WATERTIGHT PIPE JOINT SURVEY

Final Report

State Research Project #543

Oregon Department of Transportation

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FINAL REPORT

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by

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for

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16. Abstract

Oregon Department of Transportation (ODOT) has been specifying watertight pipes for storm sewer and some culvert pipe installations. The ODOT designer is responsible for specifying the watertight requirement, but there is no currently accepted standard for where a watertight pipe should be specified. Plastic, concrete and metal pipes are being used, and there is concern that all of the pipes do not perform equally in terms of watertightness. There are specifications for watertightness for plastic and concrete pipes, but no standard for metal pipes.

To determine the state of the practice, a literature search and electronic survey of state Departments of Transportation were performed.

Based on the results, it is recommended that ODOT develop standards for where and when watertight pipes should be required, as well as laboratory testing requirements for pipe joint systems. Test methods are readily available for testing polyethylene, concrete, and polyvinylchloride joints. AASHTO test method M 198 appears to be effective for metal pipes.

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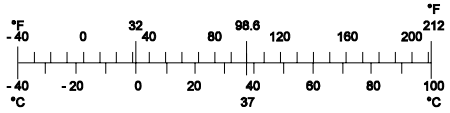
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



***** SI is the symbol for the International System of Measurement (4-7-94 jbp)

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DISCLAIMER

WATERTIGHT PIPE JOINT SURVEY

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1.0 INTRODUCTION

Historically, the Oregon Department of Transportation (ODOT) has been specifying watertight pipes for storm sewer and some culvert pipe installations. Storm sewers are typically designed to remove surface water from the highway pavement and when necessary convey additional runoff from intercepting storm sewers. Storm sewer installations are non-pressurized and are generally open on one end. A typical storm sewer design life is 50 to 75 years. Culverts are designed to convey water through a roadway embankment or past some other type of flow obstruction. Culverts are generally open on both ends with a design life of 50 years or less.

The ODOT designer is responsible for specifying the watertight requirement, however, there is no currently accepted standard for where a watertight pipe should be specified. Three types of pipes are being used by ODOT including plastic, concrete, and metal. There is concern that all of the pipes do not perform equally in terms of watertightness. There are watertight specifications for plastic and concrete pipes but no standard for metal pipes.

In order to determine the state of the practice, a literature search was performed and an electronic survey was sent to all the state Departments of Transportation (DOT's). The survey included questions about material usage and watertight joint pressure requirements. A sample survey form is included in the Appendix.

This report documents the results of the literature search and national survey.

2.0 LITERATURE REVIEW

A wide variety of literature is available regarding pipe performance, however, very little was found that addresses watertight joints. Publications from the concrete and steel pipe industry are quick to point out the limitations of polyethylene pipe, including the need for careful inspections during installation and the potential for joint separation *(ACPA 2000, ENR 1998).*

Construction and joint separation issues were confirmed in a study done in Kentucky *(Fleckenstein 1989).* This report documented the installation and performance of corrugated polyethylene pipe. The study found that the ends of the pipes at the joints were rarely butted completely together. The separations ranged to 100 mm at one joint, with 12.5 mm separations being fairly common. Deflections were also noted in some locations. The issues raised in the articles appear to be related to construction quality control and not necessarily joint design.

A report by the Louisiana Department of Transportation, *Metal Pipe Coupling Study (Law 1975)* was also reviewed. The research objectives included, among other things, evaluating test procedures and various watertight coupling systems. AASHTO Specification M 198 was used to evaluate the effectiveness of the corrugated metal pipe joints. The specification requires the system to be subjected to a hydrostatic head of 10 psi for 10 minutes. In general, the larger size of metal pipe of each type was tested first. If it passed the test, then testing on that type of pipe was ceased. The study noted problems with the deflection part of the test and recommended further review. Rivet locations were found to be a source of some leakage and arched annular corrugated metal culvert pipe joints were generally not watertight. The joint could not be made watertight due to the nature of the coupling system and the shape of the pipe.

A literature review was also included in the Louisiana study *(Law 1975).* Similar to our findings, little was found regarding watertight systems. Most states at that time followed the AASHTO requirements, however, there were no requirements for watertight systems or a test for checking watertightness.

