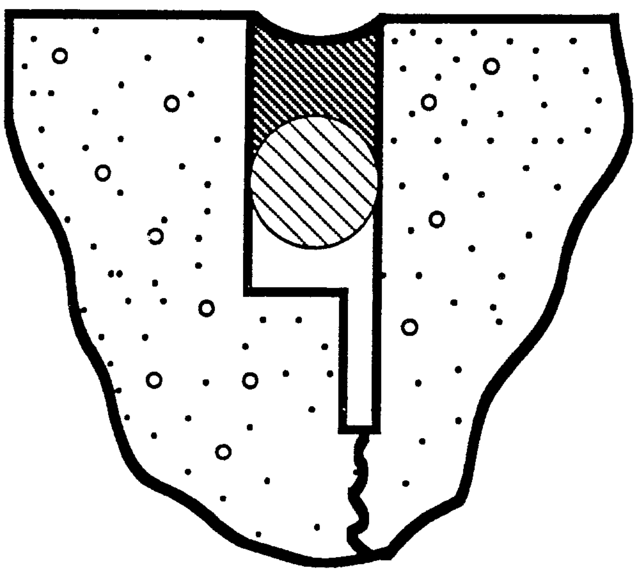
PROCEEDINGS

Pavement Crack and Joint Sealants for Rigid and Flexible Pavements Conference

May 20-21, 1997

Hosted by

Airfields and Pavements Division
USAE Waterways Experiment Station
Vicksburg, MS



SUMMARY OF STATE HIGHWAY AGENCY USE OF JOINT SEALANT FOR TRANSVERSE CONTRACTION JOINTS IN HIGHWAY PAVEMENTS

Gerald F. Voigt, P.E.[1]

ABSTRACT

The most widely accepted definition of the purpose of joint sealant is to minimize infiltration of surface water and incompressible material into the joint system. There is no doubt that water can contribute to subgrade or subbase softening, and lead to pumping of subgrade or subbase fines. This degradation usually results in loss of structural support, pavement settlement and/or faulting. Therefore, engineers have for many years used joint seals to minimize passage of surface water through joints.

Another accepted function of joint sealants is to prevent incompressible material from entering the joint reservoir. Incompressibles contribute to spalling by obstructing pavement expansion in hot weather, which causes pressure along the joint faces during joint closure.

In recent years, engineers and contractors have begun questioning the cost-effectiveness of sealing joints in concrete pavement. Several state agencies have recently begun using the strategy of providing a permeable subbase to control water within the pavement structure and then using a joint "filler" to minimize incompressible infiltration into the joints. This approach does not rely on the joint filling material to prevent moisture infiltration. One state agency has become an advocate for eliminating sealing altogether and has research data justifying their no-seal policy.

Considering this potential change in philosophy and practice, this report provides background information on the use of joint sealants in transverse contraction joints by highway agencies. This paper contains the present practices of each state agency and discussion of the relative cost of sealants.

HISTORY & BACKGROUND

Sealant use dates back to the early 1900's. [1,2] Today, 98% of the state agencies building and maintaining concrete roadways, and all U.S. agencies building and maintaining concrete airport pavements, require joint sealing for new pavements.

The most widely accepted definition of the purpose of joint sealant is to <u>minimize</u> infiltration of surface water and incompressible material into the joint system. [3] Sealants also reduce the potential for dowel bar corrosion by reducing entrance of de-icing chemicals. Some individuals erroneously claim that joint sealant <u>prevents</u> surface water

[1] Director of Technical Services, American Concrete Pavement Association, Skokie, IL

from entering the joint system. Vacuum tests clearly show that no sealant will provide a perfectly watertight seal. [4]

There is no doubt that water can contribute to subgrade or subbase softening, and lead to pumping of subgrade or subbase fines. This degradation usually results in loss of structural support, pavement settlement and/or faulting. [3,5,6] Unfortunately it is not practical to construct and continually maintain a completely watertight pavement. Therefore the prevailing current practice for highways uses joint sealants to minimize passage of surface water through joints and also provides a permeable subbase to remove water from the pavement.

Another important function of joint sealants is to prevent incompressible material from entering the joint reservoir. [3,7] Incompressibles may contribute to spalling and in extreme cases may induce "blow-ups." In either case, the incompressibles may obstruct pavement expansion in hot weather and cause pressure along the joint faces.

Years ago, the term "joint fillers" described the materials placed in pavement joints. In fact, some specifications still refer to joint sealants as joint fillers. The expectation of filler materials was more to keep out incompressibles than to minimize water infiltration. It appears that sometime in the 1970's there was a switch in expectations on joint fillers. The new expectation that joint fillers would also prevent water infiltration was likely a result of the competitive claims of the increasing variety of available sealing materials. The word sealant became more common and in essence clearly defined a switch in expectations.

CURRENT PRACTICE

Table 1 provides the detailed information on the history and practice of each state highway agency for subbases and joint sealing over the past 25 years[2]. The current information was gathered in part from a telephone survey of state highway agency personnel and local industry representatives. Some entries also reflect information from agency specification books and common knowledge of well-established practices. Reference 8-10 provide more information on practices through 1992.

As agency practices do change from time-to-time, there may be some errors in the table that are the result of alterations in state practice. Judgment was also necessary to qualify the varied practice of some agencies. It was particularly difficult to narrow the practice of certain state agencies that allow many pavement design decisions to occur at their district level. Judgments were also necessary to discern the prevalent practice of agencies that use different designs for their urban concrete pavement than their rural concrete pavement, or different designs for their state highway pavement than their interstate pavement.

