TESTING OF BULLDOG PVC RESTRAINT JOINT FOR TRENCHLESS TECHNOLOGY

Prepared for Bulldog Restraint System™

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Abstract

Trenchless technology is a method of underground pipe installation with minimal disruption to ground surface. The nature of forces applied on the product pipe (pipe to be installed) during trenchless installations, however, is different from conventional open-cut methods. The pipe installed by trenchless methods like horizontal directional drilling are subject to tensile force during the installation. The Bulldog™ PVC pressure pipe integral joint restraint system was originally designed for use in open-trench construction of PVC pressure pipelines (Bulldog Restraint Systems). However, they are advantageous in trenchless applications because of their quick and easy installation and hydraulic capacity. The tests described in this report have been made in order to investigate the behavior of the joint under tensile loads which is significant during installations using trenchless methods. Tensile tests were conducted for 4" and 8" diameter PVC pipe assemblies with Bulldog Restraint Joint System. The test specimens were subjected to constant displacement and load and strain were measured. The observations and results of the tests are described in this report.

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1. Introduction

Trenchless technology is a method of underground pipe installation with minimal disruption to ground surface (Najafi & Gokhale, 2005). The footage of pipe installed by trenchless technology is increasing because due to its lower social costs, greater worker safety, etc. The nature of forces applied on the product pipe (pipe to be installed) during trenchless installations, however, is different from conventional open-cut methods. The pipe installed by trenchless methods like horizontal directional drilling are subject to tensile force during the installation. This makes it essential that the pipe and the joint is able to withstand the tensile force applied during the installation.

2. Background

Center for Underground Infrastructure Research and Education (CUIRE), University of Texas at Arlington (UTA) conducted tensile tests for Bulldog™ PVC pressure pipe integral joint restraint systems for 4 in. and 8 in. pipes as per the contract with Bulldog Restraint Systems™ (BRS). Description of each specimen is given in Section 4. The tests were conducted at the Civil Engineering Laboratory Building (CELB) at the University of Texas at Arlington.

The Bulldog™ PVC pressure pipe integral joint restraint system was originally designed for use in open-trench construction of PVC pressure pipelines (Bulldog Restraint Systems). However, they are advantageous in trenchless applications because of their quick and easy installation and hydraulic capacity. The tests described in this report have been made in order to investigate the behavior of the joint under tensile loads, which is significant during installations using trenchless methods.

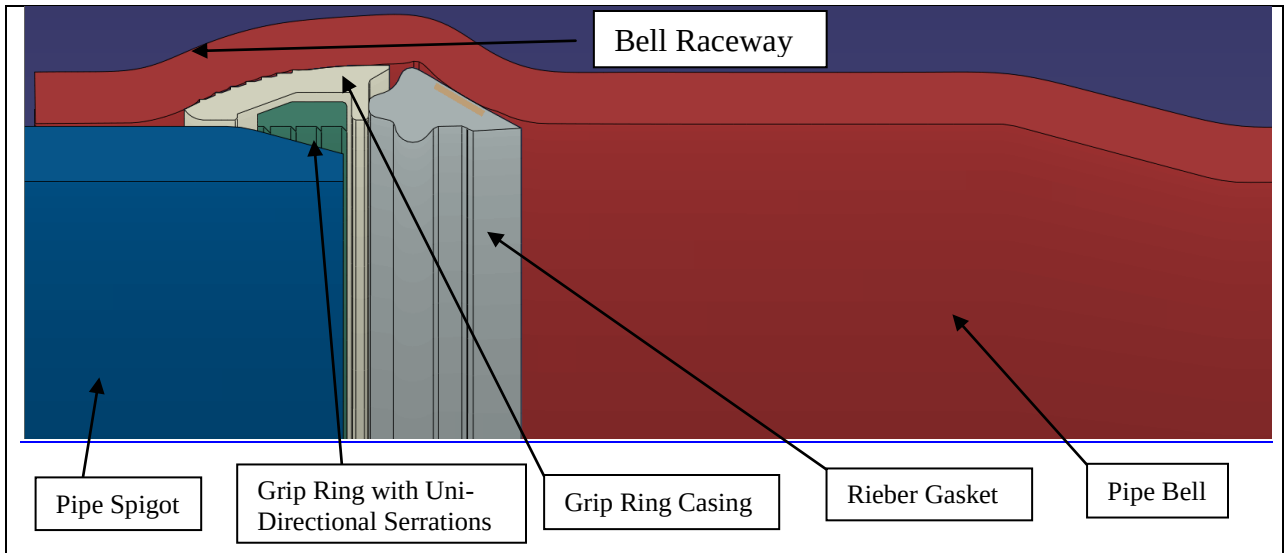

Figure 1: Components of Bulldog Restraint System

The current version of the Bulldog™ is designed for integration into AWWA C900 PVC pipe and fittings in diameters 4-inch through 12-inch. The mechanism consists of a metal casing that sits adjacent to the Rieber gasket in the bell; and the casing is molded into the raceway of the bell during pipe belling. A C-shaped grip-ring with several rows of uni-directional serrations is

