new	Bituthene 5000	2"	Type II	Joints only, No tack under membrane	Shanley
1988	1706	Cushman, N Ramp	new	*	2"	Type II	Joints Only	
1988	1707	W- West Ramp	new	*	2"	Type II	Joints Only	
1993	1912	W-N Ramp	new	Bituthene 5000	2"	Type II	Joints only, No tack under membrane	
1978	231	Chena River	*	*	2"	Type II	Full Width, tacked over membrane let truck pick up	Harnois
1993	1793	Noyes Slough	new	Geo-Tac	2"	Type II	Joints only	
1990	1697	ARR UC	new	Pave Prep	2"	Type II	Joints only, Tacked under membrane	Harnois
1991	1806	Noyes Slough E Ramp	new	Polyguard 665	2"	Type II	Joints only, Tacked under membrane	Harnois
1991	1766	Noyes Slough Main	new	Polyguard 665	2"	Type II	Joints only, Tacked under membrane	Harnois
1991	1807	Noyes Slough W Ramp	new	Polyguard 665	2"	Type II	Joints only, Tacked under membrane	Harnois
1991	1203	Soloman Creek	*	*	2"	Type II	Corrosion failure, attributed to membrane failure	

Prior to 1988 isolated failures had occurred. However, it was not until 1988 that membrane failing to bond to asphalt pavements became more prevalent. Six major failures have occurred from 1988 to 1993. Those failures are: McCarrey Street Overpass (Bridge # 1526), Boniface Interchange Overpass (Bridge #1525), Tudor Road at Seward Highway Overpass (Bridge # 1323), Glenn Highway Southbound Knik River Bridge (Bridge # 1885), Glenn Highway Northbound Knik River Overflow Bridge (Bridge # 1887), and Glenn Highway Southbound Matanuska River Bridge (Bridge # 1889).

Not all installations of bridge deck membranes have resulted in failures. Recent applications that are performing well are Glenn Highway Southbound Knik River Overflow Bridge (Bridge #1888), Little Susitna Bridge at Schrock Road (Bridge # 496), and Chulitna River Bridge (Bridge # 255).

McCarrey Street Overpass (Bridge # 1526) and Boniface Interchange Overpass (Bridge # 1525) McCarrey Street Overpass and Boniface Interchange Overpass were constructed in 1988. *Chevron Industrial Spray-on Membrane* which was allowed by specifications of the project at that time was applied only above the girder joints of the bridge decks. The membrane did not require the use of tack coat. During the paving of McCarrey Street Overpass the hot asphalt mix did not adhere to the membrane. The asphalt mix slid on top of the membrane as soon as the roller started compacting. The pavement on the bridge deck was immediately pushed off, the membrane remained in place, the deck was cleaned, tack coated with CSS-1, and re-paved. With tack coat the hot asphalt adhered to the bridge deck. Tack coated was also applied over the same membrane used on the Boniface Interchange Structure (Bridge #1525). Both bridge decks were overlaid with 2 inches of asphalt.

Immediately after the second paving, the pavement on McCarrey Street Overpass started delaminating and potholing. The pavement deteriorated so rapidly, that it was necessary to remove the remaining pavement from the deck. *Bituthene 5000* was then applied to McCarrey Street Overpass and overlaid with 2 inches of asphalt. This pavement has performed satisfactorily since then.

The failure of the second pavement on McCarrey Street Overpass was attributed to bond failure of the membrane as well as failure of the asphalt pavement. According to interviews with the project manager, the resident engineer, and the paving inspector the asphalt mix contained clumps of silt as large as pieces of aggregate. A new materials source was found and was used to produce the remainder of the hot asphalt mix for the project including the mix used to repave McCarrey Street Overpass the third time and to pave Boniface Interchange Overpass.

The pavement on Boniface Interchange Overpass developed problems in the left turn lanes that were attributed to bond failure of the membrane. The asphalt in the turn lanes began to shove and pothole. Failure areas on Boniface Interchange were repaired by removing the asphalt and membrane, applying tack coat, and repaving. Repairs were performed at the same time as McCarrey Street but the membrane was never replaced. As of April 1994, pavement distress, potholing and shoving, is visible on Boniface Interchange, especially in the left hand turn pockets. At the present time

McCarrey Street is not showing signs of pavement distress.

Tudor Road Overpass (Bridge # 1323) In 1991, the Tudor Road at Seward Highway Overpass needed a new waterproofing membrane after the original *Bituthene 5000* membrane was damaged during pavement removal. The damaged membrane was removed with a great deal of effort using a G-14 grader and weed burners. Areas of the concrete bridge deck that were damaged during rotomilling were repaired with epoxy grout. *Polyguard 665* membrane was applied, and the bridge was overlaid with 2 inches of Type I (1 inch minus aggregate) asphalt mix.

Within 6 months the pavement in the left hand turn pockets was shoving and potholes developed. This pavement failure was attributed to delamination between the pavement and the membrane.

The following construction season, weather prohibited installation of new membrane, the turn lanes were patched and the entire bridge was overlaid with 2 inches of Type I (1 inch minus aggregate) asphalt mix, leaving the existing membrane in place. In the spring of 1993, the pavement was rotomilled off, the *Polyguard 665* membrane was removed, *Bituthene 5000* (for 95% of the deck) and *Bituthene H & B* (for 5% of the deck) membranes were placed and the bridge was overlaid with two 2 inch lifts of Type I (1 inch minus aggregate) asphalt. Both membranes were used on this bridge since not enough *Bituthene 5000* was available to complete the work during the available time frame. As of September 1996, there was no signs of shoving or potholing in the asphalt over the bridge deck.

Glenn Highway Northbound Knik River Overflow Bridge (Bridge # 1887) Glenn Highway Northbound Knik River Overflow Bridge was overlaid in the fall of 1992 with 2 inches of Type I (1 inch minus aggregate) asphalt. Eighteen inch wide strips of GeoTac over the girder joints and was tack-coated with CSS-1 prior to paving.

By spring of 1993, the asphalt was shoving and potholing near the expansion joints at both ends of the bridge. To repair the driving surface, the pavement was rotomilled, leaving the membrane in place and repaved with 1 inch of Type III (½ inch minus aggregate) asphalt mix and then 2 inches of Type I (1 inch minus aggregate) asphalt mix. The pavement on the Knik River Overflow Bridge is currently in good condition and is showing no signs of pavement distress.

Glenn Highway Southbound Matanuska River Bridge (Bridge # 1889) Glenn Highway Southbound Matanuska River Bridge was overlaid in the fall of 1992 with 2 inches of Type I (1 inch minus aggregate) asphalt. *Bituthene H & B* membrane over the entire deck and was paved without tack coat in accordance with the manufacturer's recommendations.

By spring of 1993, the asphalt was shoving and potholing near the expansion joints at both ends of the bridge. To repair this bridge, the pavement and membrane were rotomilled off and the bridge was tack-coated with STE-1 and repaved with 2 inches of Type II (¾ inch minus aggregate) asphalt mix. The Matanuska River Bridge is currently in good condition and is showing no signs of pavement distress.

Glenn Highway Southbound Knik River Bridge (Bridge # 1885) Glenn Highway Southbound Knik River Bridge was overlaid in the fall of 1992 with 2 inches of Type I (1 inch minus aggregate) asphalt. *Bituthene H & B* membrane was placed over the entire deck.

By spring of 1993, the asphalt was shoving and potholing near the expansion joints at both ends of the bridge. Due to time constraints only the potholes on this bridge were patched and the entire deck was not reconditioned during the 1993 construction.

By the fall of 1995 the pavement on this bridge had deteriorated to the extent the entire right-hand lane of the bridge was repaired. Repair involved removing the remaining asphalt, membrane, applying STE-1 tack coat, and re-paving. A project is currently being designed to remove the asphalt and the membrane in the lefthand lane of this bridge and re-pave. This should be completed in the 1997 construction season.

Glenn Highway Southbound Knik River Overflow Bridge (Bridge # 1888) The Glenn Highway Southbound Knik River Overflow Bridge had 18 inch wide strips of *GeoTac* membrane placed over the girder joints and was tack-coated prior to paving with 1 inch of Type III (½ inch minus aggregate) mix then 2 inches of Type I (1 inch minus aggregate) mix. This bridge is a high volume roadway (ADT 15,000). This bridge is currently in good condition and is showing no signs of pavement distress.

Little Susitna Bridge at Schrock Road (Bridge # 496) The Little Susitna Bridge at Schrock Road has *Bituthene 5000* with 2 inches of Type II (¾ inch minus aggregate) mix. This bridge is mainly subject to local traffic. The pavement on this bridge was inspected in the spring 1994 and found to be performing well.

Chulitna River Bridge (Bridge # 255) The Chulitna River Bridge has *Bituthene H & B* membrane that was applied with concrete conditioning agent on the southbound lane and *Bituthene P-3000* primer on the northbound lane. The membrane was tack coated with CSS-1 prior to paving. A 2 ¼ to 2 ½ inch Type II (¾ inch minus aggregate) asphalt pavement overlay was placed on the membrane.

During the paving of the southbound lane the tack coat over the membrane was sticking to the tires of the end dumps. Cement powder was sprinkled over the tack coat to prevent the tires from sticking to and picking up the membrane. Two and one half inches of asphalt pavement was then placed over the cement.

The manufacturers representative was contacted. They recommended that a primer be applied to the other side of the bridge deck prior to placement of the membrane. The primer was used to increase the bonding between the concrete bridge deck and the membrane. *Bituthene P-3000* primer was used in the northbound lane. Cement was not needed for paving the northbound lane.

Chulitna River Bridge does not have high traffic volumes (ADT 840), but does have a relatively high EAL (EAL for 2005, 703,000) due to truck traffic from Anchorage to Fairbanks. The pavement on this bridge was inspected in the September 1996 and found to be performing well.

Summary With the exception of McCarrey Street, all of these failures have been on high traffic volume roadways (+ 15,000 ADTs). The problem areas tend to begin where the pavement experiences the greatest horizontal shear forces from braking or at the expansion joints, resulting in the shoving of the pavement. Failure locations for Boniface Interchange and Tudor Road Bridge were in the left hand turn pockets. Horizontal stresses are higher in turn pockets due to the continuous stopping, starting, and turning of vehicles. In all cases water ponding in potholes accelerated the degradation of the asphalt.

FIELD EVALUATION

Pavement cores were taken on several bridge decks to see if bonding between the pavement and the membrane was occurring. These bridge decks were also inspected for signs of pavement distress and potholing.

Hiland Phase II, Eagle River Bridge (Bridge #1739) Cores indicated that there was bonding between the membrane, *Bituthene 5000*, and the asphalt. The asphalt on this bridge is performing well. Minor signs of pavement distress were noticed shortly after paving, the distress has not advanced.

North Eagle River Interchange (Bridge # 1600) Cores indicated there is bonding between the asphalt and *GeoTac* membrane. The asphalt on the bridge is performing well except at the expansion joints where a wedge was filled to correct a bump that developed the first year after being opened.

Chulitna River Bridge (Bridge # 255) Six cores were taken from the southbound lane. Two cores were taken from the area where the membrane was picking up with the truck tires, and four from the areas where the cement had been sprinkled over the membrane to prevent trucks from picking up the membrane. The asphalt application temperatures for two cement area cores were 225°F and 215°F. These temperatures are at or below the minimum temperature required by the specifications for compaction. All six cores indicated good bonding between the bridge deck, membrane, and asphalt.

Four additional cores were taken from northbound lane. Three out of four of these cores showed good bonding between the bridge deck, membrane, and asphalt. The remaining core membrane failed to bond to the asphalt, but was bonded to the concrete. The asphalt application temperature of this core was 252°F. Table III summarizes the ten cores taken on the Chulitna River Bridge.

The pavement on Chulitna River Bridge is in good condition and showing no signs of pavement distress.

Table III
Chulitna River Bridge Coring Summary

Core No.	Lane	Asphalt Laydown Temp.	Concrete Bond	Asphalt Bond
1	South	*	yes	yes
2	South	*	yes	yes
3	South	*	yes	yes
4	South	*	yes	yes
5	South	225	yes	yes
6	South	215	yes	yes
9	North	252	yes	no
10	North	263	yes	yes
11	North	245	yes	yes
12	North	*	yes	yes

* Information not available

SHEAR TEST

A shear test procedure was developed to determine the bond between the pavement and the membrane and the membrane and the concrete deck. The effects of bridge deck temperatures, surface preparations, and asphalt application temperatures on selected membranes were evaluated.

The membranes were placed on 6 inch concrete cylinders in accordance with the manufactures recommendations. Two inches of Type II (¾ inch minus aggregate) asphalt mix was compacted on top of the membrane. Three samples of each selected membrane were tested at each asphalt application temperature (225°F, 250°F, and 275°F) and each of the concrete cylinder temperatures.

Since bridge construction in Alaska is generally done during the spring and summer, bridge decks are usually not ready for membrane application and paving until late summer or early fall. Concrete cylinder temperatures of 35°F, 45°F, and 55°F were used to evaluate the effects of temperature of the bridge deck on membrane installation.

To ensure that the concrete cylinders had stabilized at the appropriate test temperatures the concrete cylinders were placed in the University of Alaska, Anchorage's (UAA) cold room for a minimum of 48 hours. Then 12 samples at a time would be transported to the State of Alaska's Material Laboratory where they would be placed in a cold box. Three samples at a time would then have the membranes and asphalt applied and then were returned to the cold box. When all 12 sample were complete, they would be returned to UAA's cold room for an additional 72 hours. The same procedure was followed when removing the samples for testing.

To determine the shear strength of the bonds between the concrete and the membrane and the membrane and the asphalt, the specimens were placed horizontally in a bracket. A load was applied to the pavement portion of the specimen until the asphalt sheared off the concrete cylinder (Figure 5). Displacement and load were measured. Loading was done at a strain rate of 0.25 inches/minute.