[2] The key for the entries in Table 1 is found after the table.

Table 1. Predominate subbase, joint design & sealant usage on transverse contraction joints in concrete pavement highways. Historical information from references 8, 9 and 10. Current information from survey of selected state DOT and local industry engineers.

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing (ft)	Reinf. Joint Spacing (ft)	Min. Reservoir Width (in.)	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Preformed	Current Standard Sealant
Alabama	1972	DG, AT,CT		20	57.5	0.3750	0.25 d	D-1190	-	-	-	
	1982	DG, AT,CT		20	-	0.3750	0.33 d	D-1190	-	X	D-2628	
	1992	DG, AT,CT		20	-	0.3750	0.33 d	D-1190	-	X	D-2628	
	1996		**ATPB**									**Silicone**
Arizona	1972	DG, CT		15	-	0.2500	0.22 d	D-1190	-	-	D-2628	
	1982	DG, CT, LC		15 av.	-	0.1250	0.25 d	D-3406	D-1850	-	-	
	1992	DG, AT		15 av.	-	0.1250	0.25 d	-	-	X	-	
	1996		**DG**									**Silicone**
Arkansas	1972	DG, CT		-	45	0.1875	0.25 d	D-1190	-	-	-	
	1982	DG, AT, CT		15	45	0.3750	0.33 d	-	-	X	D-2628	
	1992	OG, ATPB, CTPB		15	45	0.3750	0.33 d	-	-	X	D-2628	
	1996		**CTPB**									**Silicone**
California	1972	DG, AT, CT		15.5 av.	-	0.2500	0.21 d	Used only where roads are sanded			-	
	1982	DG, CT, LC, AT		15.5 av.	-	0.2500	0.25 d	Used only where roads are sanded			-	
	1992	DG, CT, ATPB		15.5 av.	-	0.5000	0.33 d	-	-	X	-	
	1996		**LC**			**0.25**		**D-3405 mod.**				**Hot-Pour**
Colorado	1972	DG, AT, CT		15.5 av.	-	0.1250	0.25 d	D-1190	-	-	-	
	1982	DG, CT, LC, AT		15.5 av.	-	0.2500	0.25 d +0.25"	D-1190	D-1850	-	D-2628	
	1992	DG, AT		15.5 av.	-	0.1250	0.25 d	-	-	X	-	
	1996		**DG**									**Silicone**
Conn.	1972	DG		-	40	0.3750	0.33 d	D-1190	-	-	-	
	1982	DG, CT		-	40	0.3750	0.33 d	D-1190	X	-	X	
	1992	DG, CT		-	40	0.3750	0.33 d	D-1190	-	X	-	
	1996		**CT**									**Silicone**

Table 1. Continued (2 of 7)

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing (ft)	Reinf. Joint Spacing (ft)	Min. Reservoir Width (in.)	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Pre-formed	Current Standard Sealant
Delaware	1972	DG, CT		-	45	0.1875	0.25 d +0.25"	D-1190	-	-	D-2628	
	1982	DG, CT		-	45	0.1875	0.25 d +0.25"	D-1190	-	-	D-2628	
	1992	DG, CT		20	-	0.5000	0.25 d +0.25"	D-1190	-	-	D-2628	
	1996		**CT w/ ATPB**					**D-3405**				**Hot-Pour**
Florida	1972	AT		20	-	0.3750	0.28 d	D-1190	-	-	-	
	1982	DG, CT, LC		15	-	0.2500	0.25 d	D-1190	-	-	D-2628	
	1992	AT, OG		15.5 av.	-	0.3750	0.25 d	D-1190	-	-	D-2628	
	1996		**OG**									**Silicone**
Georgia	1972	CT, AT		19.5 av.	-	0.1875	0.25 d	SS-1401	-	-	-	
	1982	DG, CT, LC		20	-	0.3750	0.28 d	SS-1401	-	X	-	
	1992	DG, CT, LC, AT		20	-	0.5000	0.20 d	-	-	X	-	
	1996		**LC**									**Silicone**
Idaho	1972	CT		15 av.	-	0.2500	0.25 d	-	-	-	D-2628	
	1982	DG, AT, CT		15 av.	-	0.2500	0.25 d	Used only where roads are sanded			-	
	1992	DG, AT, CT		15 av.	-	0.2500	0.25 d	-	-	X	-	
	1996		**ATPB**									**Silicone**
Illinois	1972	LT, CT, AT		-	100	0.1250	0.28 d	D-1190	D-1850	-	-	
	1982	LT, CT, LC, AT		-	50	0.6250	0.28 d	D-3405	-	-	-	
	1992	CT, AT, ATPB		15 hinge	45	0.625/0.25	0.28 d	D-3405	-	-	D-2628	
	1996		**AT**									**Preformed**
Indiana	1972	DG, AT		-	40	0.1250	0.25 d	D-1190	D-1850	-	-	
	1982	DG, AT		-	40	0.2500	0.25 d	D-1190	-	-	D-2628	
	1992	DG, OG		20	-	0.2500	0.25 d	-	-	X	D-2628	
	1996		**OG**									**Silicone**
Iowa	1972	DG, AT, CT		20	-	0.1250	0.25 d	D-1190	-	-	-	
	1982	DG		20	-	0.1250	0.25 d	D-3405	-	X	-	
	1992	OG		20	-	0.3750	0.33 d	D-3405	-	X	-	
	1996		**OG**			**0.25**		**D-3405 mod.**				**Hot-Pour**