The Washington Department of Transportation (WSDOT) completed a study on culvert joint testing in 1997. The project goal was to develop a joint leakage test that could be used to evaluate the performance of currently accepted culvert joints. The test included putting the pipe system into a basin, filling the basin with water, and monitoring the infiltration rate into the pipe system. The results were variable depending on the pipe material, coupling band and gasket type. For all pipe materials tested, however, there was at least one pipe system that did not leak *(WSDOT 1997).*

3.0 SURVEY RESULTS

In April 1999, the ODOT Research Group sent an electronic survey to research units in all the state Departments of Transportation. The individual research units were asked to forward the survey to the appropriate person in their organization for completion. Fifteen responses were received, nine via electronic mail and six via traditional mail.

3.1 TABULATED RESULTS

The first set of questions related to the material types used for culverts and storm sewers. In addition, questions were asked regarding watertight pipe joint requirements. The survey responses for these questions are presented in Table 3.1.

Table 3.1: Material Usage and Joint Requirements

State Department of Transportation	Types of Materials Allowed for Culverts [1]	Types of Materials Allowed for Storm Sewers	Watertight Joints Required for Culverts? PSI Required	Watertight Joints Required for Storm Sewers? PSI Required
Alaska	P, M, C	P, M, C	Sometimes; 10 psi	Sometimes; 10 psi
Arizona	P, M, C	P, C	No	No
Arkansas	M, C	M, C	No	No
California	P, M, C, PVC	P, M, C, PVC	Yes, 4.3 psi [9]	Yes, 4.3 psi [9]
Connecticut	P, M, C [2]	P, M, C, PVC	No	No
Georgia	P, M, C, PVC	P, M, C, PVC	No	No
Kentucky	P, M, C, PVC	M, C, PVC	No	No
Louisiana	P, M, C, PVC	P [6], C, PVC	Yes, 5 psi	Yes, 10 psi
Montana	P, M, C, PVC	M, C	No	Yes, 15 psi
New Hampshire	P, M, C, PVC [3]	P, M [7], C, PVC	No	No
New York	P, M, C, PVC	P, M, C, PVC	No	No
Ohio	M, C	P, M, C, PVC	No	No
Oregon	**P, M, C, PVC**	**P, M, C, PVC**	**Sometimes**	**Yes**
South Carolina	P, M, C, PVC [4]	P, M, C, PVC [8]	Yes, No recomm.	Yes, No recomm.
Tennessee	P, M, C	C	No	No
West Virginia	P, M, C [5]	M, C	No	No

[1] P = Polyethylene, M = Metal, C = Concrete, PVC = Polyvinylchloride
[2] Only on low ADT roadways with light truck traffic. The ban on PVC culverts is an informal internal policy in engineering.
[3] Only on roadways with ADT's < 5,000.
[4] Limited use of polyethylene culverts; metal pipes are limited to aluminum; PVC pipe use is experimental.
[5] Use is limited to special applications.
[6] Ribbed only.
[7] Moving away from metal use.
[8] Limited use of polyethylene storm sewers; metal pipes are limited to aluminum; PVC pipe use is experimental.
[9] See discussion under *California:* on page 7.

Also, as noted in Table 3.1, three states required watertight joints for culverts all of the time, with pressures of 4.3 and 5 psi. One state sometimes specified culvert watertightness, with a pressure of 10 psi, and eleven states had no watertightness requirement. Storm sewer joints are required to be watertight by four of the state DOT's all of the time with pressures ranging between 4.3 and 15 psi. One state sometimes specified storm sewer watertightness with a pressure of 10 psi; and ten states had no requirement.

Table 3.2 includes a summary of the responses noted in Table 3.1. It appears that three of the four materials are widely accepted.

Table 3.2: Summary of Survey Responses

Material	# of States that Allow Material for Culverts	# of States that Allow Material for Storm Sewers
Polyethylene	13	10
Metal	15	12
Concrete	15	15
Polyvinylchloride	8	9

An additional question was asked regarding ASTM requirements: *"ASTM requires the pipes to remain watertight when subjected to the following pressures. Do you support these?"* The responses to these questions are presented in Table 3.3.