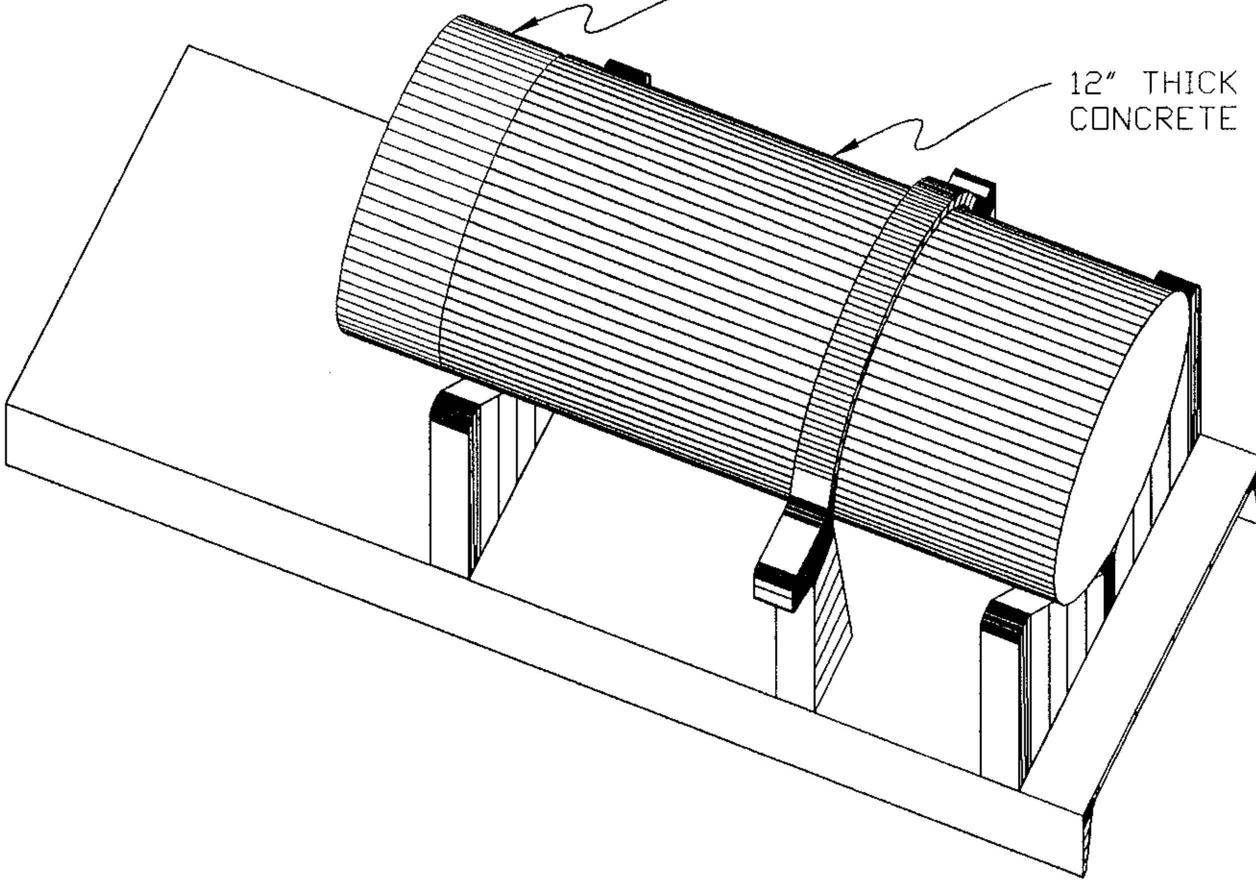

FIGURE 5

Shear stress and strain were calculated for each sample for the maximum load. Shear stress was calculated from the following formula:

Shear Stress = Load/Sample Area

Sample area for all samples was 28.27 square inches. Strain was calculated from the following formula:

Strain = Displacement/Sample Diameter

Charts 1-3 in Appendix B summarize the results of shear strength vs. asphalt mix temperatures for 35°F, 45°F, and 55°F concrete cylinders, respectively. The test results to not yield any noticeable trends, therefore, the test results are inconclusive.

Charts 4-6 in Appendix B summarize the results of shear strength at .005 in displacement vs. asphalt mix temperatures for 35°F, 45°F, and 55°F concrete cylinders, respectively. The test results to not yield any noticeable trends, therefore, the test results are inconclusive.

Charts 7-9 in Appendix B summarize the results of shear strength vs. concrete cylinder asphalt mix temperatures for 225°F, 250°F, and 275°F concrete cylinders, respectively. The test results to not yield any noticeable trends, therefore, the test results are inconclusive.

Charts 10-12 in Appendix B summarize the results of shear strength at .005 in displacement vs. concrete cylinder asphalt mix temperatures for 225°F, 250°F, and 275°F concrete cylinders, respectively. The test results to not yield any noticeable trends, therefore, the test results are inconclusive.

The shear test results were not consistent with field performance. One factor that may have affected the shear test results was the roughness of the concrete cylinders. Based on the shear tests there was no single membrane that performed consistently better or worse that the other membranes. However, the shear tests did indicate that the bond failure occurred between the membrane and asphalt for the *GeoTac* and the *Petrotac* membranes and generally occurred between the concrete cylinder and the membrane for the *Bituthene 5000, Bituthene H & B* and *Polyguard* membranes.

SHEAR TESTING FOR SANDBLASTING AND POWERWASHING

Some membranes were delaminating from the asphalt and some from the concrete. To determine if better bonding between the membrane and concrete could be obtained by using different deck preparation techniques additional shear testing was done to simulate sandblasting and power washing of the concrete decks. These methods were chosen since portable sandblasters and power washers are readily available and therefore, feasible for construction projects. Samples were shear tested at a control temperature of 45°F and a hot asphalt pavement application temperature of

250°F.

The membranes that showed a tendency to delaminated from the concrete were retested with the deck preparation methods. *Bituthene 5000, Bituthene H & B,* and *Polyguard 665* were the membranes that tended to delaminate from the concrete. Since *Bituthene 5000* and *Bituthene H & B* are similar membranes, where the only difference is that *Bituthene 5000* has a tack coat applied to the woven geotextile, only the *Bituthene 5000* and *Polyguard 665* were tested.

Although the test results simulating the sandblasted concrete deck were higher than power washing but they were within the accuracy of error based on the initial testing. A summary of test results are presented in Charts 16 and 17 in Appendix B and complete test results can be found in Appendix C.

PULL-OUT TESTING

A pull-out test was used to determine the tensile bond strength between the asphalt overlay and the membrane. This test was done in accordance with ASTM C-900 using a PROCEQ Dyna Z15 Pull-off Tester manufactured by SDS Company. The test is performed by applying a tensile force to a metal disk attached with epoxy to a cored asphalt section measuring the force required to separate the pavement core from the membrane and concrete (Figure 6).

PULL-OUT TEST

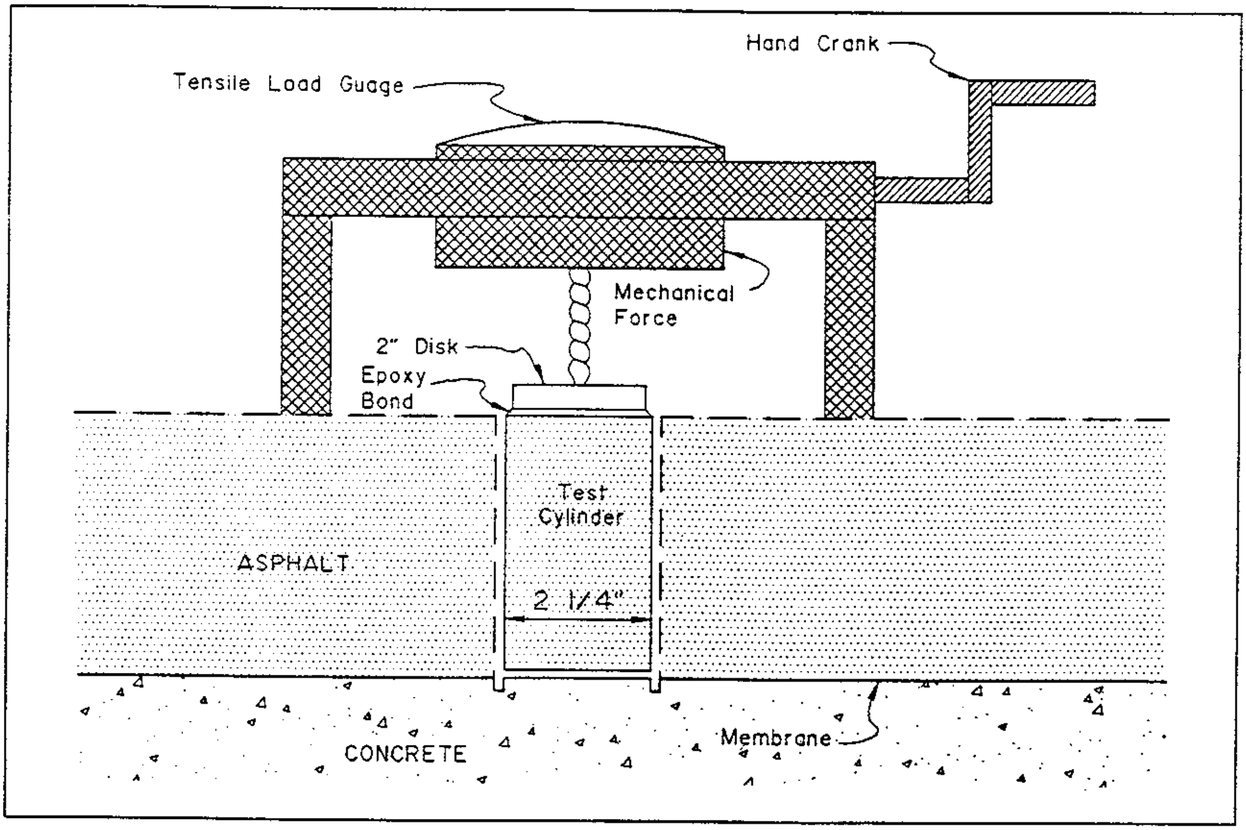

FIGURE 6

Test is run to determine tensile strength in membranes.

Test results indicate that tensile strengths tend to increase with asphalt application temperatures and ambient temperatures. Tensile strengths did not vary significantly between the membranes tested. Charts 13-15 in Appendix B summarize Pull-out Test results and complete test results are in Appendix C.

CONCLUSIONS

1) Failures of the bridge deck overlays using waterproof membranes that consist of rubberized asphalt and polyproplyene woven geotextile have occurred on high volume roads. Failure generally starts in left turn pockets where shear forces exerted on the asphalt pavement are the greatest or the lowest part of the bridge deck where water can accumulate. The bridges that have been repaired and overlaid by more than 2 inches of asphalt pavement have performed well and, to date, are showing no signs of distress. By using more than a 2 inch overlay, the shear stresses on the membrane are reduced and the thicker pavement allows future pavement rehabilitation of pavement milling and repaving to occur without damaging the existing membrane.

2) The results of the shear test developed as part of this research project to simulate the shear stresses placed on the membrane are not conclusive. Using a consistent texture on the surface of the concrete cylinders may yield more consistent and conclusive results.

RECOMMENDATIONS

1) The waterproof membrane should be covered with four inches of pavement. This will reduce the shear stresses on the membrane and allows for future pavement surface rehabilitation without damaging the existing membrane.

2) Continue development of the membrane shear test procedure by testing samples with cylinders with the same surface texture.

3) The manufacturers recommendations for *Royston Bridge Deck Membrane No. 10* require asphalt application temperatures between 290°F and 340°F. The minimum application temperature is greater than the asphalt mix temperature of 280°F to 290°F normally used for AC-5 asphalt binder. This membrane was not tested. Due to the temperature requirements of this membrane it is recommended that it be removed from the 1993 APL. *Royston Bridge Deck Membrane No. 10* revised its minimum asphalt application temperature to 250°F and it has been approved for the 1996 APL.

4) *Protecto Wrap M-400 A* membrane requires that the maximum aggregate size of the asphalt pavement be ½ inch. This membrane could only be used with Type III asphalt, therefore, it is being recommended that this membrane be removed from the APL and be used on a conditional basis for projects that would meet these special asphalt mix requirements. *Protecto Wrap M-400 AR* is a new membrane that was

added to the 1996 APL and is currently being used in by the Department.

SYMBOLS AND DEFINITIONS

AASHTO - American Association of State Highway and Transportation Officials.

ADT - Average Daily Traffic - indicates the average volume of vehicles that travel a particular roadway in one day.

ASTM - American Society for Testing and Materials - standardized test methods and procedures.

APL - State of Alaska, Department of Transportation and Public Facilities Approved Products - lists products that have been approved for use on State projects.

EAL - Equivalent Axle Load - indicates equivalent 18-kip repetitions based on various assumed load distributions.

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ACKNOWLEDGMENTS

Special thanks to the Engineering Department at the University of Alaska Anchorage for the use of their cold room facilities, to Central Region Materials Laboratory for the use of their equipment and staff, and to FHWA for providing funding for this research. Without their cooperation, this project could not have been complete in a timely manner.

APPENDIX A

RODUCT USE: Membrane Waterproofing SHEET 17 OF 28

MANUFACTURER	PRODUCT	APPLICATION REQUIREMENTS
rotecto Wrap Company 2255 South Delaware St. Denver, Colorado	Protecto Wrap M 400 A Cold applied	275-300°F. No tack coat required 1/2" maximum aggregate size
W. R. Grace and Company 6051 West 65th St. Chicago, Illinois	Bituthene 5000 Cold applied	250-300°F. No tack coat required Minimum 2 1/2" overlay
Royston Laboratories, Inc. 128 1st Street Pittsburgh, Pennsylvania	Royston Bridge Membrane No. 10 Cold applied	290-340°F. No tack coat required Minimum 1 1/2" overlay
Petromat Systems Phillips Fibers Corp. Phillips 66 Co. 523 South Washington Ave. Kent, WA 98032	Petrotac Cold applied	300°F. maximum No tack coat required Minimum 1" overlay
Paveprep Corporation 141 Central Avenue West Field, NJ 98032	Geo Tac Cold applied Pave prep Cold applied	No temperature constraints Tack: Paveprep, required Geo Tac, not required Minimum 1 1/2" overlay
Polyguard Products, Inc. P.O. Box 755 Ennis, TX 75120-0755	Polyguard 665	270-300°F. Tack coat required Minimum 2" overlay

GENERAL REMARKS:

Prepare concrete surface and install membrane according to manufacturer's instructions.