Table 1. Continued (3 of 7)

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing (ft)	Reinf. Joint Spacing (ft)	Min. Reservoir Width (in.)	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Pre-formed	Current Standard Sealant
Kansas	1972	DG		-	61.5	0.3750	0.25 d	X	-	-	-	
	1982	DG, AT, CT		-	30	0.3750	0.25 d	X	-	-	X	
	1992	DG, CT, ATPB, CTPB		15	-	0.3750	0.25 d	X	-	X	-	
	1996		CT									Preformed
Kentucky	1972	DG		-	50	0.1250	0.20 d	D-1190	-	-	-	
	1982	DG, CT		-	25	0.3750	0.20 d	D-1190	-	-	D-2628	
	1992	DG, LT, CT		15 av.	-	0.2500	0.20 d	D-3405	-	X	D-2628	
	1996		DG									Silicone
Louisiana	1972	DG, AT, CT		20	58.5	0.4375	-	-	-	-	D-2628	
	1982	DG, AT, CT		20	-	0.4375	-	X	X	X	D-2628	
	1992	AT, CT		20	-	0.4375	-	-	-	-	D-2628	
	1996		DG w/ AT									Silicone
Maine	1972	DG		-	-	-	-	-	-	-	-	
	1982	DG		20	-	0.5000	0.25 d	SS-S-1401	-	-	-	
	1992	DG		20	-	0.5000	0.25 d	SS-S-1401	-	-	-	
	1996		DG									Hot-Pour
Maryland	1972	DG		-	40	0.2500	0.25 d	D-1190	D-1850	-	D-2628	
	1982	DG		-	40	0.2500	0.25 d	D-1190	D-1850	-	D-2628	
	1992	DG, AT, CT, ATPB		Continuously Reinforced only				-	-	-	-	
	1996		ATPB									-
Mass.	1972	DG		-	40	0.3750	0.25 d	D-3406	-	-	-	
	1982	DG		-	40	0.3750	0.25 d	D-3406	-	-	-	
	1992	DG		-	40	0.3750	0.25 d	D-3406	-	-	-	
	1996		DG									Hot-Pour
Michigan	1972	DG		-	71.17	0.5000	0.25 d	-	-	-	D-2628	
	1982	DG, OG		-	41	0.5000	0.25 d	D-1190	D-1850	-	D-2628	
	1992	OG, AT, CT, ATPB		-	41	0.5000	0.25 d	-	-	-	D-2628	
	1996		ATPB									Preformed

Table 1. Continued (4 of 7)

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing (ft)	Reinf. Joint Spacing (ft)	Min. Reservoir Width (in.)	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Pre-formed	Current Standard Sealant
Minn.	1972	DG		20	27	0.3750	0.25 d	D-1190	-	-	D-2628	
	1982	DG		15.5 av.	27	0.3750	0.25 d	D-1190	-	-	D-2628	
	1992	DG, OG		15.5 av.	27	0.3750	0.25 d	D-1190	-	X	-	Silicone
	1996		OG									
Miss.	1972	CT, AT		-	63.75	-	-	D-1190	-	-	-	
	1982	CT, AT		-	-	-	-	D-1190	-	-	D-1751	
	1992	CT, AT		16	-	0.3750	0.33 d	D-1190	-	X	-	Silicone
	1996		AT									
Missouri	1972	DG		30	61.5	0.3750	0.25 d	D-1190	-	-	-	
	1982	DG		30	61.5	0.3750	0.25 d	D-1190	-	-	-	
	1992	DG, OG		30	61.5	0.3750	0.25 d	D-1190 mod.	-	-	-	Hot-Pour
	1996		DG									
Montana	1972	CT, AT		15.5 av.	-	0.1250	0.25 d	D-3406	-	-	-	
	1982	CT, AT		15.5 av.	-	0.1250	0.25 d	D-3406	-	-	-	
	1992	DG, AT, CT		15.5 av.	-	0.1250	0.50 d	D-3405	-	-	-	Hot-Pour
	1996		DG w/ CT									
Nebraska	1972	DG, CT		15	46.5	0.1250	0.25 d	D-1190	-	-	-	
	1982	DG, CT		15.5 av.	46.5	0.1250	0.25 d	D-1190	-	-	D-2628	
	1992	DG, CT		16.5	-	0.1250	0.25 d	D-3405	-	-	-	Silicone
	1996		DG									
Nevada	1972	CT		15.5 av.	-	0.1250	0.22 d	X	-	-	X	
	1982	CT		15.5 av.	-	0.1250	0.25 d	X	-	-	-	
	1992	CTPB, ATPB		15.5 av.	-	0.1250	0.25 d	-	-	X	-	Silicone
	1996		ATPB									
New Jsy.	1972	OG		-	78.17	-	-	X	-	-	-	
	1982	OG		-	78.17	-	-	X	-	-	-	
	1992	OG		-	78.17	-	-	X	-	-	-	Hot-Pour
	1996		OG									

Table 1. Continued (5 of 7)

