HOBAS Sewer Pipe-Joint Infiltration Leak-Rate Testing

1. ABSTRACT

While numbers of small to large older cities are undertaking repairs and maintenance, several other newer cities are planning on installing wastewater systems. Infiltration due to leaking pipes, manholes, laterals and other components of a wastewater system will add to the problem of overflow and substantially load the treatment facilities. Frequent overflows not only lead to regulatory problems but also increase the treatment cost. Leaking systems will result in the erosion of soils through the leaking joints leading to the settlement of the ground surface, formation of sinkholes and damage to surrounding pavements and structures. Literature review indicated that Standard ASTM pipe-joint tests varied with the type and size of pipe.

In order to quantify the infiltration at various types of pipe-joints, a unified testing program was developed to test 30-in. diameter sewer pipe–joint up to a hydrostatic pressure of 7 psi. A testing protocol was developed and approved by a steering committee with representation from the EPA, pipe associations, cities and consulting engineers. The testing protocol outlined the procedures to determine the leakage rates at pipe –joints under shear loading and angular deflection. A testing facility was designed and constructed in the CIGMAT Laboratory at the University of Houston. Pipe joints were tested in duplicate.

Based on the test results, there was no leakage at the 30-in. Hobas pipe-joint when the joint was tested with and without shear loading and angular deflection. During the straight test (unloaded joint) the joint was subjected to hydrostatic pressure incrementally to a maximum hydrostatic pressure of 7 psi with a total testing time of 30 minutes and there was no leakage. During the shear test, the joint was subjected to shear force incrementally to a maximum shear force of 2900 lb. The total testing time was 5.5 hours and the joint was subjected to a maximum hydrostatic pressure of 7 psi at every increment of shear load and there was no leakage. During the Angular Test, the joint was subjected to angular rotation in steps to a maximum rotation of 2^o at the joint. The total testing time was 2 hours and the joint was subjected to a maximum hydrostatic pressure of 7 psi and the

shear load at the joint varied from 1,000 to 5,000 lbs. during the angular test. There was no leakage.

2. **INTRODUCTION**

Infiltration due to leaking pipes, manholes, laterals and other components of a wastewater system will add to the problem of overflow and substantially load the treatment facilities. Frequent overflows not only lead to regulatory problems but also increase the treatment cost [Water Environmental Federation, 1999]. Leaking systems will result in the erosion of soils through the leaking joints leading to the settlement of the ground surface, formation of sinkholes and damage to surrounding pavements and structures. Erosion of soil materials around the pipes and manholes can lead to formation of void and settlement of pipes accelerating the damage. Eroding soils entering the wastewater system through the leaking joints can cause problems within the wastewater system. Several ASTM standards were reviewed and are summarized in Table A1 in Appendix A [ASTM, 2000]. The test methods cover pipe sizes from 3 to 144 inches. Both air and water have been recommended for use in infiltration/exfiltration tests. Of the test methods reviewed, 85% were exfiltration and 28% were infiltration tests. Test methods for plastic, fiberglass, concrete and clay pipes have also recommended misalignment (angular) and shear force tests at the joints. The testing pressure varied from 3.5 to 40 psi. Acceptable leak rates varied based on type of pipe and application (Table A1).

Literature review indicated that each type of pipe is tested differently in determining the infiltration rate at the pipe joint. Hence it was necessary to develop a unified testing method to better quantify the infiltration at various pipe joints under more realistic joint-loading conditions. Since several factors in the field can affect the performance of pipe joint, it is important to identify the important factors through controlled experiments where important variables are studied one at a time. Based on the review of the literature and ASTM testing standards, a testing protocol for determining the infiltration at the pipe-joint must be developed.

Based on the preliminary testing at the University of Houston, a comprehensive testing protocol (Appendix B) was developed and submitted to the steering committee for review and approval. The steering committee members were representing the USEPA, cities, consulting engineers, general contractors, professional associations and pipe industries. Once the testing plan was reviewed and approved by the steering committee, pipe-joints were tested under this test plan.