APPROVED PRODUCTS LIST

PRODUCT USE: Membrane Waterproofing

MANUFACTURER	LAB NO.	PRODUCT	REMARKS
Bridge Deck Membranes:			
Protecto Wrap Company 2255 South Delaware St. Denver, Colorado		Protecto Wrap M400 AR, Cold Applied	250-300°F. No tack coat required Minimum 2" Overlay
W. R. Grace and Company 6051 West 65th St. Chicago, Illinois		Bituthene Highway and Bridge Deck Membrane, Cold Applied	**Rejected**
Royston Laboratories, Inc. 128 1st Street. Pittsburgh, Pennsylvania		Royston Bridge Membrane No. 10AN Cold Applied	250-340°F. No tack coat required Minimum 1 1/2" overlay
Crack Repair Membranes:			
Paveprep Corporation 141 Central Avenue West Field, NJ 98032		Paveprep Cold applied	Tack coat required Minumum 1 1/2" Overlay

GENERAL REMARKS:

Prepare concrete surface and install membrane according to manufacturer's instructions.

APPENDIX B

CHART 1

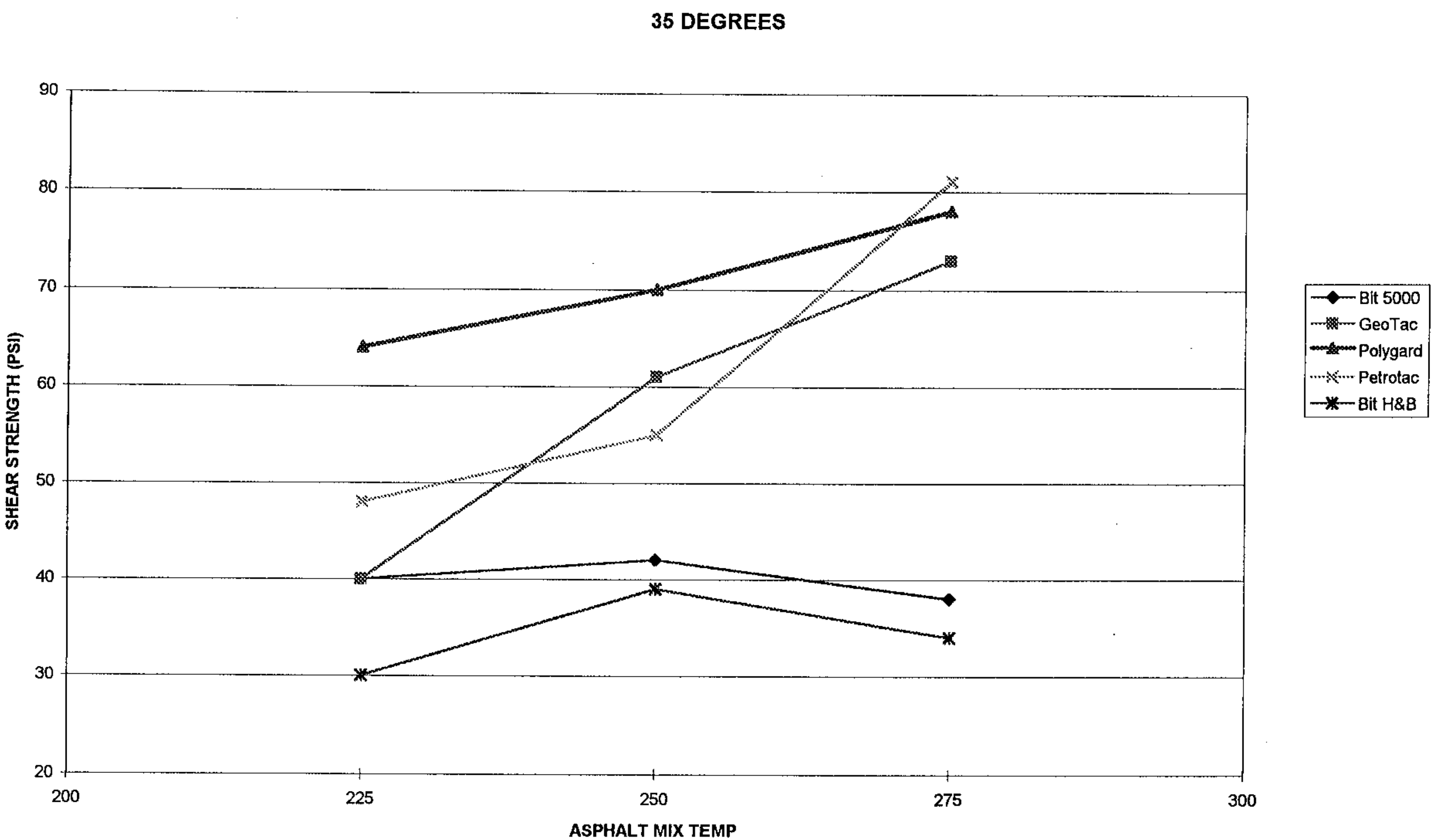

35 DEGREES
SHEAR STRENGTH (PSI)
90
80
70
60
50
40
30
20
200
225
250
275
300
ASPHALT MIX TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 2

45 DEGREES

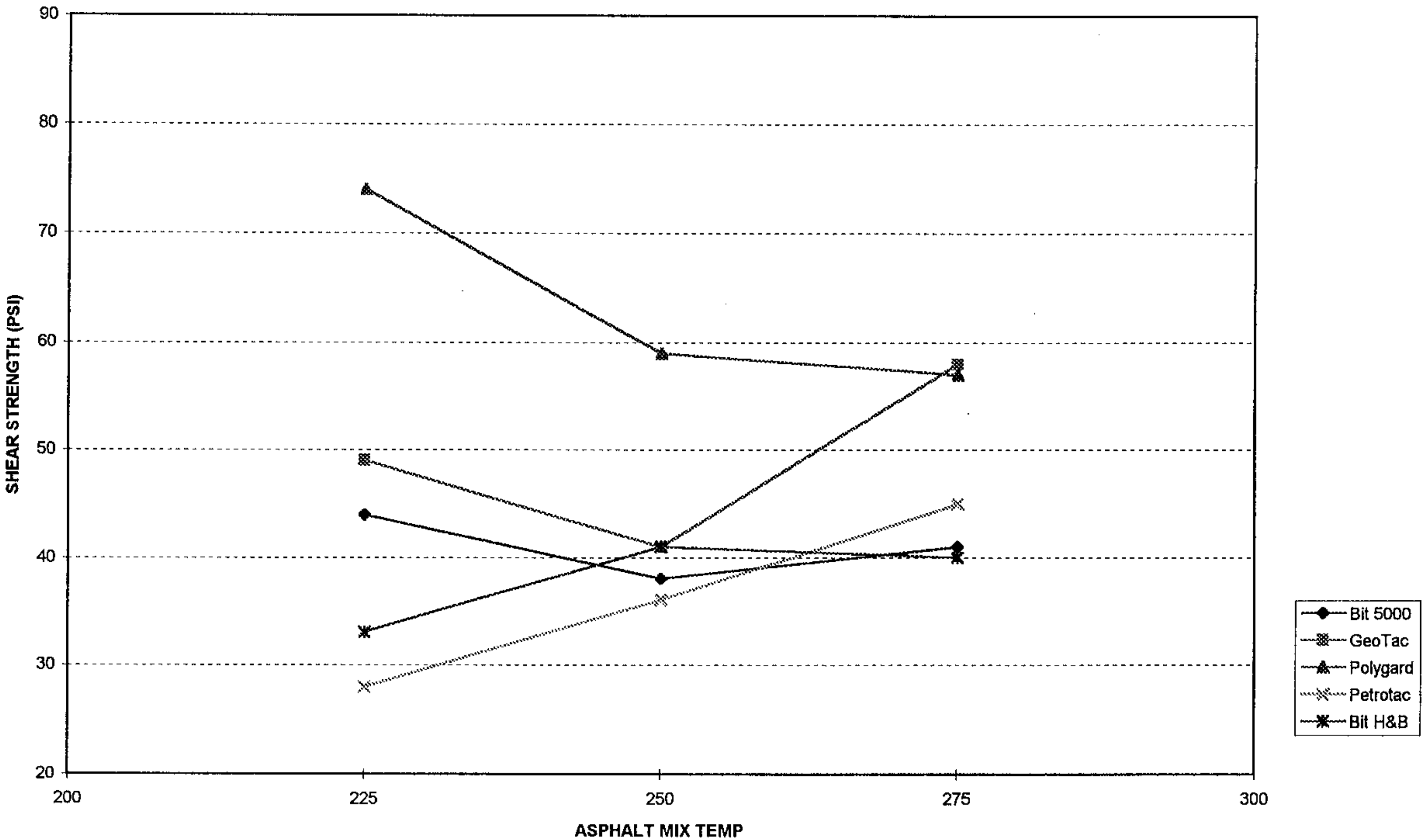


CHART 3

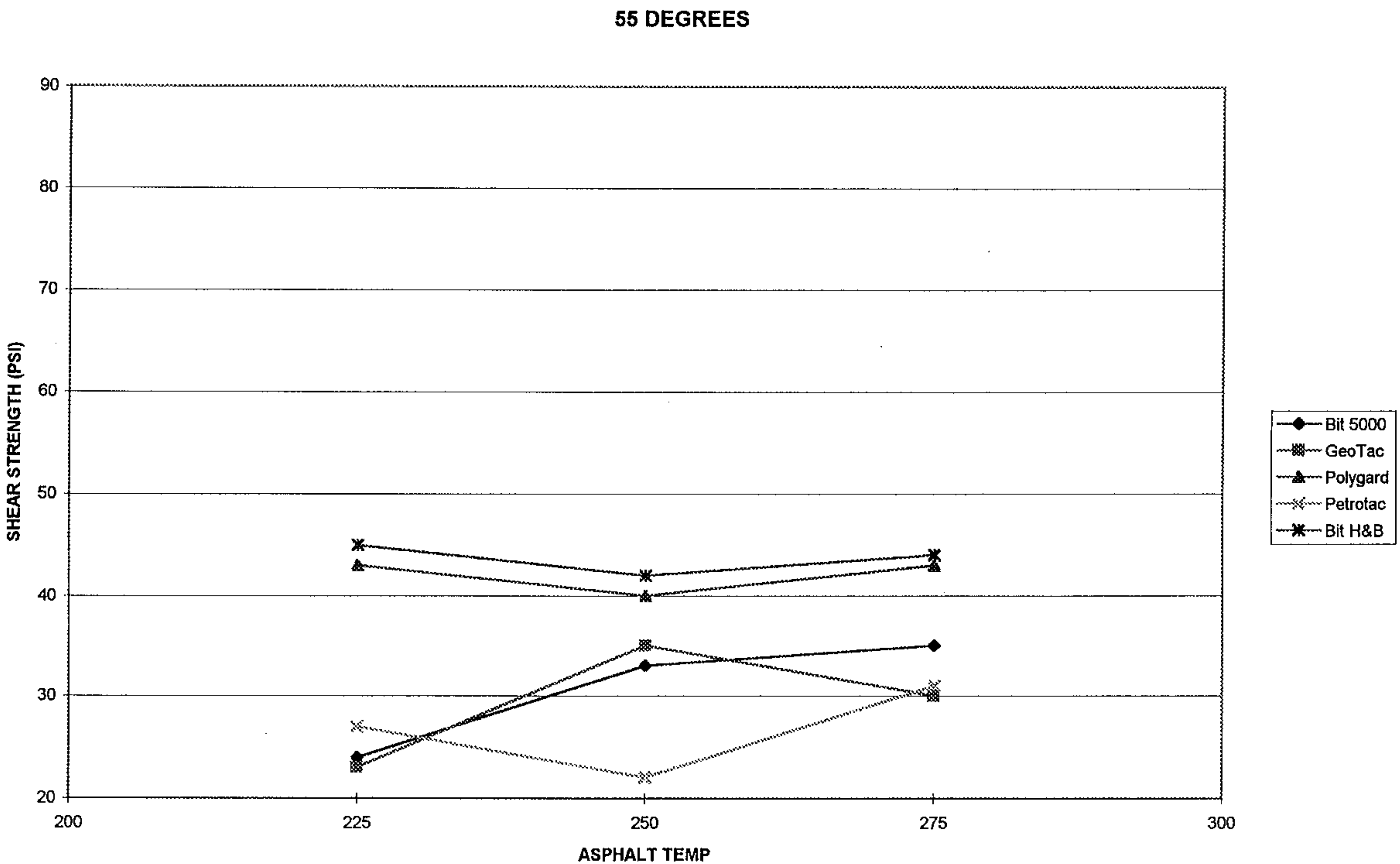

55 DEGREES
90
80
70
60
50
40
30
20
SHEAR STRENGTH (PSI)
200
225
250
275
300
ASPHALT TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 4