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing (ft)	Reinf. Joint Spacing (ft)	Min. Reservoir Width (in.)	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Pre-formed	Current Standard Sealant
New Mex.	1972	CT		20	-	0.2500	0.22 d	D-1190	D-1850	-	-	
	1982	CT, AT		15.5 av.	-	0.2500	0.25 d	D-1190	D-1850	X	-	
	1992	ATPB		13.5 av.	-	0.2500	0.25 d	D-1190	-	X	-	
	1996		ATPB									Silicone
New York	1972	DG		-	60.8	0.6250	0.22 d	-	-	-	D-2628	
	1982	DG		-	60.8	0.3750	0.22 d	X	-	-	D-2628	
	1992	DG, OG		20	-	0.3750	0.33 d	-	-	X	D-2628	
	1996		OG									Preformed
N. Carol.	1972	DG		30	-	0.3175	0.25 d +0.25"	D-1190	-	-	D-2628	
	1982	DG, CT, LC, AT		21.5 av.	-	0.3175	0.25 d +0.25"	-	-	X	D-2628	
	1992	ATPB		21.5 av.	-	0.3175	0.25 d +0.25"	-	-	X	-	
	1996		ATPB									Silicone
N. Dakota	1972	AT		20	-	0.3750	0.34 d	D-1190 mod.	-	-	D-2628	
	1982	DG, LC		16 av.	-	0.2500	0.25 d	D-1190 mod.	-	-	D-2628	
	1992	DG, ATPB, CTPB		13.5 av.	-	0.3175	0.25 d	D-1190 mod.	-	X	D-2628	
	1996		DG w/ CTPB									Silicone or Preformed
Ohio	1972	CG, AT, CT		17	40	0.2500	0.20 d	D-1190	X	-	D-2628	
	1982	CG, AT, CT		17	21	0.2500	0.20 d	D-1190	X	-	D-2628	
	1992	CG, AT, CT		17	-	0.6250	0.25 d	D-3405	-	X	D-2628	
	1996		CG									Preformed
Okla.	1972	AT		15	-	0.3750	0.25 d	D-1190	-	-	-	
	1982	AT		15	-	0.3750	0.25 d	-	X	X	D-2628	
	1992	ATPB, CTPB		15	-	0.3750	0.25 d	-	X	X	D-2628	
	1996		ATPB									Silicone
Oregon	1972	DG, AT, CT		-	61.5	1.1250	0.25 d	D-1190	-	-	D-1751	
	1982	AT, CT, LC		Continuously Reinforced only				-	-	-	-	
	1992	DG, ATPB, CT		Continuously Reinforced only				-	-	-	-	
	1996		DG w/ ATPB									-

Table 1. Continued (6 of 7)

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing	Reinf. Joint Spacing	Min. Reservoir Width	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Pre-formed	Current Standard Sealant
				(ft)	(ft)	(in.)						
Penn.	1972	DG		-	46.5	0.3750	0.25 d	D-3406	-	-	-	
	1982	DG, AT, CT, LC		20	40	0.5000	0.25 d	D-3405	-	-	D-2628	
	1992	DG, AT, CT, LC, Rub		15	-	0.5000	0.25 d	D-3405	-	X	D-2628	
	1996		**DG w/ OG**									**Preformed**
Rhode Is.	1972	DG		-	40	0.2500	0.25 d	D-1190	-	-	-	
	1982	DG		-	40	0.2500	0.25 d	D-1190	-	-	-	
	1992	DG		-	40	0.2500	0.25 d	D-1190	-	-	-	
	1996		**DG**									**Hot-Pour**
S. Carol.	1972	DG, AT, CT		21.5 av.	-	0.2500	0.22 d	D-1190	-	-	-	
	1982	CT, LC		21.5 av.	-	0.3750	0.25 d	D-1190	-	X	-	
	1992	ATPB, CTPB		20	-	0.3750	0.33 d	D-1190	-	X	-	
	1996		**ATPB**									**Silicone**
S. Dakota	1972	DG, AT, CT		20	-	0.2500	0.25 d	D-1190	-	-	D-2628	
	1982	LT		15	-	0.3750	0.25 d	D-1190	-	X	-	
	1992	LT, DG		20	-	0.3750	0.25 d	D-3405	-	X	-	
	1996		**DG**									**Silicone**
Tenn.	1972	DG, AT, CT		25	-	0.2500	0.22 d	D-1190	X	-	D-2628	
	1982	DG, CT, LC		15.5 av.	-	0.3750	0.25 d	D-1190	-	-	D-2628	
	1992	DG, AT, CT, LC		15.5 av.	-	0.3750	0.25 d	D-1190	-	X	D-2628	
	1996		**AT**									**Silicone**
Texas	1972	AT, CT		15	60	0.5000	0.25 d	X	X	-	D-2628	
	1982	AT, CT		15	-	0.5000	0.25 d	X	-	X	-	
	1992	AT, CT		15	-	0.5000	0.25 d	X	-	X	D-2628	
	1996		**AT**									**All - by district**
Utah	1972	DG, CT		15 av.	-	0.1250	0.25 d	D-3406	-	-	-	
	1982	DG, LC		15 av.	-	0.1250	0.33 d	D-3406	-	-	-	
	1992	DG, LC		15 av.	-	0.1250	0.33 d	D-3406	-	-	-	
	1996		**LC**									**Silicone**

Table 1. Continued (7 of 7)