Table 3.3: ASTM Watertight Pipe Pressure Requirements Support

State Department of Transportation	Polyethylene D3212 10.8 psi	Concrete C443 13 psi
Alaska	Yes	See note 1.
Arizona	Yes	Yes
Arkansas	No response	No response
California	No	No
Connecticut	Yes	Yes
Georgia	No	No
Kentucky	No	No
Louisiana	No	No
Montana	No	Yes
New Hampshire	NA	NA
New York	No	No
Ohio	No	No
Oregon	Yes	Yes
South Carolina	No	Yes
Tennessee	No response	No response
West Virginia	No	No

[1] Rely on AASHTO M 198 (10 psi).

Of the states that responded to the ASTM requirement questions, three supported the requirements for polyethylene pipe while nine did not. Four supported the pressure requirements for concrete pipe while seven did not.

The final survey question was: *"If you require watertight installations, do you require any kind of "field" performance testing like pressure testing?"* The following responses were received:

California: When watertight joints are shown on the plans or specified in these specifications or the special provisions, the assembled joint shall pass the following performance test without leakage at the joint:

A hydrostatic pressure test on a joint shall be made on an assembly of two sections of pipe, properly connected in accordance with the joint design. At the option of the Contractor, suitable bulkheads shall be provided within the pipe adjacent to and on either side of the joint, or the outer ends of the two joined pipe sections shall be bulkheaded. No mortar or concrete coatings, fillings, or packings in addition to that normally required for the joint shall be placed prior to water-tightness tests. After the pipe sections are fitted together with the gasket or gaskets in place, the assembly shall be subjected to a pressure resulting from a head of 10 feet of water above the crown of the pipe for 10 minutes. Moisture or beads of water appearing on the surface of the joint will not be considered as leakage. The tests on individual joints may be performed at the fabricator's facility or at the job site.

The joint watertightness test shall be performed on pipe sections in straight alignment and on pipe sections deflected from straight alignment. When testing pipe sections not on straight alignment, the pipe sections shall be positioned to create a gap on one side of the outside perimeter of the pipe that is 1/2 inch wider than the gap for pipe sections in straight alignment. When coupling bands are used to test pipe sections not on straight alignment and the maximum gap on one side of the outside perimeter of the pipe is less than 1/2 inch wider than that for pipe sections in straight alignment, said coupling band pipe sections shall be positioned to provide maximum gap.

Montana: We can require the contractor to cap the ends, attach a standpipe and fill it with water to top of standpipe. Seldom used.

Ohio: Ohio does not require watertight joints for the majority of our pipe installations. However, in areas of silty or sandy soils (Lake Erie drainage basin) we do require a tighter joint. Typically we would require the pipe to be a gasketed joint per ASTM 3212 for plastics or an elastomeric gasket for concrete or metal. We do not require pressure testing for these joints. It is extremely cost prohibitive for the intended purpose considering these are gravity flow sewers**.**

In response to the opening question "What is watertight?": The AASHTO flexible pipe liaison committee is currently working on this exact question.

Defining pipe joint performance is one area the committee is working on. If pipe performance is a critical issue in your state, I urge you, or a representative of your state, to become involved in this committee. It is a sub-committee of AASHTO Bridge Committee T-13 and state DOT involvement is inadequate. Currently only 5 states are actively involved in the committee.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Minimal information is readily available concerning the watertight pipe joint requirements. Information was found from a 1975 Louisiana study that posed the same questions as the ODOT study: What constitutes watertight? How should it be tested? When are watertight joints necessary? *(Law 1975)*. Unfortunately, these questions aren't easily answered.

Based on the study done by the Louisiana DOT, steel pipes may be watertight with the appropriate joint details *(Law 1975)*. Testing done by Louisiana, based on AASHTO M 198 indicated that helical pipe joints are difficult to seal as compared to round corrugated metal pipes that were readily sealed with gasket materials and coupling systems. Washington DOT also performed tests on several types of pipes with various coupling bands and gaskets with variable results. Oregon could perform similar tests on materials available locally to determine effective systems for metal pipes.

Ohio mentioned the only criteria which cites joints, where they require a *tighter joint* in areas of silty or sandy soils. Two test methods were identified for testing pipe joints including using AASHTO Specification M 198 for metal pipes and a joint leakage test method developed by the Washington DOT. The advantages of AASHTO M 198 is that the standards are set in terms of concrete and were shown to be transferable to metal pipe systems.