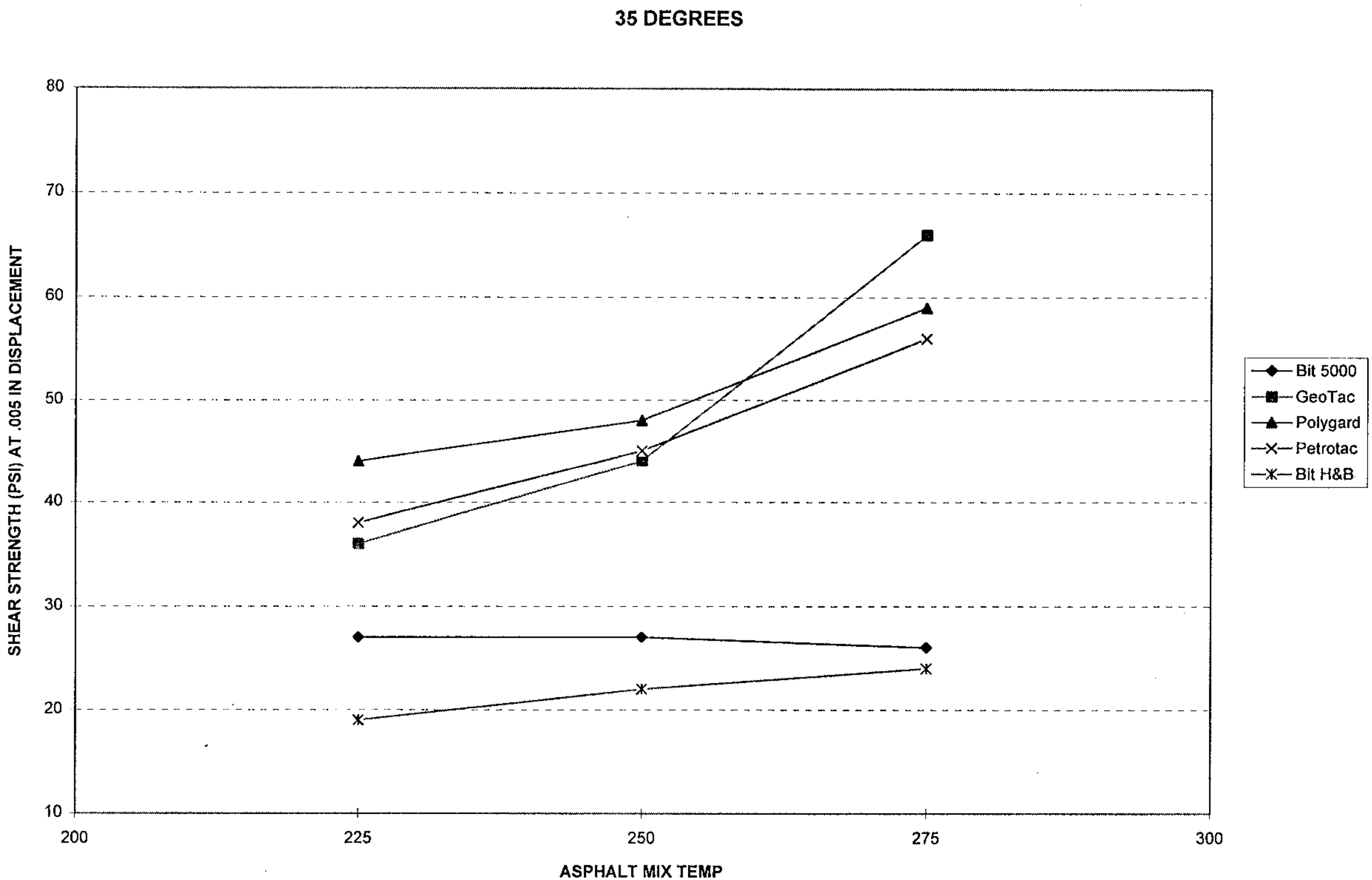

35 DEGREES
80
70
60
50
40
30
20
10
SHEAR STRENGTH (PSI) AT .005 IN DISPLACEMENT
200
225
250
275
300
ASPHALT MIX TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 5

45 DEGREES

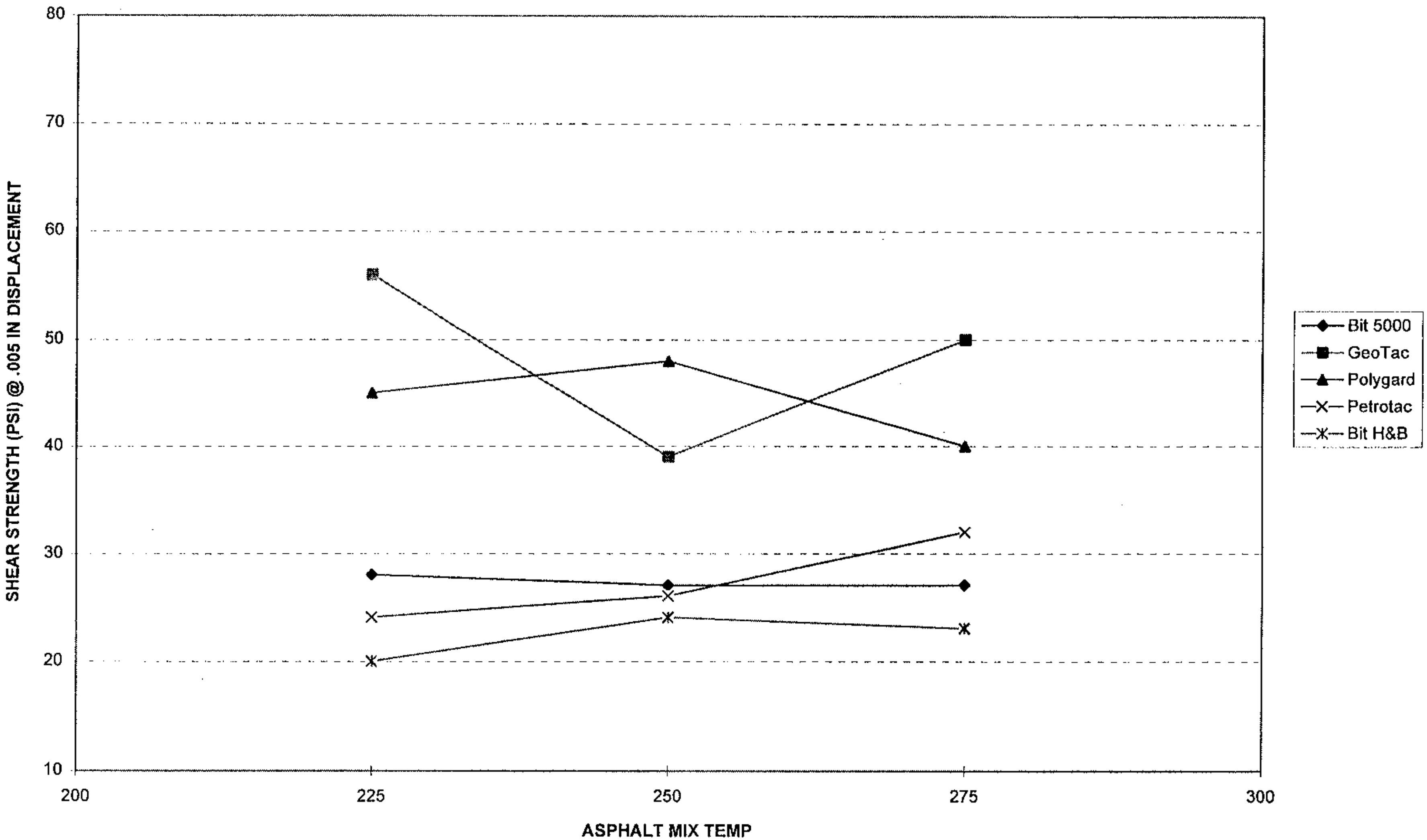
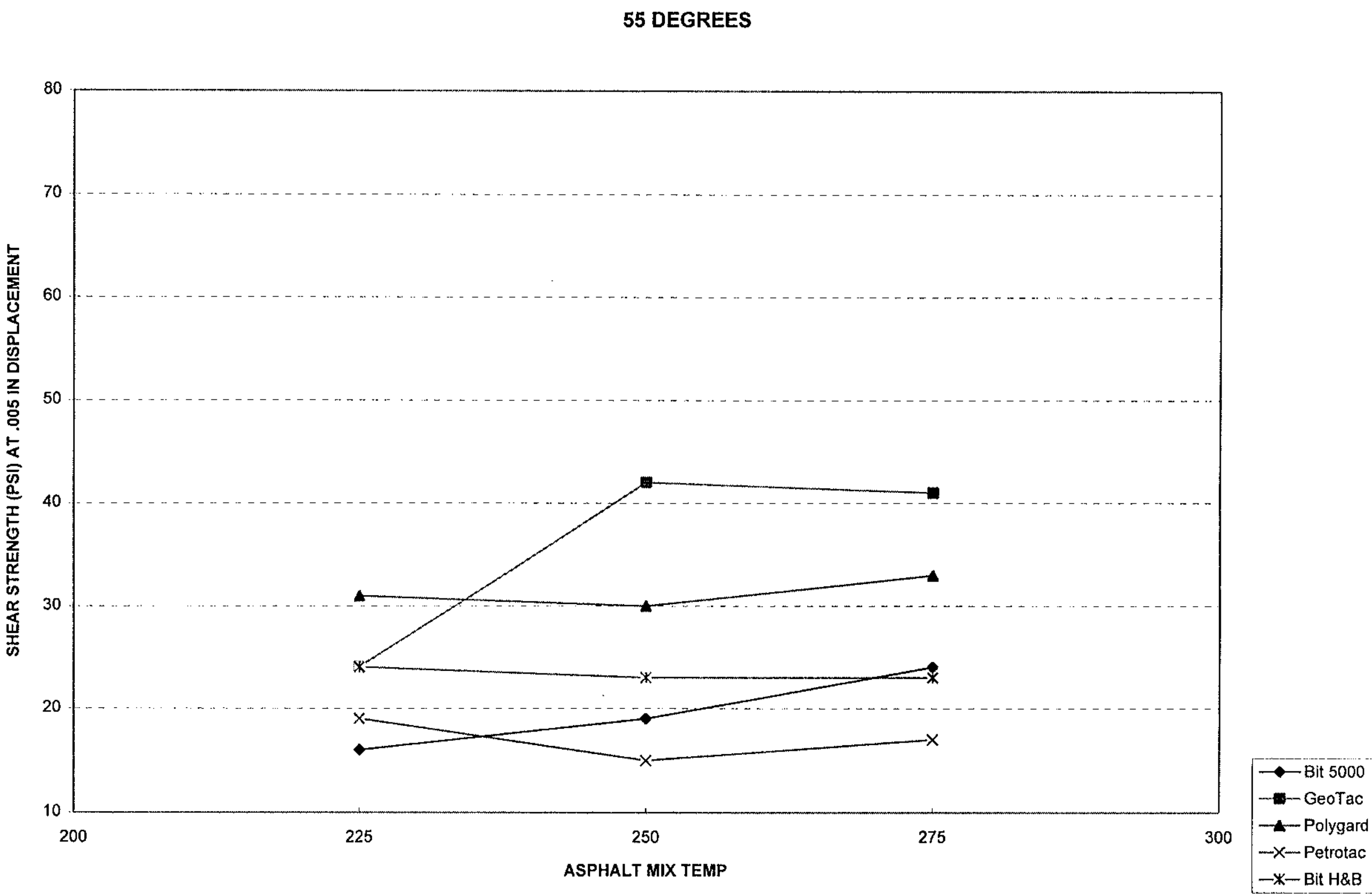
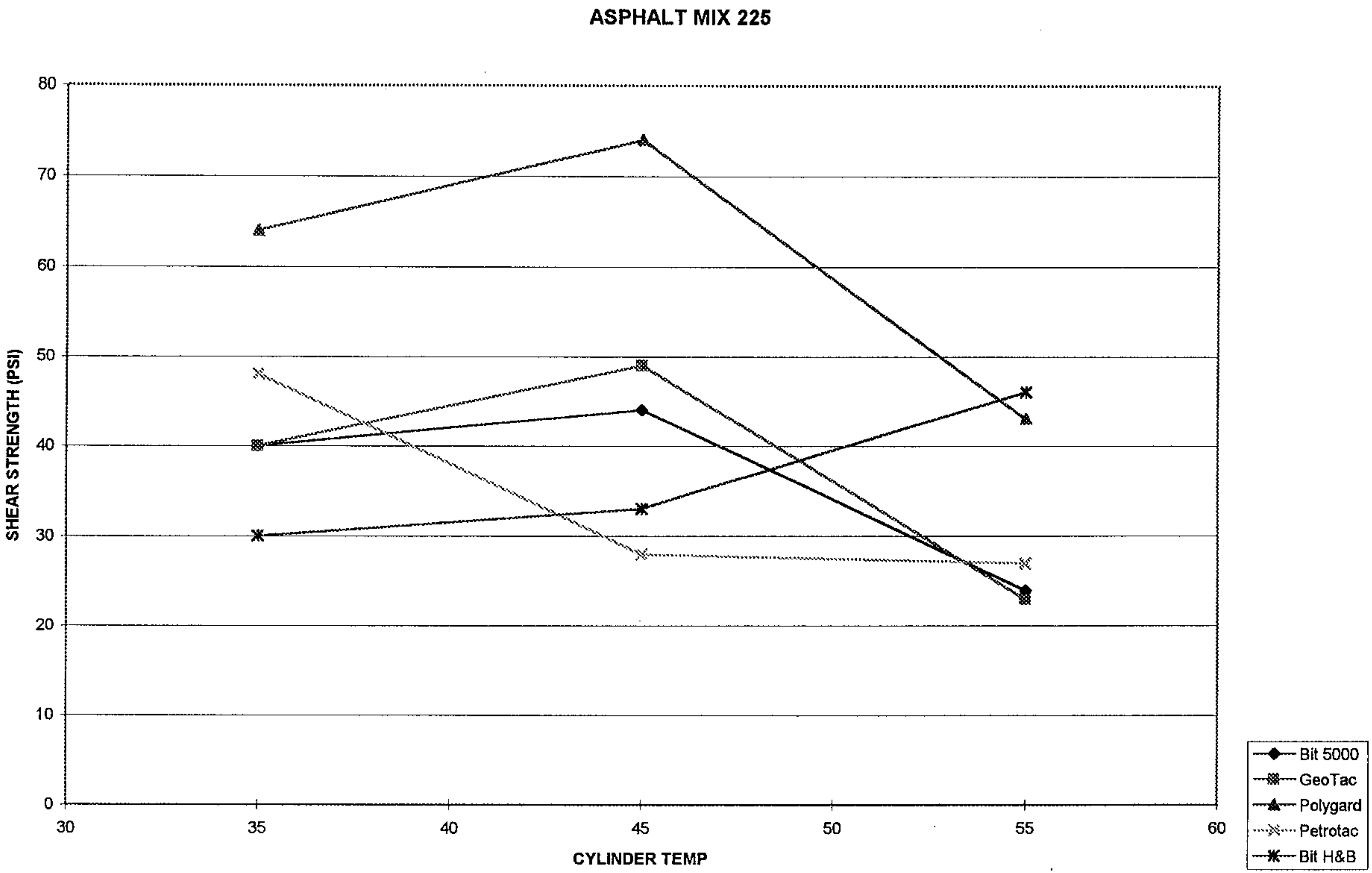


CHART 6



55 DEGREES
SHEAR STRENGTH (PSI) AT .005 IN DISPLACEMENT
80
70
60
50
40
30
20
10
200
225
250
275
300
ASPHALT MIX TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 7


ASPHALT MIX 225
SHEAR STRENGTH (PSI)
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
CYLINDER TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