State	Year	Allowable Base Types	Predominate Base Type	Plain Joint Spacing (ft)	Reinf. Joint Spacing (ft)	Min. Reservoir Width (in.)	Min. Joint Depth	Allowable Hot-pour	Allowable Cold-Pour	Allowable Silicone	Allowable Pre-formed	Current Standard Sealant
Vermont	1972	DG		-	-	0.2500	0.20 d	D-1190	X	-	-	
	1982	DG		-	-	0.2500	0.20 d	D-1190	X	-	-	
	1992	DG		-	-	0.2500	0.20 d	D-1190	X	-	-	
	1996		**DG**									**Hot-Pour**
Virginia	1972	CT		20	40	0.3750	0.25 d	D-1190	D-1850	-	D-1056	
	1982	DG, CT, LC		20	40	0.6250	0.25 d +0.25"	D-1190	-	-	D-142	
	1992	ATPB, CTPB		15	-	0.2500	0.25 d	-	-	X	-	
	1996		**CTPB**									**Silicone**
Wash.	1972	DG, AT		20	-	0.1250	0.17 d	D-1190	D-1850	-	-	
	1982	DG, AT		11.5 av.	-	0.1250	0.17 d	D-1190	D-1850	-	-	
	1992	DG, ATPB		11.5 av.	-	0.1250	0.25 d	D-1190	-	-	M-220	
	1996		**ATPB**									**Hot-Pour**
W. Va.	1972	DG, AT, CT		-	61.5	0.2500	0.25 d	D-1190	-	-	D-2628	
	1982	DG, AT, CT		-	40	0.2500	0.25 d	D-1190	-	X	D-2628	
	1992	DG, ATPB, CTPB		15	-	0.2500	0.25 d +0.25"	D-3405	-	X	D-1056	
	1996		**ATPB**									**Silicone**
Wisc.	1972	DG, AT		-	80	0.2500	0.20 d	D-1190	-	-	-	
	1982	DG		15.5 av.	40	0.2500	0.25 d	-	-	X	D-2628	
	1992	DG, ATPB, CTPB		15.5 av.	-	0.2500	0.25 d	No sealant used in any pavement			-	
	1996		**CTPB**									**None**
Wyoming	1972	DG, CT		15.5 av.	-	0.1250	0.22 d	D-1190	-	-	D-2628	
	1982	DG, CT		13.75 av.	-	0.3750	0.25 d	D-1190	-	X	-	
	1992	DG, CT, CS		13.75 av.	-	0.3750	0.25 d	D-1190	-	X	D-2628	
	1996		**DG**									**Preformed**

Note: Key for the entries in this table is found on the next page.

Key for entries in Table 1:	
DG = Dense-graded aggregate or crushed stone	**X** = Either data not available, or no ASTM or AASHTO specification exists
CG = Clean gravel	**D-1190** = ASTM D-1190 or AASHTO M-173 Hot-poured polymeric asphalt-based
LT = Lime treated	**SS-S-1401** = Fed. SS-S-1401 Hot-poured polymeric asphalt-based
AT = Asphalt treated	**D-3405** = ASTM D-3405 or AASHTO M-301 Hot-poured polymeric asphalt-based
CT = Cement treated	**D-3405 mod.** = ASTM D-3405 mod. Hot-p. polymeric asphalt-based (low modulus)
LC = Lean concrete or econocrete	**D-3406** = ASTM D-3406 or Fed SS-S-1614 Elastomeric PVC coal tar
OG = Open-graded granular	**D-2628** = ASTM D-2628 or AASHTO M-220 Preformed Polychloroprene elastomeric joint seal
ATPB = Asphalt-treated permeable subbase	
CTPB = Cement-treated permeable subbase	**d** = depth or thickness of concrete slab.

Sealants

Today, the most common joint sealant remains the hot-pour liquid sealant. Hot-pour liquid sealants were the first type used for concrete pavement, and have evolved over many years of research and development. [1,2] Manufacturers have improved their adhesive qualities and now provide low-modulus materials with better elasticity than previous materials. About 25% of roadway agencies use hot-pour sealants in transverse joints of highway pavements. However, most of the hot-pour sealants sold by manufacturers are used in low-volume concrete roads and highway pavement longitudinal joints.

Silicone sealants are a field-poured liquid with a base ingredient of silicone polymer. Agencies began using these materials in the 1970's. [11] Installation procedures are similar to those for hot-pour materials. Much care is necessary to clean and prepare the joint reservoir for silicone sealants. About 52% of roadway agencies now use silicone sealant in their highway pavement transverse joints.

Manufacturers introduced compression seals in the early 1960's. They differ from liquid sealants because they are manufactured ready for installation. Unlike liquid sealants, which experience both compression and tension, preformed compression seals are in compression throughout their life. Therefore their success depends solely on the lateral pressure exerted by the seal. Compression seals are often called "neoprene" seals after the seal's primary compound. Today, 21% of roadway agencies use compression seals in their highway pavement transverse joints.

Presently, the Wisconsin DOT is the only roadway agency that does not use any sealant to seal transverse joints in their concrete pavements. Wisconsin started this practice in about 1990 after several long-term in-state studies concluded that sealants had no positive impact on pavement performance. [12,13] In the last 25 years, Idaho and California are the only other states to have ever had a policy not to seal joints. [8] These two states only sealed joints in mountainous areas where they use sand for traction control. Idaho used this practice for about ten years. Omitting joint sealants or fillers from the design was a long-standing practice of CALTRANS. Today both agencies require a sealant for transverse contraction joints in all new concrete pavements.