The following conclusions may be made based on the results of the survey to other state Departments of Transportation:

- Polyethlylene, metal and concrete are the materials of choice for both culverts and storm sewers. Some DOT's also allow PVC.

- Watertight pipe joints are not required for culverts and storm sewers by the majority of states that responded.

- Almost all of the DOT's that call for watertight joints require them for both culverts and storm sewers. The exceptions are Alaska, where watertight joints are sometimes required, and Montana, where only storm sewers are required to be watertight.

- Of the states that responded, the majority do not support the ASTM required pressures for watertight pipes. Of those surveyed, four support the ASTM pressure requirements for concrete pipes versus three for polyethylene to be watertight.

- California described the only field test mentioned. Also, Montana can require the contractor to cap the ends, attach a standpipe and fill the water to the top of the standpipe. The respondent noted, however, that the method is seldom used.

Based on the results of the survey, it appears that ODOT may be over-specifying the use of watertight joints, most likely at a cost to the Department. In addition, without test procedures to validate the effectiveness of the pipe joint systems, ODOT may not be getting the watertight pipes they have requested.

4.2 RECOMMENDATIONS

- Criteria for where and when watertight installations are necessary should be established based on Oregon conditions. The Roadway Engineer should establish the criteria.

- Pipe joint systems should be tested in the laboratory to determine if the system is watertight. Passing joint systems will be included on the ODOT Qualified Products List. The following specifications with corresponding required pressures are recommended (Table 4.1).

Table 4.1: Recommended Laboratory Testing Requirements

Material	Specification	Pressure
Polyethylene	ASTM D3212	10.8 psi
Metal	AASHTO M 198	10 psi
Concrete	ASTM C443	13 psi
Polyvinylchloride	ASTM C990	10 psi

5.0 REFERENCES

American Concrete Pipe Association, "You Should Know" Bulletins, "DOTs Take Action Regarding Flexible Pipe". www.concrete-pipe.org/ysk , March, 2000.

Engineering News Record, *Corrugated Steel Pipe Surpasses Plastic in Culvert Installations*. Volume 241, Issue 9, September 1998.

Fleckenstein, L. John and David L. Allen, *Construction and Inspection Report on Corrugated Polyethylene Pipe, N-12.* Kentucky Transportation Center, University of Kentucky, Lexington, Kentucky, October 1989.

Law, Sheldon M., *Metal Pipe Coupling Study*, Final Report. Louisiana Department of Highways, Research and Development Section, Baton Rouge, Louisiana, November 1975.

Washington State Department of Transportation, *Culvert Joint Testing*. Olympia Service Center, Hydraulics Branch, Olympia, Washington, January 1997.

APPENDIX

Highway Drainage Questions – What is Watertight?

Please return to Liz Hunt by email:	elizabeth.a.hunt@odot.state.or.us
or mail:	Oregon Department of Transportation Research Group 200 Hawthorne SE, Suite B-240 Salem, Oregon 97301-5192

Culverts: Convey water through a roadway embankment or past some other type of flow obstruction. Culverts are generally open on both ends. They are generally used when the specifications require a 50-year or less life span.

Storm Sewers: Designed to remove surface water from the highway pavement and when necessary also convey additional runoff from intercepting storm sewers. Storm Sewer installations are non-pressurized and generally are open on one end, but might be closed on both ends. Specifications require 50 to 75-year life spans.

Questions:

1. What types of materials do you allow to be used for Culverts? Please mark the appropriate box.

	Yes	**No**
Polyethylene		
Metal		
Concrete		
PVC		

2. What types of materials do you allow to be used for Storm Sewers?

	Yes	No
Polyethylene		
Metal		
Concrete		
PVC		

3. Do you require water-tight joints with any of the following pipe installations? If so, what pressure do you require?

	Yes	No	
Culvert			psi:
Storm Sewer			psi:

4. ASTM requires the pipes to remain watertight when subjected to the following pressures. Do you support these?

Material	Method	psi	Yes	No
Polyethylene	D 3212	10.8		
Metal	None	N/A		
Concrete	C 443	13		
PVC	____	____		

5. If you require watertight installations, do you require any kind of "field" performance testing like pressure testing? If yes, please describe.