3. OBJECTIVES

The overall objective was to determine, through controlled laboratory tests, the infiltration leak-rates for different types of 30-in. diameter sewer pipe-joints under various loading conditions. The specific objectives were as follows:

1. Develop a testing protocol to determine the infiltration at the pipe-joint under the following conditions:
    a. Straight joint (Method A)
    b. Angular deflection (Method B)
    c. Shear load (Method C)

2. Develop a testing facility to perform the tests under external hydrostatic pressure.

3. Perform tests according to the testing protocol on pipe joints assembled by the pipe companies/representative.

4. TESTING PROGRAM

Two instrumented test stands were designed and constructed at the University of Houston. Each test stand was capable of accommodating two three-foot lengths of 30-inches or greater diameter pipe joined together for testing. Provisions were made to constrain the pipe from moving laterally. The loading points were instrumented with 20,000 pound load cells to measure the applied and reaction loads (Figs. 1 and 2). Test

stand provisions will also allow the pipe-joint to be tested under deflection and shear load in accordance with the test protocol. The pipe-joint was first tested under no load followed by the shear test and angular test.

Since water leakage can occur under several joint conditions, three model tests were proposed to closely represent the field situations. In all the cases, after loading, infiltration was tested with a hydrostatic pressure up to 7 psi. Tests were performed in duplicates resulting in six model tests for each pipe joint. The data sheet on the joint characteristics (from pipe manufacturer/ supplier) is in Appendix C.

5. RESULTS AND DISCUSSIONS

Two Hobas pipe joints were tested (ASTM Specification: ASTM D 4161) and the properties of the pipe and joint are in Appendix C. The joints were tested under aligned (straight and shear load tests) and misaligned positions (angular test) (Fig. 1 (a), (b) and (c)). The bladders were built to fit the pipe joints using a combination of rubber and plastic sheets (Fig. 2). The joints were pressurized under each mode of loading starting at 3 psi hydrostatic pressure. The first Hobas pipe-joint was tested in May 2001. The second pipe joint was tested in Oct. 2001.

5.1 Test No. 1 (Hobas Pipe-Joint No. 1)

METHOD A: Straight Pipe Joint Test (Fig. 1(a))

The results of the test are summarized in Table 1. No water leak was observed at the joint during the total test period of 30 minutes with a maximum hydrostatic pressure of 7 psi for 10 minutes.

METHOD B: Angular Deflection Test (Fig. 1(b))

In the angular deflection test, the angles 0.50, 1.00, 1.50 and 2.00 degrees at the joint were tested. The testing time under each angle was 30 minutes with a maximum hydrostatic

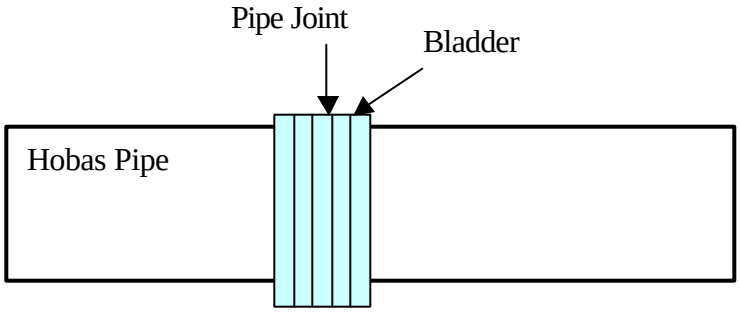
pressure of 7 psi for 10 minutes. The results of the test are summarized in Table 1. The relationship between the angle of rotation at the joint and the shear load at the joint is shown in Fig. 3. The shear load at the joint increased with the angular deflection and varied from 1000 to 3000 lbs. No water leak was observed at the joint during the total test period of 4.5 hrs.