In Europe joint sealing practices also vary widely. The British require a reservoir cut and sealant in all pavement joints. Austria allows some joints to be cut narrow and left unsealed. Spain, allows unsealed joints in the dry regions, but requires a sealant in the wet regions. [14]

Subbases & Drainage Philosophy

An important aspect of pavement design is the consideration of drainage. This is because water will always be a potential contributor to pavement distress. In the past, almost all concrete pavement designs included relatively impermeable materials surrounding the pavement layers. These "bathtub" pavement sections were particularly prone to moisture-related problems. The need to minimize surface water infiltration in these pavements was an important factor that focused attention on joint sealing.

Table 2 reflects state highway agency concerns regarding drainage and indicates their current drainage philosophy. [8] Presently, almost two-third of all state agencies attempt to both seal the pavement and control water through a drainage system.

Table 2. State agency drainage philosophies. [8]

STATED PHILOSOPHY	NUMBER OF AGENCIES
Attempt to seal pavement as well as possible and are not to concerned about subsurface drainage	9
Take position that water will enter the pavement and attempt to control the water through use of:	
• Drainage Layer	4
• Other Subsurface Drainage	5
• Both	2
Attempt to seal pavement as well as possible and attempt to control the water through use of:	
• Drainage Layer	7
• Other Subsurface Drainage	3
• Both	20

Note: Some states use more than one philosophy depending on the situation.

In recent years the concern for drainage has led to a significant shift in the expectations placed on subbase materials. In the past, subbases were primarily expected to provide uniform support to the pavement and to serve as a platform for construction. Aiding load transfer and promoting drainage, were only secondary requirements of subbase materials.

Today, the permeability of subbases is a primary requirement and the subbase layer is an integral part of the pavement drainage system. Permeable subbases use a uniform grading that leaves voids for water passage. In theory, water that gets under a pavement will flow quickly through a permeable subbase to an edge drain system. The drainage system pipes carry the water away from the pavement to ditches or storm sewer pipes.

According to our survey, permeable subbases are the predominate subbase used by 50% of roadway agencies for highway pavements. The use of permeable subbase use has grown to 24 states from just 2 states over a ten year period; they now seem accepted by most designers as the best approach to remove water from a pavement system and to attempt to maximize pavement performance. Table 3 shows the types of permeable subbases currently in use in the United States.

Table 3. Permeable subbase use in the United States.

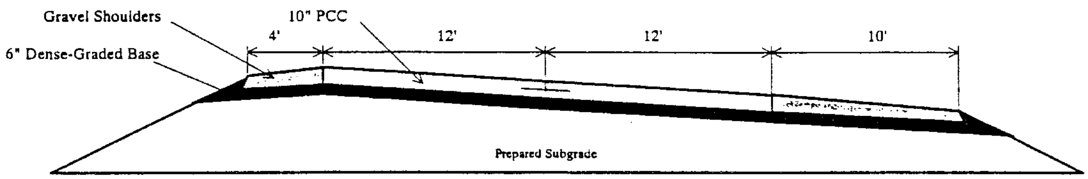
PREDOMINATE PERMEABLE SUBBASE	NUMBER OF STATES
Open-graded Granular	7
Asphalt-treated	13
Cement-treated	4

RELATIVE COST OF SEALANTS

To begin to define the relative cost of sealing joints we included a joint sealant evaluation section in a recent survey regarding pavement design features. We sent the survey to thirty contractor members of the American Concrete Pavement Association (ACPA) and have received 12 replies. The survey asked the contractors to estimate the cost of four different cross-sections based locally available materials. Figure 1 shows the reference section and the comparison sections.

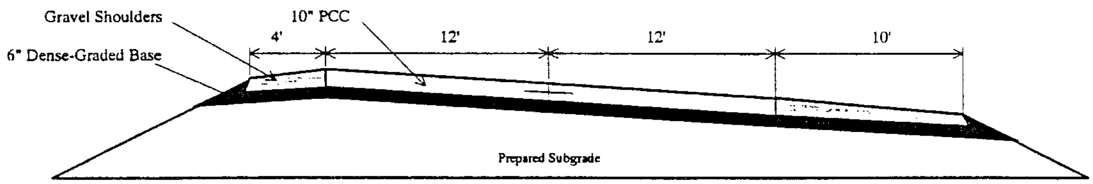
The relative cost for the reference section was set at 100%. The reference section consists of a typical rural multilane divided highway with two 250-mm (10-in.) thick by 3.6-m (12-ft) wide lanes tied together with #10M (0.5-in. diameter) deformed tie bars 750 mm (30 in.) on centers. The transverse joints are at a uniform 6 m (20 ft) spacing and are neither skewed nor doweled. All joints in the reference section have a single-width saw cut to a depth of 75 mm (3 in.) and are filled with a hot-poured filler (sealant). The shoulders are gravel, 3 m (10 ft) wide on the right side and 1.2 m (4 ft) wide on the left side. The concrete slabs rest on a dense-graded, crushed-aggregate, subbase layer compacted to 150 mm (6 in.) thick. The subgrade for the pavement consists of soil scarified to depth of 150 mm (6-in.) and recompacted at optimum moisture content.

Figure 1. Reference and comparison cross-sections used for survey of contractors.