manually inserted into the casing at the manufacturing facility. Both the casing and the grip ring are made of ductile iron that has been coated using an electro-coating process that achieves a uniform thickness and provides superior corrosion resistance. When the pipe arrives at a jobsite, the bell already contains the casing with the grip ring inserted in it, and no additional hardware is needed to provide a restrained joint. Figure 1 shows a cross-sectional view of the components in the joint.

3. Apparatus

3.1 Apparatus for 4" and 8" pipes

3.1.1 Testing Machine

MTS 810 material test system with a capacity of 100 KIP was used for the test. It is comprised of the following members.

3.1.1.1 Fixed Member

A fixed or stationary member carrying one grip was positioned in the top end of the machine.

3.1.1.2 Movable Member

A movable member carrying the other grip was positioned in the bottom end of the machine.

3.1.1.3 Grips

Grips are used for holding the test specimen between the fixed and the movable member of the testing machine. In this test, fixed grips which made uniform serrations to prevent the slippage of the specimen were used to hold the specimen rigidly between the fixed and the movable members. Heads with teeth were inserted into the ends of pipe specimen which acted as grips to hold the pipe during the test. The head used for 8" pipe is shown in Figure 2.

3.1.2 Drive Mechanism

For specimen 1 to 4, a uniform, controlled velocity was applied to the movable member with respect to the fixed member. The velocity used during the tests was 0.2 inches of displacement per minute. For specimen 5 and 6, load was increased at contant rate of 2,500 lbs per minute.

3.1.3 Load Indicators

MTS load cells with a capacity of 110KPS/500KN capacity was used to indicate the total tensile loads carried by the test specimen.

3.1.4 Strain Gages

Two rectangular strain gage rosettes were attached on the specimen in order to measure the strain and strain directions on the specimen. One assembly of strain gage rosettes was placed on the bell side of the pipe assembly while the other was on spigot side of the pipe assembly as shown in the Figure 3.

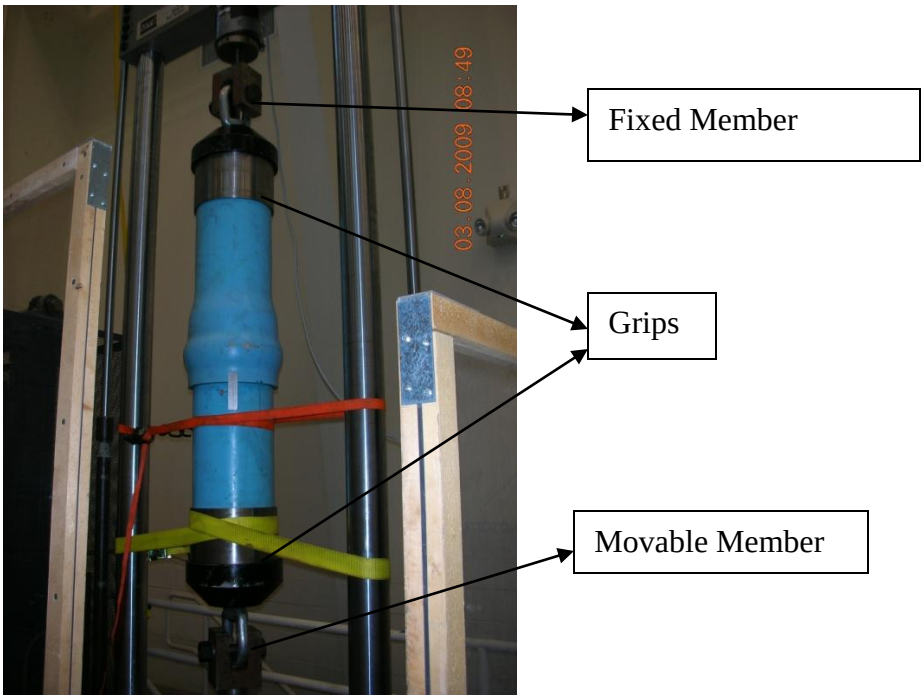

Figure 2: Apparatus Assembly for 8" Pipe

Figure 3: Specimen Pipe Assembly with Rosette Strain Gages

4. Pipe Specimen and Preparation

Pipe specimens were received at the CELB unassembled and with equal numbers of bell and spigot ends. Pipe specimens as received are shown in Figure 4. Pipe specimens were provided by two different PVC pipe manufacturing companies.