(c) METHOD C: Shear Load Test (Fig. 1(c))

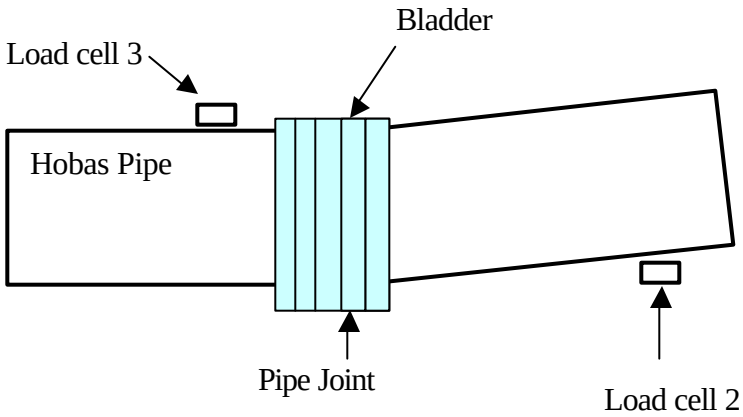
The joint was tested under shear loading according to Method C (Appendix B). The load was applied through load cell 1 on the pipe and was increased in steps of 500, 1000. 1500. 2000, 2500, 3000, 3500, 4000 and 4500 lbs. The test results are summarized in Table 2. The Shear load at the joint vs. Applied load and the deflection of the pipe vs. Applied load are shown in Fig. 4 and Fig. 5 respectively. The maximum shear load at the joint was 1800 lbs. and there was no water leak. The maximum pipe deflection occurred at the edge of the pipe with 3.67% and -4.48% in the horizontal and vertical directions respectively. No leakage was observed.

Test No.1 Summary

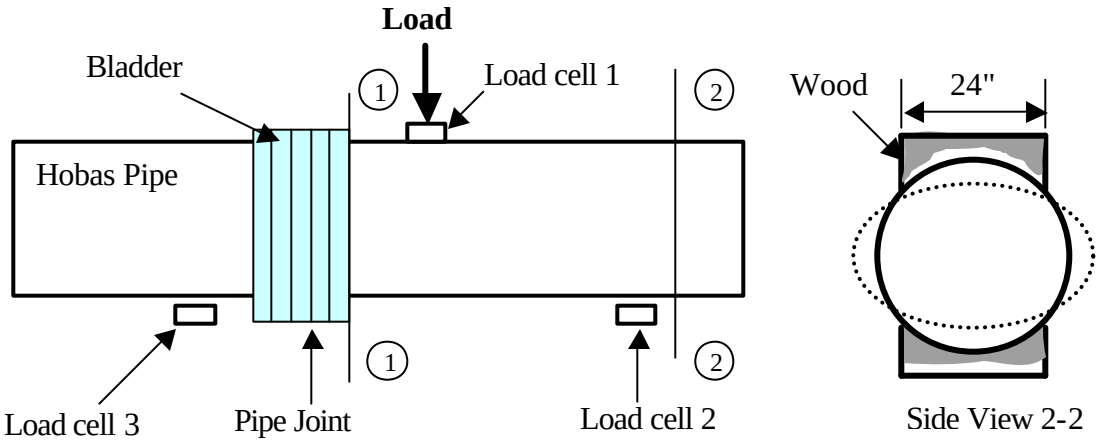
The composite bladder performed as designed. Total testing time for Method A, B, and C were 0.5 hour, 2 hours and 5.5 hours respectively. No water leakage was observed at the joint for all the testing conditions. The maximum shear load at the joint was 1760 lbs. (over 65 lbs/in diameter). The maximum deflection of the pipe occurred at the edge of the pipe with 3.67% and -4.48% (based on the diameter) in the horizontal and vertical directions respectively.