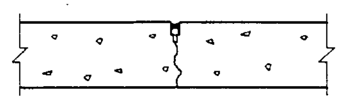


Reference Section

- Typical rural multilane divided highway with two 10" thick by 12' lanes tied with #4 deformed tie bars 30" oc.
- Transverse joints at a uniform 20' spacing with no skew no and no dowels.
- All joints have single-width saw cut to a depth of 3" with hot-poured asphaltic filler.
- Gravel shoulders, 10' wide on the right side and 4' on the left side.
- Dense-graded crushed-aggregate base layer compacted to 6" thick.
- Subgrade prepared by scarifying to depth of 6" and recompacting at optimum moisture content.

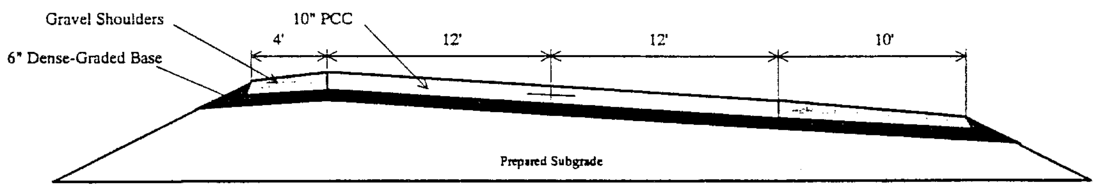


Silicone Sealant

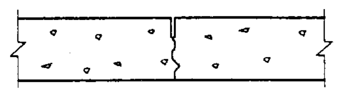


Same as reference section except:

- Widened cut to 1" depth with backer rod and silicone sealant.

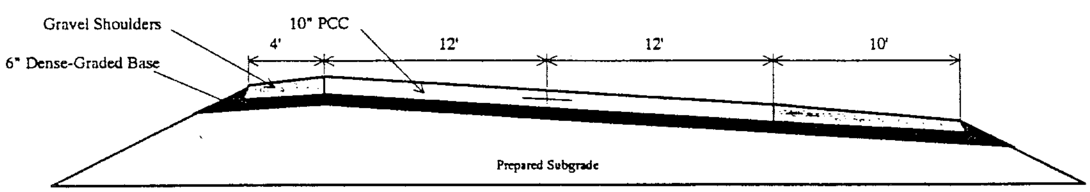


Unsealed

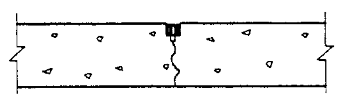


Same as reference section except:

- No joint sealant of filler.



Preformed Compression Seal



Same as reference section except:

- Widened cut to 1" depth with preformed compression seal.

Table 4 shows the results of the survey. On average, the additional cost on an entire pavement section is about 7.0% when comparing unsealed joints to those sealed with compression seals. The additional cost for joints sealed with silicone compared to unsealed joints is about 4.5%, and about 2.2% for joints sealed with hot-pour sealants versus unsealed joints.

Table 4. Tabulation of pavement design features survey of pavement contractors showing the relative costs of joint sealants to a reference section using hot-pour as a filler.

JOINT SEALANT DESIGN	AVERAGE RELATIVE COST
Hot-pour sealant in a 3-inch deep single-width saw cut (20-ft. joint spacing)	100%
Silicone sealant with backer rod in an appropriate reservoir (20-ft joint spacing)	102.3%
Unsealed single-saw cut (20-ft joint spacing)	97.8%
Preformed-compression seal in an appropriate reservoir (20-ft joint spacing)	104.8%

DISCUSSION

There remain many questions on the effects of both sealants and permeable subbases on concrete pavement longevity. Certainly, the current drainage philosophy of most state highway agencies suggests that any measure they can take to reduce the influence of moisture is beneficial. However, a growing concern exists to optimize the cost of concrete pavement, and one area of concern is the cost-effectiveness of joint sealing.

It is logical that a permeable subbase may negate the need to seal joints for surface water control. Certainly, if the subbase efficiently removes water, there is no need to prevent water from entering the pavement. However, not much information on the benefit or longevity of permeable subbases is currently available. Some of the only long-term performance information on unsealed joints on a permeable subbase is from France. After 10 years the French found that the permeable subbase materials clogged with dust and debris. [15] They attributed this partially to the unsealed joints.

The outlet systems for permeable subbases require frequent maintenance for satisfactory performance. Without cleaning, the drain pipes and outlets easily clog with debris and prevent the water from flowing out of the pavement. It is reasonable to question if the DOT's will maintain these systems over the life of the pavements.

Despite the growing use of permeable subbases, water will always remain a potential contributor to pavement distress. Perhaps this fact alone will continue to define the expectations that many engineers will place on joint sealant performance. It certainly contributed to the current expectation that sealants must minimize passage of surface water, in addition to keeping out incompressibles from the joints. It remains debatable whether this expectation is too high for some classes of sealing materials. Never-the-less, the need to minimize water infiltration should remain a primary focus for many concrete pavements. Designs that include relatively impermeable layers will continue to exist, particularly for low-volume roads and streets.

Incompressibles will also remain a potential contributor to pavement distress. Incompressibles that get into open joint reservoirs can cause spalling upon joint closure. While spalling is less likely on slabs less than 6 m (20 ft), studies show that joint filling does reduce joint spalling even on short-panel pavements. [6] This issue deserves more study to determine if sealing reduces spalling enough to be cost-effective. Most of the past studies were made on jointed reinforced concrete pavements with slab lengths considerably longer than the 4.5-6.0 m (15-20 ft) lengths common today.