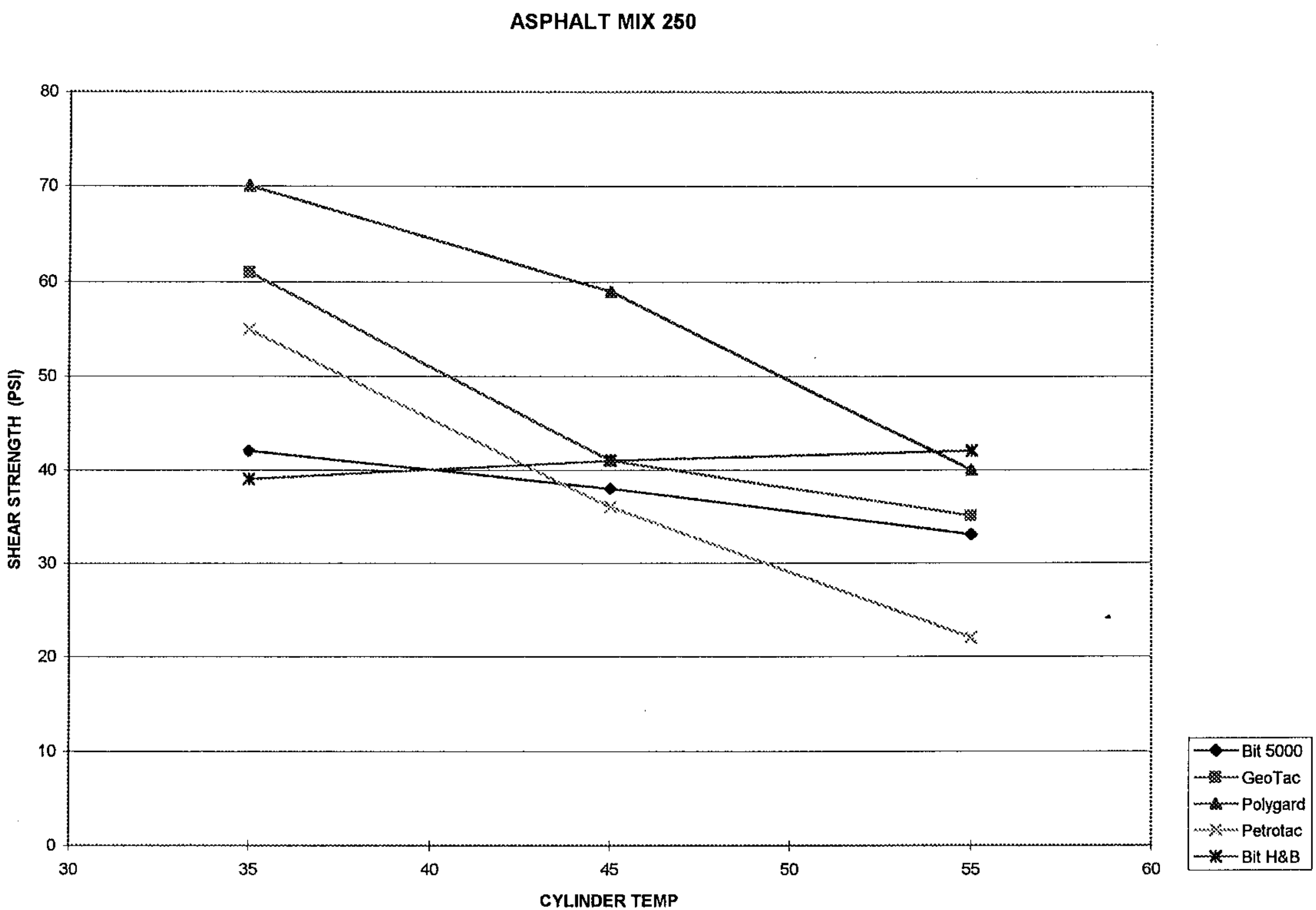

ASPHALT MIX 250
SHEAR STRENGTH (PSI)
80
70
60
50
40
30
20
10
0
30
35
40
45
50
55
60
CYLINDER TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 9

ASPHALT MIX 275

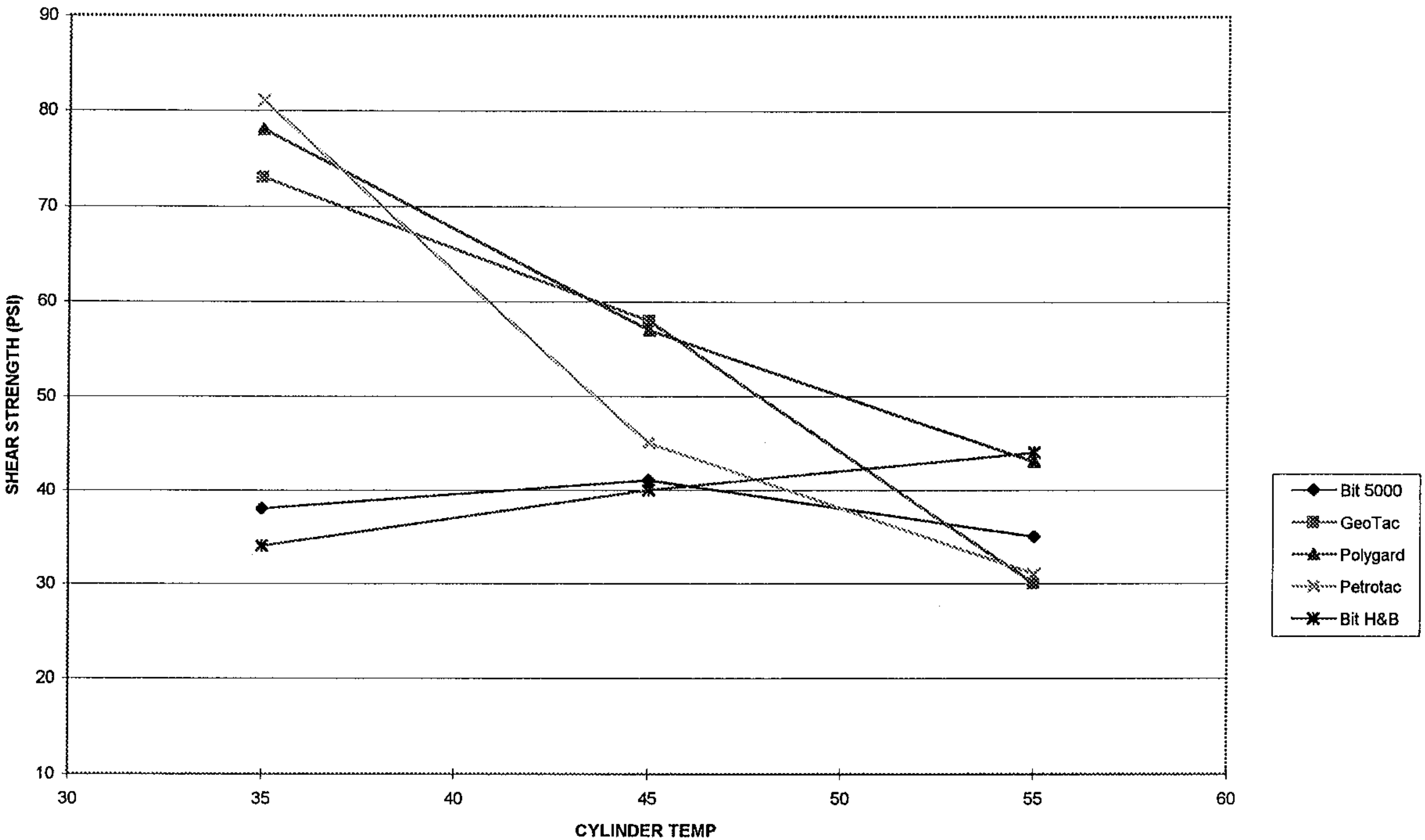
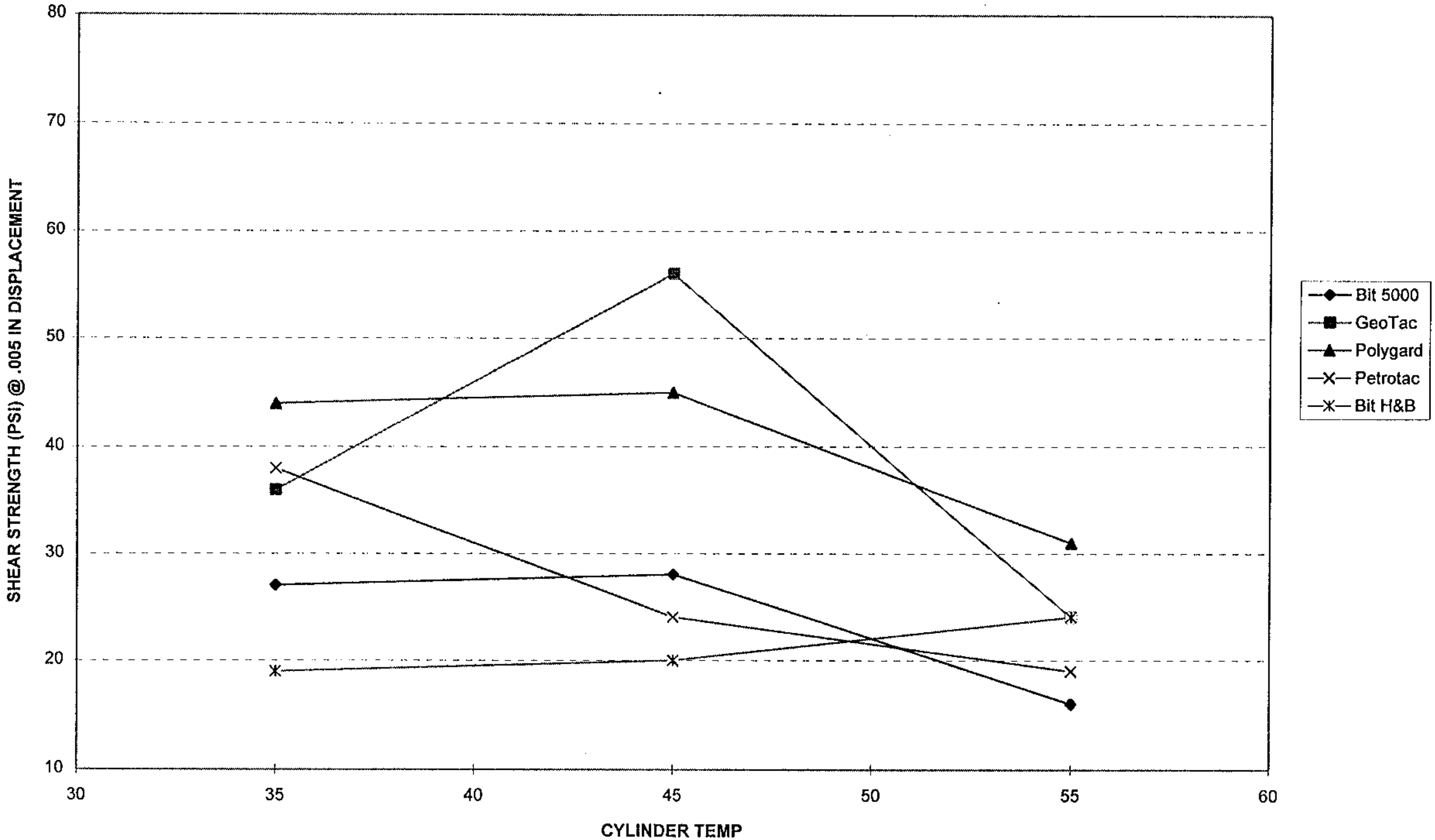


CHART 10

ASPHALT MIX 225



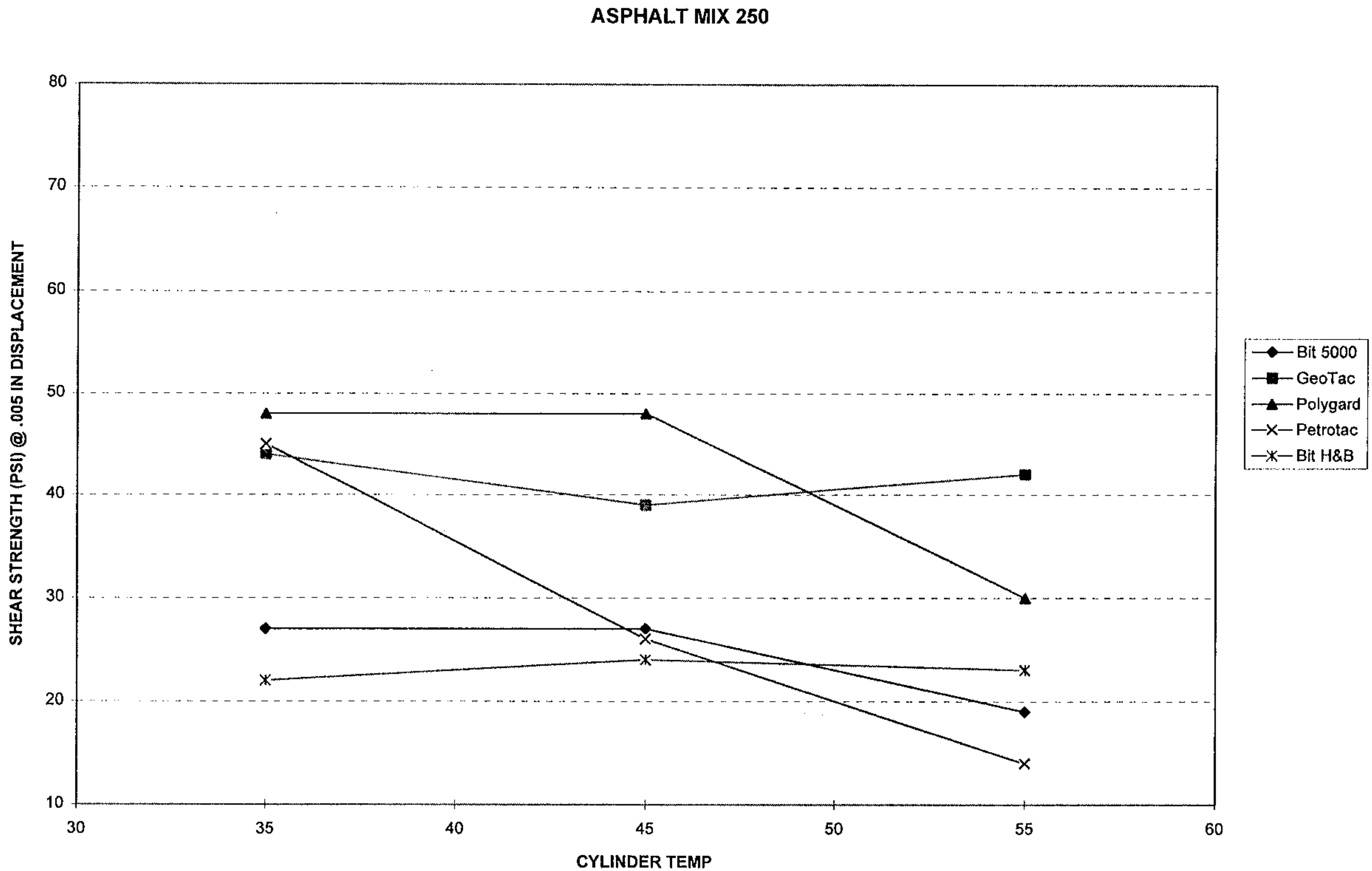

ASPHALT MIX 250
SHEAR STRENGTH (PSI) @ .005 IN DISPLACEMENT
CYLINDER TEMP
80
70
60
50
40
30
20
10
30
35
40
45
50
55
60
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 12