(a) Method A: Straight Pipe Joint Test

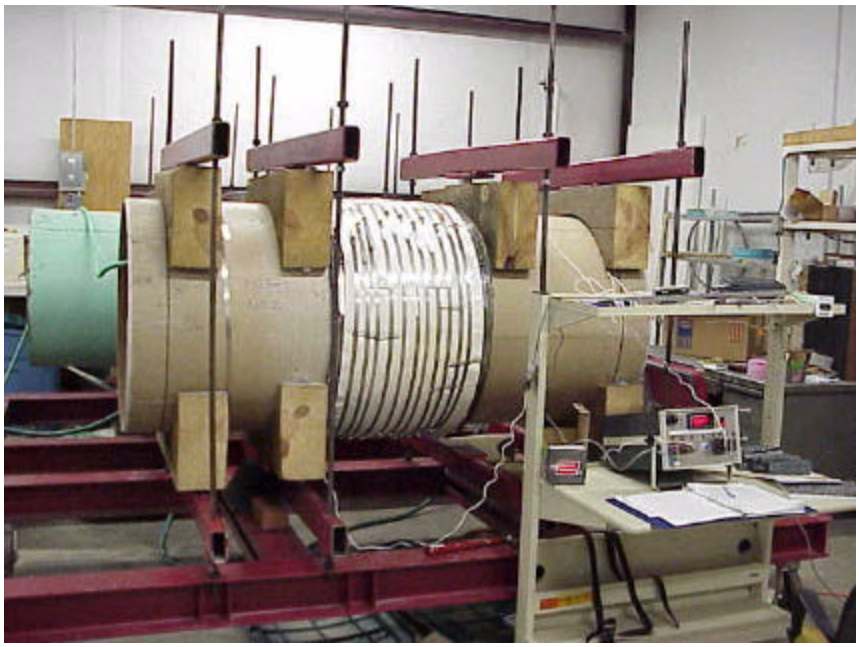


(b) Method B: Angular Deflection Test

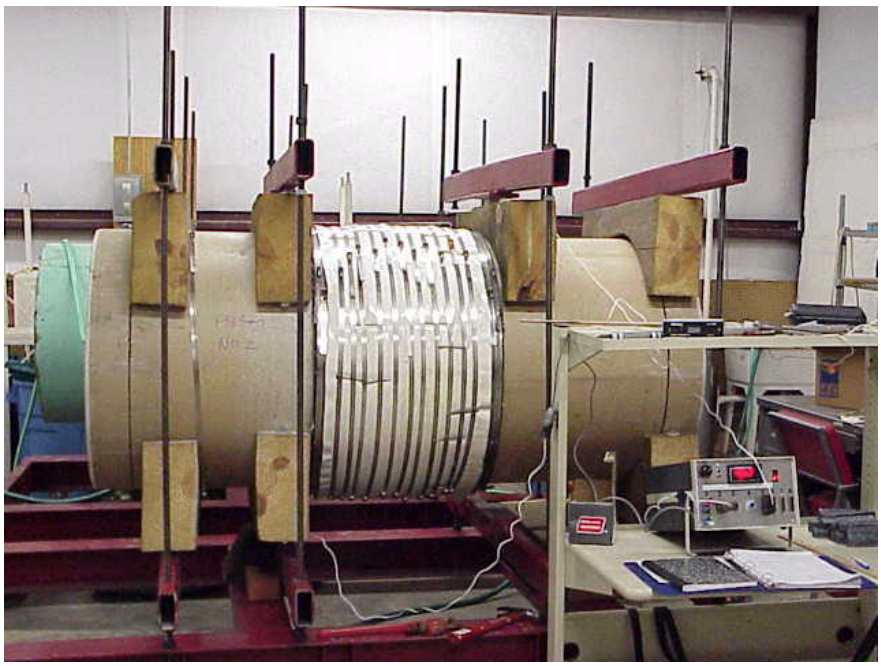


(c) Method C: Shear Load Test

Figure 1 Pipe-Joint Test Configurations



Method B: Angular Deflection Test



Method A and C: Straight Alignment and Shear Load Tests

Figure 2. Views of the Hobas Pipe Joint Tests and Loading Frame

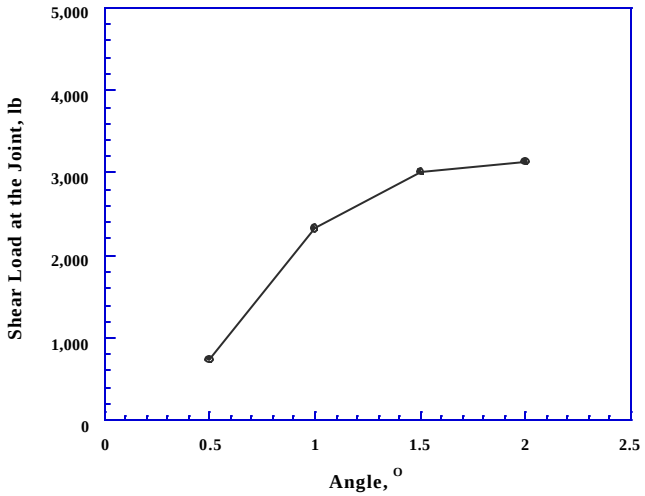


Figure 3. The Relationship between Angle and Applied Load in Test No. 1

Table 1 Results of Straight and Angular Deflection Test (Test No.1)