Figure 4: Pipe Specimens as Received

The pipe specimens were cut to sizes required so that the pipe assembly length would be as desired for the test. The lengths of pipe assemblies tested are given in Table 1. Rectangular strain gage rosettes were carefully attached to the pipe with the center strain gage (strain gage at 45° angle from rest of strain gages) along the length of the pipe as can be seen in Figure 3. Bell and spigot pipes were assembled using MTS compression machine. Grip heads were inserted into both ends of the pipe assembly and tightened as instructed by the designer of the grip. End of the head were marked in order to monitor any slippages. The specimens were loaded into the MTS machine as shown in Figure 2.

Table 1: Details of Specimens Used for Test

Specimen No.	Pipe Material	Nominal Pipe Diameter, Inches	Joint Type	Length Inches	Minimum Wall Thickness Per C900, Inches	Dimension Ratio
1	PVC	4	BRJ	36	0.267	18
2	PVC	4	BRJ	36	0.267	18
3	PVC	8	BRJ	46	0.503	18
4	PVC	8	BRJ	46	0.503	18
5	PVC	6	BRJ	48	0.383	18
6	PVC	6	BRJ	48	0.383	18

5. Testing Methodology

With the apparatus and specimen all set up, test was conducted by applying constant displacement of 0.2 inches per minute to the movable member of the apparatus until the pipe assembly failed.

6. Observations and Test Results

Test results for each of the specimens are described below:

6.1 Specimen One

Joint of the specimen one failed at the bell of the pipe assembly as shown in Figure 5.

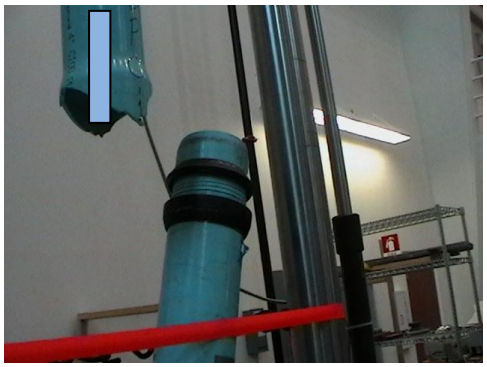

Figure 5: Failure of Specimen One.

The load at the time of failure was 19,479 lbs (see Figure 6 for load curve) while the displacement was 1.67 inches (see Figure 7 for displacement curve). Figure 8 shows load-displacement curve for specimen one. Strain recorded on the center strain gages (longitudinal) of rectangular strain gage rosettes at the bell end and the spigot end at the time of failure read 10,259 μin/in and 14,059 μin/in respectively (see Figure 9 for longitudinal strain curve). Maximum and minimum principal strains recorded at bell end at the time of failure were 10,333 μin/in and -4,103 μin/in respectively at angle of 41 degrees clockwise of the first right (R) strain gage. Maximum and minimum principal strains recorded at spigot end at the time of failure were 14,065 μin/in and -4,690 μin/in respectively at angle of 44 degrees clockwise of the first (R) strain gage. This showed that the principal strains were in the circumferential direction of the pipe assembly. Figure 10 and Figure 11 shows principal stresses curves for Bell and Spigot ends respectively.