ASPHALT MIX 275

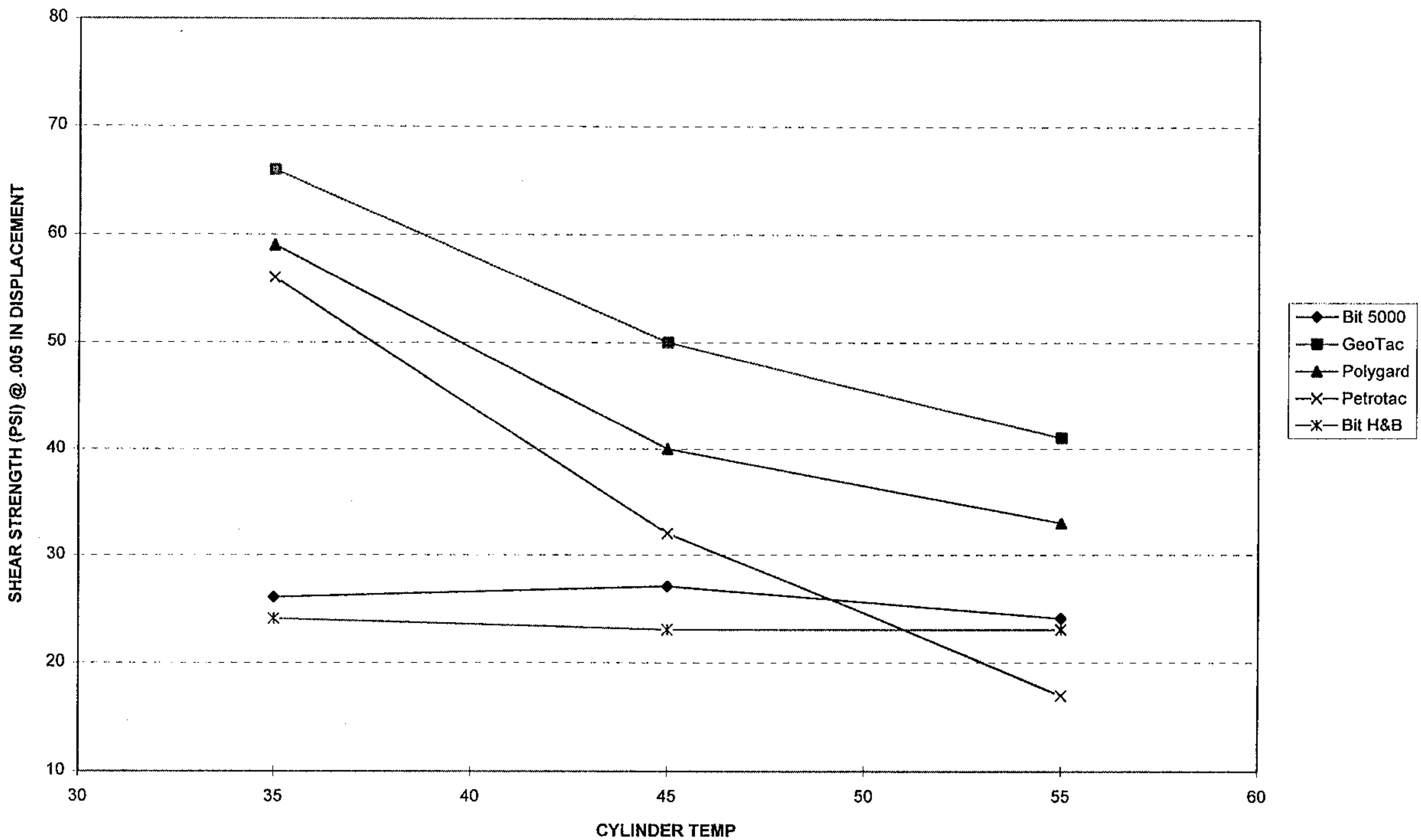


CHART 13

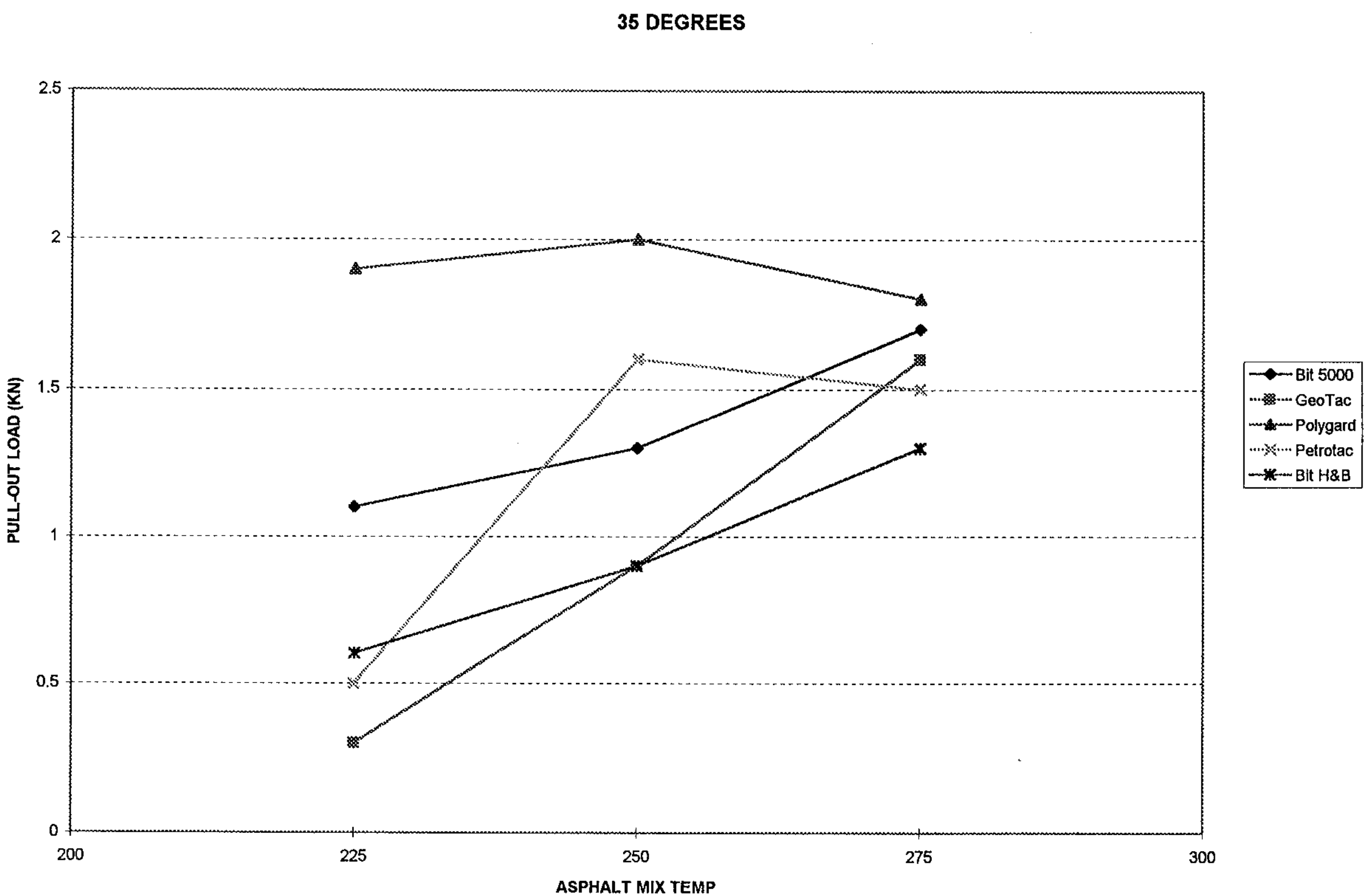

35 DEGREES
2.5
2
1.5
1
0.5
0
PULL-OUT LOAD (KN)
200
225
250
275
300
ASPHALT MIX TEMP
Bit 5000
GeoTac
Polygard
Petrotac
Bit H&B