Method	Angle (^{o})	Pressure (psi)	Time (min)	Leakage	Remarks
A	0	3	5	No	Total testing time was 30 minutes. No leakage.
		4	5	No	
		5	5	No	
		6	5	No	
		7	10	No	
B	0.5	3	5	No	Total testing time was 30 minutes. No leakage.
		4	5	No	
		5	5	No	
		6	5	No	
		7	10	No	
	1.0	3	5	No	Total testing time was 30 minutes. No leakage.
		4	5	No	
		5	5	No	
		6	5	No	
		7	10	No	
	1.5	3	5	No	Total testing time was 30 minutes. No leakage.
		4	5	No	
		5	5	No	
		6	5	No	
		7	10	No	
	2.0	3	5	No	Total testing time was 30 minutes. No leakage.
		4	5	No	
		5	5	No	
		6	5	No	
		7	10	No	
Remark	Up to 2^{o}	3 to 7 psi	Total 2.5 hrs	No Leak	Bladder performed as designed

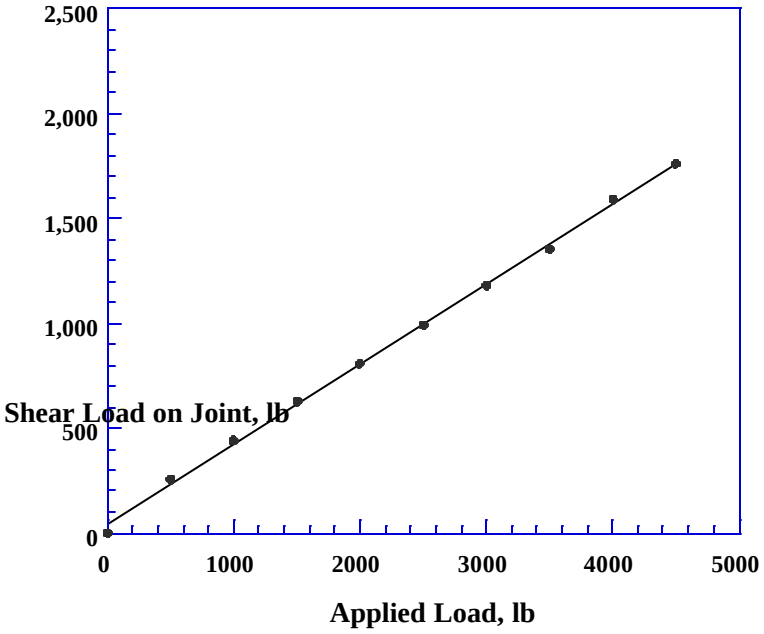


Figure 4. Shear Load vs. Applied Load in Test No. 1

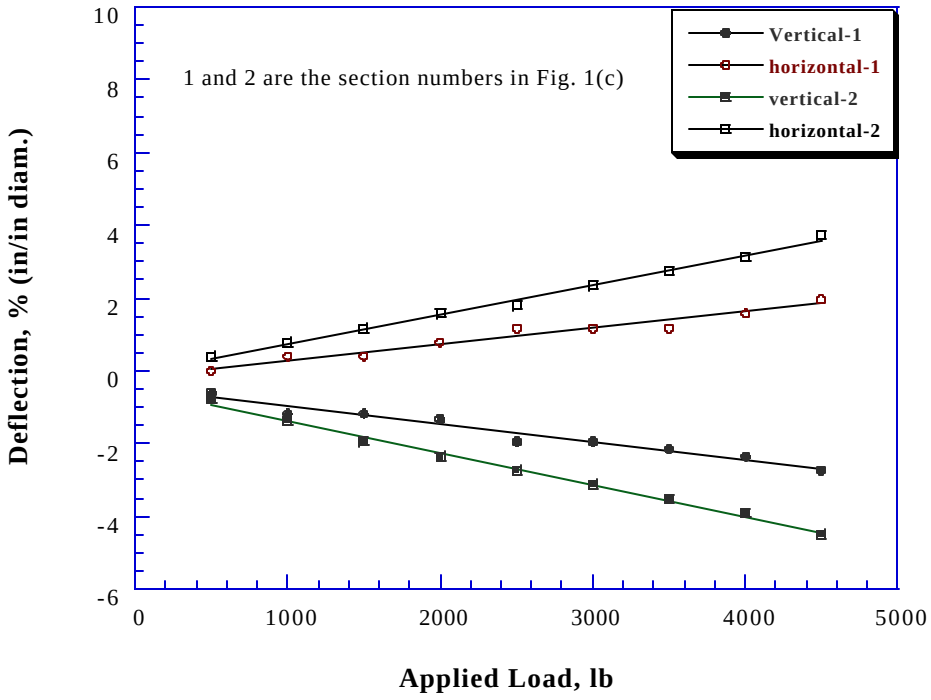


Figure 5. Deflection vs. Applied Load in Test No. 1

Table 2 Results from Shear Load Test (Test No.1)

Intended Load (lb)	Pressure (psi)	Time (min)	Leakage	Actual Load Applied (lb)	Shear Load (lb)	Remarks
500	3	5	No	498	253	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
1000	3	5	No	1000	440	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
1500	3	5	No	1502	627	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
2000	3	5	No	1999	809	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
2500	3	5	No	2501	991	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
3000	3	5	No	3003	1181	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
3500	3	5	No	3499	1356	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
4000	3	5	No	4001	1590	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
4500	3	5	No	4498	1759	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
Remarks	Up to 7 psi	Total 6.5 hrs.	No leak	Maximum load 4498 lb.	Maximum shear 1759 lb	No water leak

Test No. 2. (HobasPipe-Joint No. 2)

METHOD A: Straight Pipe Joint Test (Fig. 1 (a))