The presence of incompressibles in a joint would be insignificant if concrete did not expand and contract with variations in temperature. We normally look at how a concrete's constituent materials will affect its strength and plastic properties. Equally important are how these materials influence the concrete's thermal behavior. It is well known that the type of coarse aggregate will influence the concrete thermal coefficient. Concrete made from gravel or quartz aggregates will expand or contract to a greater degree than a concrete made with limestone. Presumably, concrete made with limestone will be more tolerant of the presence of incompressibles in the joint system. This factor has not been studied in any research on performance of concrete pavements.

The influence of incompressibles on narrow joint reservoirs, 3 mm (1/8 in.), also remains unclear. It is reasonable that the narrow reservoir will keep some larger incompressibles out of the joint, but the joint may still pack full of smaller materials. The literature does not provide any studies that indicate that incompressible particle size influences the occurrence of spalling.

Improvements in technology over the past 20 years have produced some effective sealing materials and procedures. Correct sealant application and installation can produce good results. However, some state highway agencies suggest that attaining correct sealant application and installation is a significant challenge. Down-sizing and attrition has left these highway agencies with a smaller and less experienced field inspection force.

As a result of poor performing sealants, some state highway agencies are switching to better quality sealants, and some are returning to the joint filler approach. Several agencies also have in-state research projects that they will use to compare sealed joints to unsealed joints.

CONCLUSIONS

There are a variety of materials for sealing transverse contraction joints in concrete pavements. The following conclusions can be drawn from the survey of state agency practice and the discussion of the primary factors for sealing transverse joints in concrete pavement:

1. Silicone sealants are the most common joint sealant for transverse contraction joints in concrete highway pavements. They are used by 52% of the state highway agencies.

2. Twenty-five percent of the state agencies use hot-pour sealants and 21% use preformed compression sealants.

3. Almost two-third of the state highway agencies attempt to both seal pavement joints and provide a drainage system to control the influence of water on their concrete highway pavements. Only 11 of the 50 state agencies take a position that water will enter their pavement system and are not too concerned about the effectiveness of sealing joints.

4. Permeable subbases are predominately used for highway pavements by nearly 50% of state highway agencies.

5. Enough questions remain unanswered on both the cost-effectiveness of sealing short-panel concrete pavements and the long-term performance of concrete pavement on permeable subbases to support more research.

ACKNOWLEDGEMENTS

The author extends special thanks to the many people he talked to on the telephone to complete the state practices table in this publication - they were to numerous to practically provide in the references.

REFERENCES

1. Tons, E., "A Theoretical Approach to Design of a Road Joint Seal," Highway Research Record 211, Highway Research Board, National Research Council, Washington DC, 1959.

2. "Methods of Forming Joints in Portland Cement Concrete Pavement," Draft Report, Subcommittee on Joint Forming, Highway Research Board, 1961.

3. "Joint and Crack Sealing and Repair for Concrete Pavements," American Concrete Pavement Association, TB-012P, Arlington Heights, IL, 1991.

4. Wojakowski, J.B., "Joint Sealant Test Sections - US 36 Doniphan County," NEPT KS-8904, Kansas Department of Transportation, Unpublished Research Data, 1991.

5. Ray, G.K., "Effect of Defective Joint Seals on Pavement Performance," Transportation Research Record 752, Transportation Research Board, National Research Council, Washington DC, 1980, pp. 1-2.

6. "Performance of Jointed Concrete Pavements," Volume I - Evaluation of Concrete Pavement Performance and Design Features, FHWA-RD-89-136, Federal Highway Administration, McClean, VA, March 1990.

7. McBride, J.C., Decker, M.S., "Performance Evaluation of Utah's Concrete Pavement Joint Seals," Transportation Research Record 535, Transportation Research Board, National Research Council, Washington DC, 1975, pp. 35-50.

8. McGhee, K.H., "Design, Construction, and Maintenance of PCC Pavement Joints," Synthesis of Highway Practice 211, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington DC, 1995.

9. "A Charted Summary of Concrete Highway Pavement Practices in the United States - 1982," IS201.02P, Portland Cement Association, Skokie, IL, 1982.

10. Design, Construction, and Maintenance of PCC Pavement Joints," Synthesis of Highway Practice 19, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington DC, 1973.

11. Darter, M.I., Carpenter, S.H., Zimmer, T.R., "Field Performance of a Low-Modulus Silicone Highway Sealant," Transportation Research Record 990, Transportation Research Board, National Research Council, Washington DC, 1984, pp. 31-37.

12. Rutkowski, T.S., "Joint Sealant Study," Wisconsin Department of Transportation, May 1990.

13. Shober, S.F., "Portland Cement Concrete Pavement Performance as Influenced by Sealed and Unsealed Contraction Joints," Transportation Research Record 1083, Transportation Research Board, National Research Council, Washington DC, 1986, pp. 7-12.

14. "Report on the 1992 Tour of European Concrete Highways," FHWA-SA-93-012, Federal Highway Administration, Washington, DC, 1993.

15. Charonnat, Y.J., and others, "Concrete Pavements, Cement Concrete Overlays on Flexible Pavements in France," Compilation of Technical Reports on Concrete Pavements in France, Laboratorie Central des Ponts et Chaussees (LCPC), Paris, France, 1990.