CHART 14

45 DEGREES

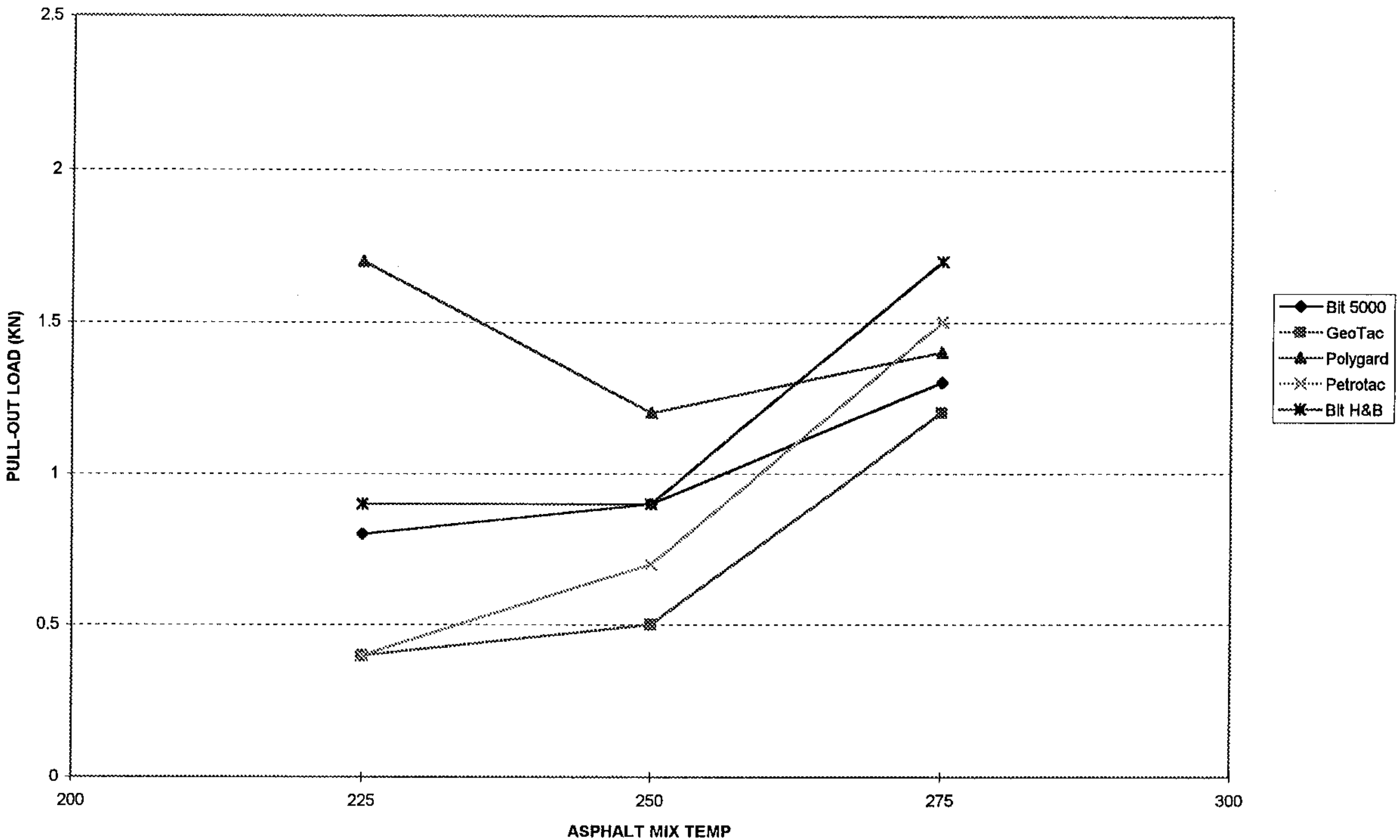


CHART 15

55 DEGREES

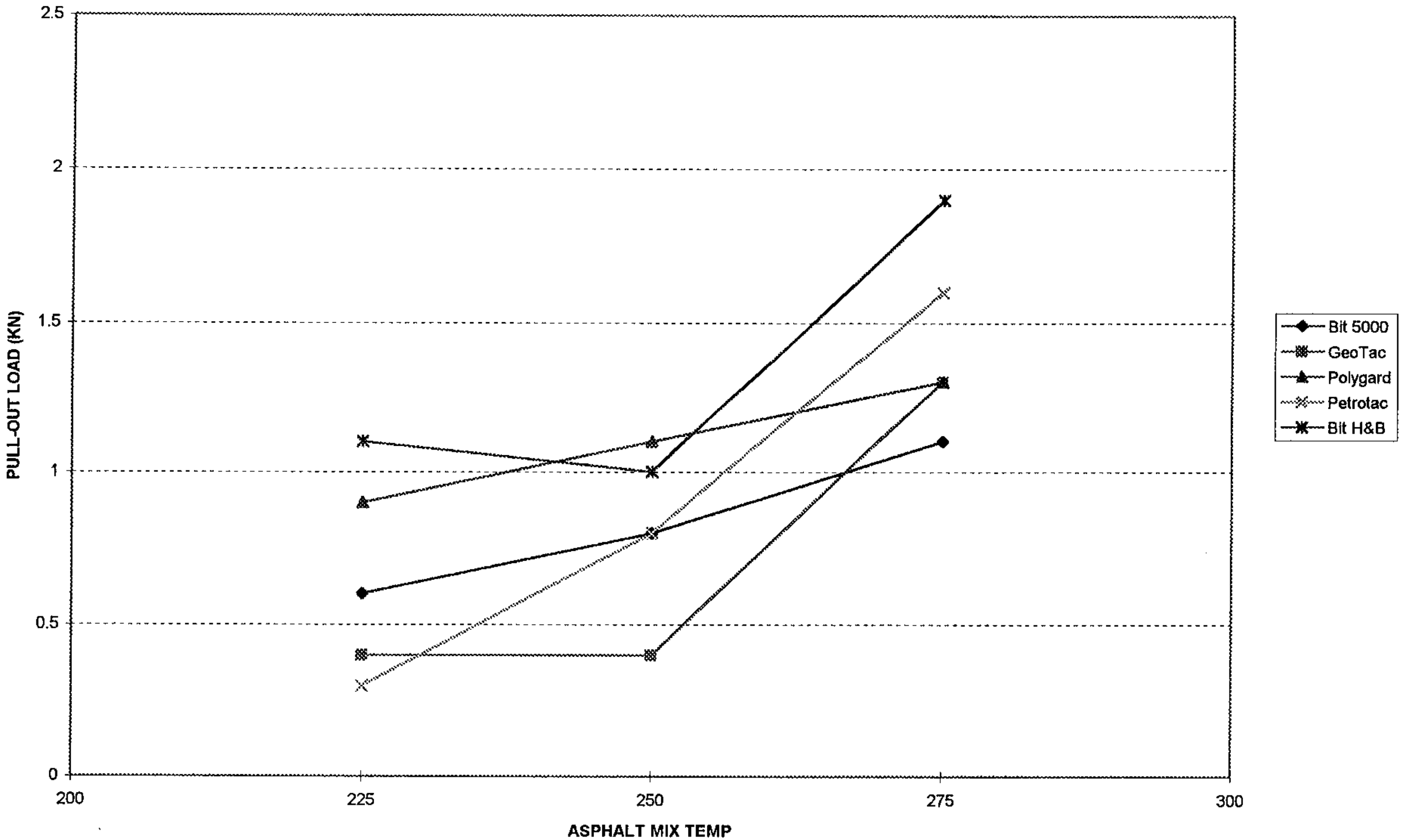
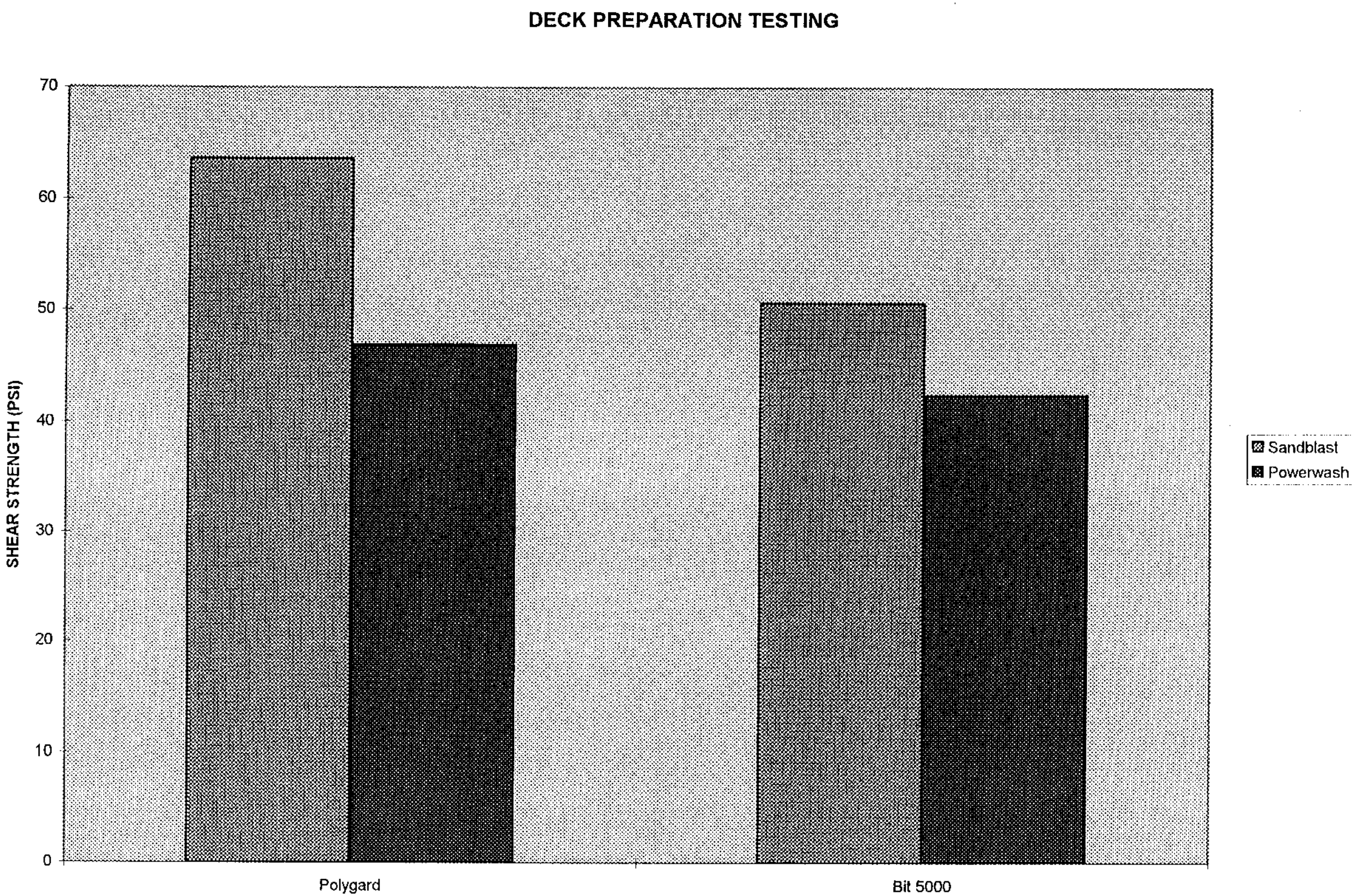
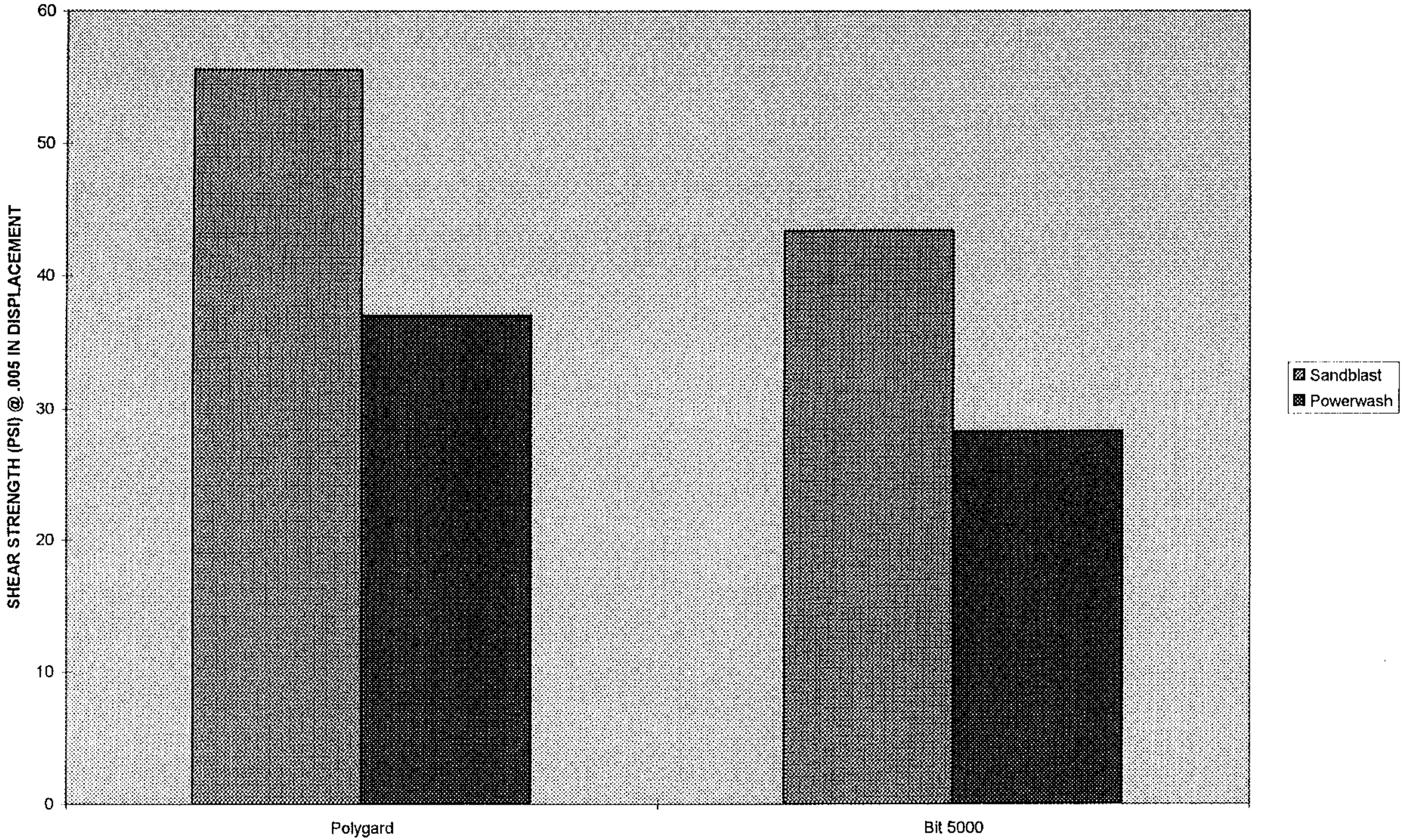


CHART 16


DECK PREPARATION TESTING
70
60
50
40
30
20
10
0
SHEAR STRENGTH (PSI)
Polygard
Bit 5000
Sandblast
Powerwash

DECK PREPARATION TESTING



APPENDIX C

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Failure (lbs)	Average Displace-ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
1	Bit. 5000	225	35	1	1260	2.50E-02	660			
2	Bit. 5000	225	35	1	960	1.25E-02	770			
3	Bit. 5000	225	35	1	1210	1.60E-02	830	1143	1.78E-02	753
4	Bit. 5000	250	35	1	1340	2.25E-02	690			
5	Bit. 5000	250	35	2	1050	1.50E-02	700			
6	Bit. 5000	250	35	1	1160	1.60E-02	860	1183	1.78E-02	750
7	Bit. 5000	275	35	1	990	1.45E-02	670			
8	Bit. 5000	275	35	2	1020	1.50E-02	810			
9	Bit. 5000	275	35	1	1180	1.60E-02	700	1063	1.52E-02	727
10	GeoTac	225	35	1	1120	6.50E-03	1060			
11	GeoTac	225	35	1	1030	7.00E-03	950			
12	GeoTac	225	35	1	1260	9.00E-03	1050	1137	7.50E-03	1020
13	GeoTac	250	35	1	1600	7.50E-03	1500			
14	GeoTac	250	35	1	1230	6.00E-03	1210			
15	GeoTac	250	35	1	1240	7.50E-03	1020	1357	7.00E-03	1243
16	GeoTac	275	35	1	2220	6.50E-03	2100			
17	GeoTac	275	35	1	2630	9.50E-03	1630			
18	GeoTac	275	35	1	1380	4.00E-03	*	2077	6.67E-03	1865
19	Polyguard	225	35	1	1750	1.55E-02	1220			
20	Polyguard	225	35	1	2120	1.65E-02	1340			
21	Polyguard	225	35	1	1580	1.60E-02	1150	1817	1.60E-02	1237
22	Polyguard	250	35	2	2220	2.00E-02	1340			
23	Polyguard	250	35	1	1980	1.85E-02	1240			
24	Polyguard	250	35	1	1760	1.10E-02	1530	1987	1.65E-02	1370

1. Asphalt/Membrane
2. Membrane/Concrete

** Not Available

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Fail ure (lbs)	Average Displace -ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
25	Polyguard	275	35	2	2100	1.10E-02	1710			
26	Polyguard	275	35	1	2170	1.90E-02	1350			
27	Polyguard	275	35	1	2330	9.50E-03	1960	2200	1.32E-02	1673
28	Petrotac	225	35	1	1260	9.00E-03	1120			
29	Petrotac	225	35	1	1320	1.20E-02	1080			
30	Petrotac	225	35	1	1470	1.15E-02	1050	1350	1.08E-02	1083
31	Petrotac	250	35	1	1550	1.25E-02	1320			
32	Petrotac	250	35	1	2010	1.75E-02	1430			
33	Petrotac	250	35	1	1080	6.50E-03	1070	1547	1.22E-02	1273
34	Petrotac	275	35	2	2290	1.85E-02	1300			
35	Petrotac	275	35	1	2220	2.25E-02	1430			
36	Petrotac	275	35	1	2340	1.45E-02	1760	2283	1.85E-02	1595
241	Bit. H & B	225	35	1	840	1.65E-02	530			
242	Bit. H & B	225	35	1	850	1.85E-02	540	845	1.75E-02	535
243	Bit. H & B	250	35	1	1290	2.75E-02	670			
244	Bit. H & B	250	35	1 & 2	920	2.50E-02	580	1105	2.63E-02	625
245	Bit. H & B	275	35	2	1030	2.25E-02	700			
246	Bit. H & B	275	35	2	870	1.50E-02	720	950	2.08E-02	667
73	Bit. 5000	225	45	1	1200	2.75E-02	700			
74	Bit. 5000	225	45	1	1140	2.00E-02	890			
75	Bit. 5000	225	45	1	1410	3.50E-02	780	1250	2.75E-02	790
76	Bit. 5000	250	45	2	810	8.50E-03	740			
77	Bit. 5000	250	45	2	1170	1.75E-02	820			
78	Bit. 5000	250	45	2	1270	2.45E-02	770	1083	1.68E-02	777