The results of the test are summarized in Table 1. No water leak was observed at the joint during the total test period of 30 minutes with maximum hydrostatic pressure of 7 psi for 10 minutes.

(b) METHOD B: Angular Deflection Test (Fig. 1 (b))

In the angular deflection test, the angles 0.50, 1.00, 1.50 and 2.00 degrees at the joint were tested. The testing time under each angle was 30 minutes with maximum hydrostatic pressure of 7 psi for 10 minutes .The results of the test are summarized in Table 3. The relationship between the angle of rotation at the joint and the shear load at the joint is shown in Fig. 6. The shear load varied from 2500 to 5000 lbs at the joint. No water leak was observed at the joint during the total testing period of 2 hrs.

(c) METHOD C: Shear Load Test (Fig. 1 (c))

The joint was tested under shear loading conditions. The load was applied at load cell 1 on the pipe and was increased in steps of 1000, 2000, 3000, 4000, 5000, 5500, 6000, 6500, 7000, 7500 and 8000 lbs. The test results are summarized in Table 4. The Shear load at the joint vs. Applied load and the deflection of the pipe vs. Applied load are shown in Fig. 7 and Fig. 8 respectively. The maximum shear load at the joint was 2900 lbs. (97 lbs/in. diameter) when 8000 lbs. load was applied on load cell No. 1 (Fig. 7). The maximum deflection of the pipe occurred at the edge of the pipe with 1.18% and -0.98% in the horizontal and vertical directions respectively (Fig. 8). No leakage was observed.

Test No. 2 Summary

The composite bladder performed as designed. Total testing time for Method A, B, and C were 0.5 hour, 2 hours and 5.5 hours respectively. No leakage was observed at the tested joint for all the methods of testing. The maximum shear load at the joint was 2900 lbs. (97 lbs/in. diameter). The maximum deflection of the pipe occurred at the edge of the pipe with 1.18% and -0.98% in the horizontal and vertical directions respectively.

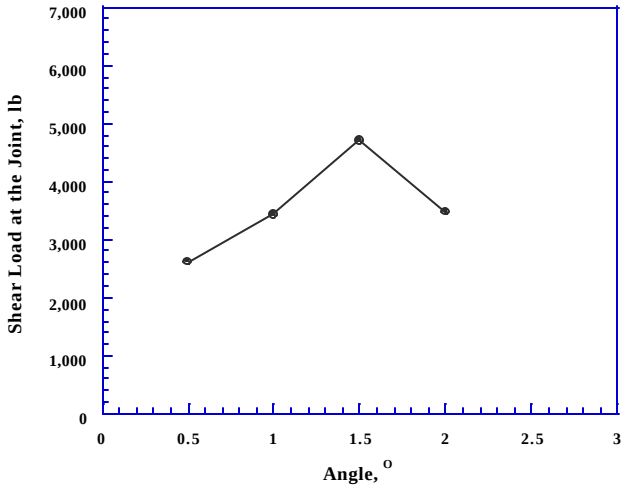


Figure 6. The Relationship between Angle and Applied Load (Test No. 2)

Table 3 Results from Angular Deflection Test (Test No. 2)

Method	Angle (^{o})	Pressure (psi)	Time (min)	Leakage	Load Cell Reading	Remarks
A	0	3	5	No	0.826	Total testing time was 30 minutes. No leakage.
		4	5	No		
		5	5	No		
		6	5	No		
		7	10	No		
B	0.5	3	5	No	4.857	Total testing time was 30 minutes. No leakage.
		4	5	No		
		5	5	No		
		6	5	No		
		7	10	No		
	1.0	3	5	No	4.540	Total testing time was 30 minutes. No leakage.
		4	5	No		
		5	5	No		
		6	5	No		
		7	10	No		
	1.5	3	5	No	3.761	Total testing time was 30 minutes. No leakage.
		4	5	No		
		5	5	No		
		6	5	No		
		7	10	No		
	2.0	3	5	No	3.078	Total testing time was 30 minutes. No leakage.
		4	5	No		
		5	5	No		
		6	5	No		
		7	10	No		
Remark	Up to 2^{o}	3 to 7 psi	Total 2.5 hrs	No Leak	Reading changed with the angle	Bladder performed as designed