1. Asphalt/Membrane
2. Membrane/Concrete

** Not Available

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Failure (lbs)	Average Displace-ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
79	Bit. 5000	275	45	2	1220	1.50E-02	900			
80	Bit. 5000	275	45	2	1050	2.30E-02	710			
81	Bit. 5000	275	45	2	1170	2.25E-02	690	1147	2.02E-02	767
82	GeoTac	225	45	1	1860	6.00E-03	1800			
83	GeoTac	225	45	1	860	4.00E-03	*			
84	GeoTac	225	45	1	1410	6.00E-03	1380	1377	5.33E-03	1590
85	GeoTac	250	45	1	1380	7.50E-03	1210			
86	GeoTac	250	45	1	1020	5.00E-03	1020			
87	GeoTac	250	45	1	1080	6.00E-03	1060	1160	6.17E-03	1097
88	GeoTac	275	45	1	1680	1.25E-02	1200			
89	GeoTac	275	45	1	1500	4.00E-03	*			
90	GeoTac	275	45	1	1720	6.00E-03	1630	1633	7.50E-03	1415
91	Polyguard	225	45	1 & 2	2130	1.55E-02	1260			
92	Polyguard	225	45	1	2050	1.75E-02	1320			
93	Polyguard	225	45	1 & 2	2090	1.85E-02	1200	2090	1.72E-02	1260
94	Polyguard	250	45	2	1780	1.00E-02	1400			
95	Polyguard	250	45	2	1490	1.10E-02	1170			
96	Polyguard	250	45	2	1740	1.05E-02	1540	1670	1.05E-02	1370
97	Polyguard	275	45	1 & 2	1290	1.05E-02	1040			
98	Polyguard	275	45	1 & 2	1580	9.00E-03	1290			
99	Polyguard	275	45	2	1930	1.75E-02	1080	1600	1.23E-02	1137
100	Petrotac	225	45	1	840	9.00E-03	700			
101	Petrotac	225	45	1	720	8.20E-03	660			
102	Petrotac	225	45	1	840	1.50E-02	690	800	1.07E-02	683

1. Asphalt/Membrane
2. Membrane/Concrete

** Not Available

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Fail ure (lbs)	Average Displace -ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
103	Petrotac	250	45	1	1000	1.50E-02	760			
104	Petrotac	250	45	1	1020	2.38E-02	680			
105	Petrotac	250	45	1	1060	1.76E-02	740	1027	1.88E-02	727
106	Petrotac	275	45	1	1310	1.10E-02	1080			
107	Petrotac	275	45	2	1150	1.90E-02	920			
108	Petrotac	275	45	1	1380	2.75E-02	850	1280	1.88E-02	898
217	Bit. H & B	225	45	**	920	2.00E-02	600			
218	Bit. H & B	225	45	**	970	2.50E-02	540	945	2.25E-02	570
219	Bit. H & B	250	45	**	1270	3.00E-02	720			
220	Bit. H & B	250	45	**	1050	2.50E-02	640	1160	2.75E-02	680
221	Bit. H & B	275	45	**	1250	2.75E-02	710			
222	Bit. H & B	275	45	**	1040	2.75E-02	600	1145	2.75E-02	655
145	Bit. 5000	225	55	2	590	1.05E-02	530			
146	Bit. 5000	225	55	1	700	2.10E-02	400			
147	Bit. 5000	225	55	1	750	3.25E-02	440	680	2.13E-02	457
148	Bit. 5000	250	55	2	880	1.75E-02	480			
149	Bit. 5000	250	55	1	1080	3.60E-02	630			
150	Bit. 5000	250	55	2	840	2.65E-02	520	933	2.67E-02	543
151	Bit. 5000	275	55	1	970	2.70E-02	590			
152	Bit. 5000	275	55	1	1020	2.50E-02	720			
153	Bit. 5000	275	55	1	960	2.65E-02	730	983	2.62E-02	680
154	GeoTac	225	55	1	400	2.00E-03	*			
155	GeoTac	225	55	1	820	8.00E-03	670			
156	GeoTac	225	55	1	770	4.00E-03	*	663	4.67E-03	670

1. Asphalt/Membrane
2. Membrane/Concrete

** Not Available

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Failure (lbs)	Average Displace-ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
157	GeoTac	250	55	1	470	3.50E-03	*			
158	GeoTac	250	55	1	1500	7.00E-03	1510			
159	GeoTac	250	55	1	970	8.00E-03	890	980	6.17E-03	1200
160	GeoTac	275	55	1	300	1.50E-03	*			
161	GeoTac	275	55	1	900	7.00E-03	1080			
162	GeoTac	275	55	1	1360	8.00E-03	1240	853	5.50E-03	1160
163	Polyguard	225	55	2	1140	1.10E-02	940			
164	Polyguard	225	55	2	1210	1.40E-02	840			
165	Polyguard	225	55	2	1290	1.75E-02	830	1213	1.42E-02	870
166	Polyguard	250	55	1 & 2	1170	1.30E-02	920			
167	Polyguard	250	55	2	1220	1.30E-02	940			
168	Polyguard	250	55	1	980	1.60E-02	650	1123	1.40E-02	837
169	Polyguard	275	55	2	1200	9.00E-03	1070			
170	Polyguard	275	55	2	1280	1.40E-02	920			
171	Polyguard	275	55	2	1200	1.40E-02	840	1227	1.23E-02	943
172	Petrotac	225	55	1	930	2.25E-02	660			
173	Petrotac	225	55	1	780	2.25E-02	480			
174	Petrotac	225	55	1	540	1.25E-02	440	750	1.92E-02	527
175	Petrotac	250	55	1	600	2.25E-02	400			
176	Petrotac	250	55	1	720	2.00E-02	550			
177	Petrotac	250	55	1	530	2.50E-02	340	617	2.25E-02	430
178	Petrotac	275	55	2	900	3.35E-02	480			
179	Petrotac	275	55	2	720	3.00E-02	440			
180	Petrotac	275	55	2	980	3.50E-02	540	867	3.28E-02	487

1. Asphalt/Membrane
2. Membrane/Concrete

** Not Available

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Failure (lbs)	Average Displace-ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
229	Bit. H & B	225	55	**	1200	3.00E-02	710			
230	Bit. H & B	225	55	**	1370	3.50E-02	670	1285	3.25E-02	690
231	Bit. H & B	250	55	**	1180	3.25E-02	610			
232	Bit. H & B	250	55	**	1200	3.25E-02	700	1190	3.25E-02	655
233	Bit. H & B	275	55	**	1400	3.00E-02	900			
234	Bit. H & B	275	55	**	1070	3.75E-02	420	1235	3.38E-02	660

1. Asphalt/Membrane
2. Membrane/Concrete

** Not Available

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Shear Test Results

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Delamination	Load @ Failure (lbs)	Displace-ment @ Failure (inches)	Load @ .005 in Displace-ment (lbs)	Aver. Load @ Failure (lbs)	Average Displace-ment @ Failure (inches)	Aver. Load @ .005 in Displace-ment
SBP1	Polyguard	225	45	2	1740	8.00E-03	1500			
SBP2	Polyguard	225	45	2	1850	9.00E-03	1710			
SBP3	Polyguard	225	45	2	1800	8.00E-03	1500	1797	8.33E-03	1570
PWP1	Polyguard	250	45	2	1150	1.40E-02	980			
PWP2	Polyguard	250	45	2	1550	1.30E-02	1380			
PWP3	Polyguard	250	45	2	1280	1.50E-02	780	1327	1.40E-02	1047
SBB1	Bit. 5000	275	45	3	1570	8.00E-03	1440			
SBB2	Bit. 5000	275	45	3	1290	1.20E-02	1140			
SBB3	Bit. 5000	275	45	3	1440	1.20E-02	1100	1433	1.07E-02	1227
PWB1	Bit. 5000	225	45	3	1250	1.40E-02	1000			
PWB2	Bit. 5000	225	45	3	1110	2.00E-02	670			
PWB3	Bit. 5000	225	45	3	1240	1.05E-02	720	1200	1.48E-02	797

SBP	Sandblast Polyguard
PWP	Powerwash Polyguard
SBB	Sandblast Bit. 5000
PWB	Powerwash Bit. 5000

1. Asphalt/Membrane
2. Membrane/Concrete
3. Split Membrane in Half

* Failed Prior to .005 inches of Displacement

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Pullout Test Results BDC= Broke During Coring

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Load (lbs)	Tensile Stress (psi)	Aver. Tensile Stress (psi)
37	Bit. 5000	225	35	4893	1558	
38	Bit. 5000	225	35	4893	1558	
39	Bit. 5000	225	35	4893	1558	1558
40	Bit. 5000	250	35	5338	1700	
41	Bit. 5000	250	35	6227	1983	
42	Bit. 5000	250	35	5338	1700	1794
43	Bit. 5000	275	35	7117	2267	
44	Bit. 5000	275	35	8007	2550	
45	Bit. 5000	275	35	7117	2267	2361
46	GeoTac	225	35	1334	425	
47	GeoTac	225	35	1334	425	
48	GeoTac	225	35	1334	425	425
49	GeoTac	250	35	4003	1275	
50	GeoTac	250	35	3559	1133	
51	GeoTac	250	35	4003	1275	1228
52	GeoTac	275	35	7117	2267	
53	GeoTac	275	35	4893	1558	
54	GeoTac	275	35	9341	2975	2267
55	Polyguard	225	35	BDC	-	
56	Polyguard	225	35	8007	2550	
57	Polyguard	225	35	8896	2833	2692
58	Polyguard	250	35	8452	2692	
59	Polyguard	250	35	8452	2692	
60	Polyguard	250	35	9341	2975	2786
61	Polyguard	275	35	8452	2692	
62	Polyguard	275	35	8007	2550	
63	Polyguard	275	35	8007	2550	2597
64	Petrotac	225	35	1779	567	
65	Petrotac	225	35	2224	708	
66	Petrotac	225	35	BDC	-	637
67	Petrotac	250	35	7562	2408	
68	Petrotac	250	35	7117	2267	
69	Petrotac	250	35	6227	1983	2219
70	Petrotac	275	35	6672	2125	
71	Petrotac	275	35	6672	2125	
72	Petrotac	275	35	7117	2267	2172
247	Bit. H & B	225	35	3114	992	
248	Bit. H & B	225	35	2224	708	850

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Pullout Test Results BDC= Broke During Coring

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Load (lbs)	Tensile Stress (psi)	Aver. Tensile Stress (psi)
249	Bit. H & B	250	35	3559	1133	
250	Bit. H & B	250	35	4003	1275	1204
251	Bit. H & B	275	35	6227	1983	
252	Bit. H & B	275	35	4893	1558	1771
109	Bit. 5000	225	45	3114	992	
110	Bit. 5000	225	45	4003	1275	
111	Bit. 5000	225	45	BDC	-	1133
112	Bit. 5000	250	45	4893	1558	
113	Bit. 5000	250	45	BDC	-	
114	Bit. 5000	250	45	2669	850	1204
115	Bit. 5000	275	45	5783	1842	
116	Bit. 5000	275	45	5338	1700	
117	Bit. 5000	275	45	6227	1983	1842
118	GeoTac	225	45	1779	567	
119	GeoTac	225	45	1334	425	
120	GeoTac	225	45	2224	708	567
121	GeoTac	250	45	1779	567	
122	GeoTac	250	45	2224	708	
123	GeoTac	250	45	2669	850	708
124	GeoTac	275	45	5338	1700	
125	GeoTac	275	45	5783	1842	
126	GeoTac	275	45	4893	1558	1700
127	Polyguard	225	45	7117	2267	
128	Polyguard	225	45	7562	2408	
129	Polyguard	225	45	8452	2692	2455
130	Polyguard	250	45	5783	1842	
131	Polyguard	250	45	5783	1842	
132	Polyguard	250	45	4893	1558	1747
133	Polyguard	275	45	5338	1700	
134	Polyguard	275	45	7117	2267	
135	Polyguard	275	45	6227	1983	1983
136	Petrotac	225	45	1779	567	
137	Petrotac	225	45	1779	567	
138	Petrotac	225	45	1334	425	519
139	Petrotac	250	45	3114	992	
140	Petrotac	250	45	3114	992	
141	Petrotac	250	45	3559	1133	1039

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Pullout Test Results BDC= Broke During Coring

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Load (lbs)	Tensile Stress (psi)	Aver. Tensile Stress (psi)
142	Petrotac	275	45	5783	1842	
143	Petrotac	275	45	7117	2267	
144	Petrotac	275	45	7117	2267	2125
223	Bit. H & B	225	45	4003	1275	
224	Bit. H & B	225	45	4003	1275	1275
225	Bit. H & B	250	45	3559	1133	
226	Bit. H & B	250	45	4003	1275	1204
227	Bit. H & B	275	45	7562	2408	
228	Bit. H & B	275	45	7117	2267	2337
181	Bit. 5000	225	55	3114	992	
182	Bit. 5000	225	55	3114	992	
183	Bit. 5000	225	55	2224	708	897
184	Bit. 5000	250	55	4003	1275	
185	Bit. 5000	250	55	4003	1275	
186	Bit. 5000	250	55	2669	850	1133
187	Bit. 5000	275	55	5338	1700	
188	Bit. 5000	275	55	4448	1417	
189	Bit. 5000	275	55	4893	1558	1558
190	GeoTac	225	55	BDC	-	
191	GeoTac	225	55	1779	567	
192	GeoTac	225	55	1334	425	496
193	GeoTac	250	55	1779	567	
194	GeoTac	250	55	BDC	-	
195	GeoTac	250	55	1334	425	496
196	GeoTac	275	55	5338	1700	
197	GeoTac	275	55	5783	1842	
198	GeoTac	275	55	6672	2125	1889
199	Polyguard	225	55	4448	1417	
200	Polyguard	225	55	3559	1133	
201	Polyguard	225	55	4448	1417	1322
202	Polyguard	250	55	5338	1700	
203	Polyguard	250	55	5338	1700	
204	Polyguard	250	55	3559	1133	1511
205	Polyguard	275	55	BDC	-	
206	Polyguard	275	55	5783	1842	
207	Polyguard	275	55	5338	1700	1771
208	Petrotac	225	55	1779	567	
209	Petrotac	225	55	1334	425	
210	Petrotac	225	55	1334	425	472

Research Project No. AK-RD-96-04
Bridge Deck Waterproof Membrane Evaluation

Pullout Test Results BDC= Broke During Coring

Sample	Membrane Type	Asphalt Temp.	Ambient Temp.	Load (lbs)	Tensile Stress (psi)	Aver. Tensile Stress (psi)
211	Petrotac	250	55	4448	1417	
212	Petrotac	250	55	2669	850	
213	Petrotac	250	55	4003	1275	1181
214	Petrotac	275	55	7117	2267	
215	Petrotac	275	55	7562	2408	
216	Petrotac	275	55	7117	2267	2314
235	Bit. H & B	225	55	4893	1558	
236	Bit. H & B	225	55	4448	1417	1487
237	Bit. H & B	250	55	4003	1275	
238	Bit. H & B	250	55	4893	1558	1417
239	Bit. H & B	275	55	8007	2550	
240	Bit. H & B	275	55	8452	2692	2621