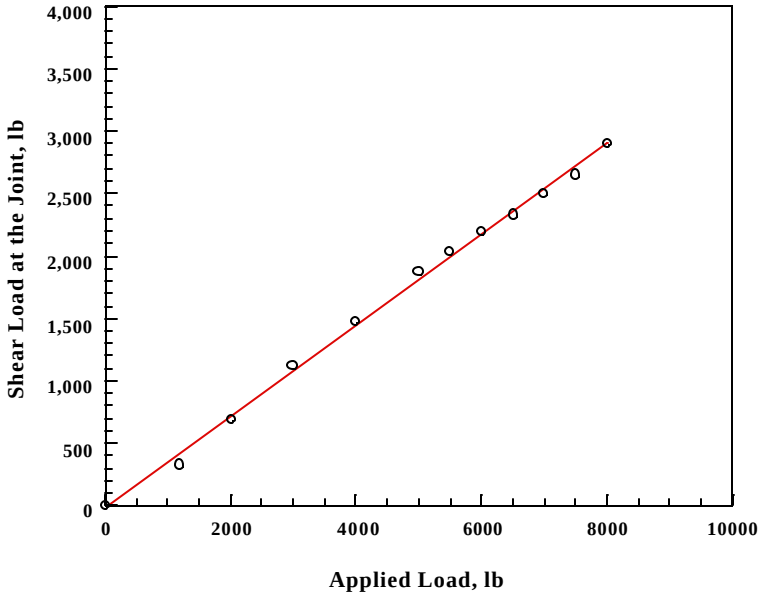


Figure 7. Shear Load vs. Applied Load in Test No. 2

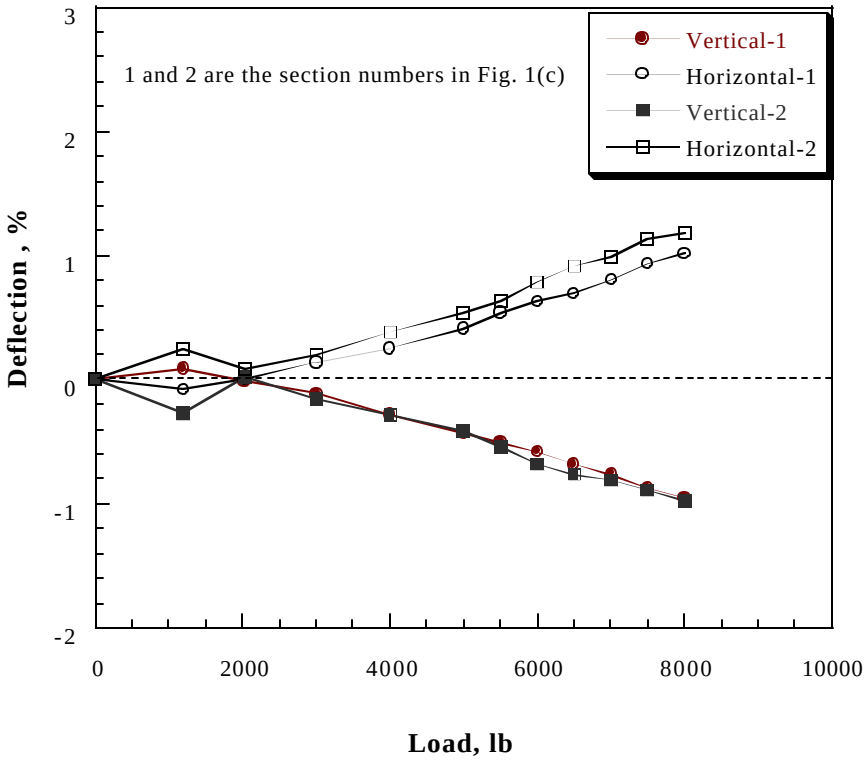


Figure 8. Pipe Deflection vs. Applied Load in Test No. 2

Table 4 Results from Shear Load Test (Test No. 2)

Intended Load (lb)	Pressure (psi)	Time (min.)	Leakage	Actual Load Applied (lb)	Shear Load (lb)	Remarks
1000lb	3	5	No	1194	330	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
2000lb	3	5	No	2025	695	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
3000lb	3	5	No	2999	1121	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
4000lb	3	5	No	4002	1476	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
5000lb	3	5	No	5002	1882	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
5500	3	5	No	5504	2039	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
6000	3	5	No	6006	2186	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
6500	3	5	No	6503	2334	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
7000	3	5	No	7006	2499	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			

(Table 4 Continue)

7500	3	5	No	7499	2652	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
8000	3	5	No	8005	2899	Total test time was 30 minutes. No leak was observed.
	4	5	No			
	5	5	No			
	6	5	No			
	7	10	No			
Remarks	Up to 7 psi	Total 5.5 hrs.	No leak	Maximum load 8005 lb.	Maximum shear 2899 lb	No water leak

6. CONCLUSIONS

The testing of the Hobas pipe-joints was performed in the CIGMAT Laboratory, University of Houston. Based on the two joint tested, following conclusions were advanced.

1. Straight Test: There was no leakage at the 30-in. Hobas Pipe-joint when the joint was tested without any external loading for a total testing time of 30 minutes.

2. Shear Test: The joint was subjected to a maximum shear force of 2900 lb. (equivalent to 97 lb/in diameter) and there was no leakage. The total testing time was 5.5 hours.

3. Angular Test: During the angular test, the joint was subjected to a maximum rotation of 2^{0} at the joint. The total testing time was 2 hours and the shear load at the joint varied from 1,000 to 5,000 lbs. during the angular test. There was no leakage.

7. REFERENCES

[1] Annual Book of ASTM Standards (2000), Section 4 (Construction) and Section 8 (Plastics), ASTM, Philadelphia, PA.

[2] Water Environment Federation (1999), Control of Infiltration and Inflow in Private Building Sewer Connections, WEF, Alexandria, VA.