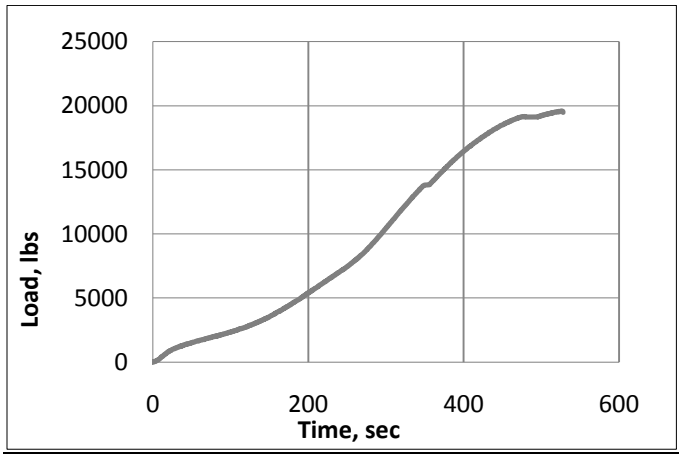

Figure 6: Load Curve for Specimen 1

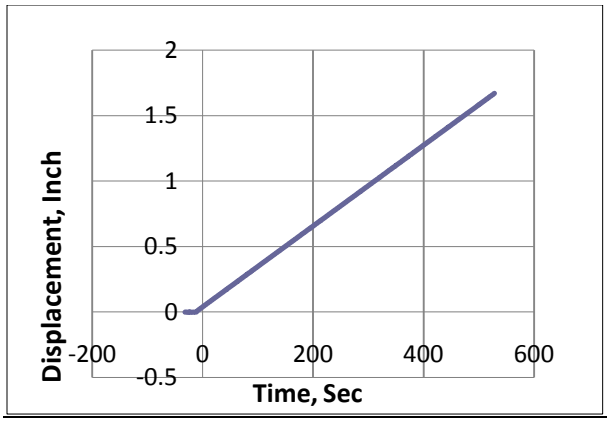

Figure 7: Displacement Curve for Specimen 1

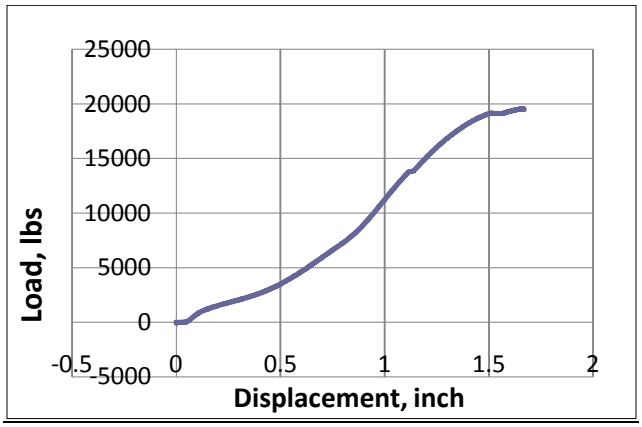

Figure 8: Load-Displacement Curve for Specimen 1

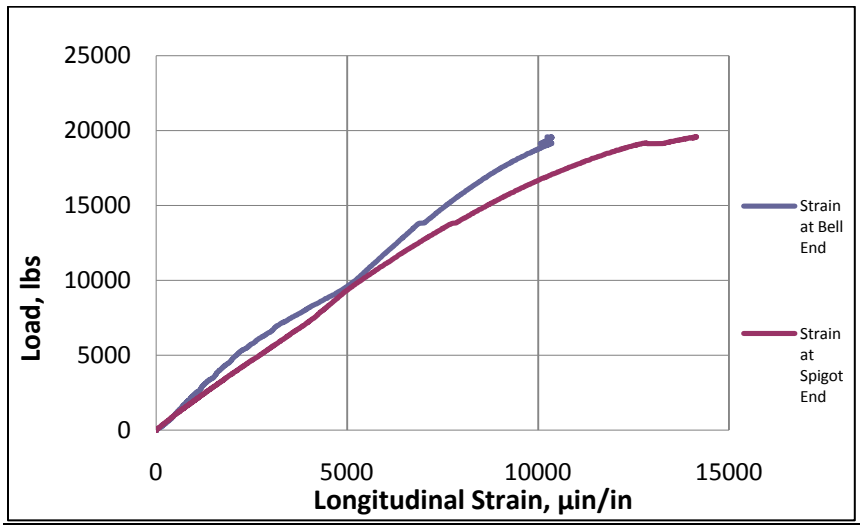

Figure 9: Longitudinal Strain Curve for Specimen 1

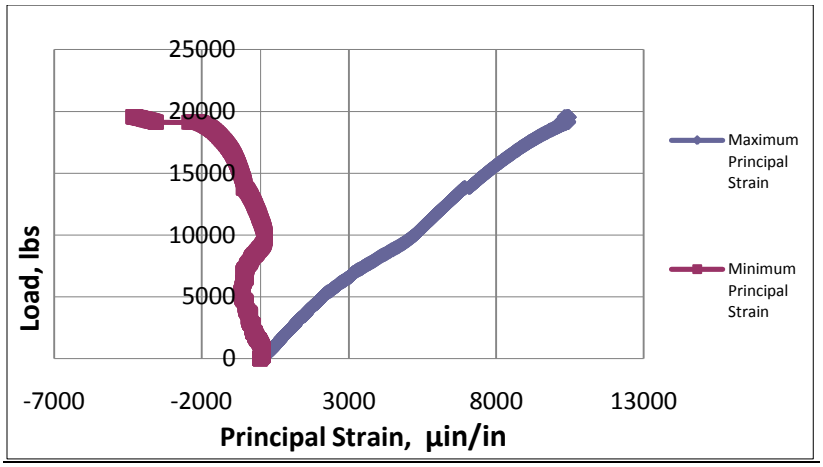

Figure 10: Principal Strain Curve – Bell End for Specimen 1

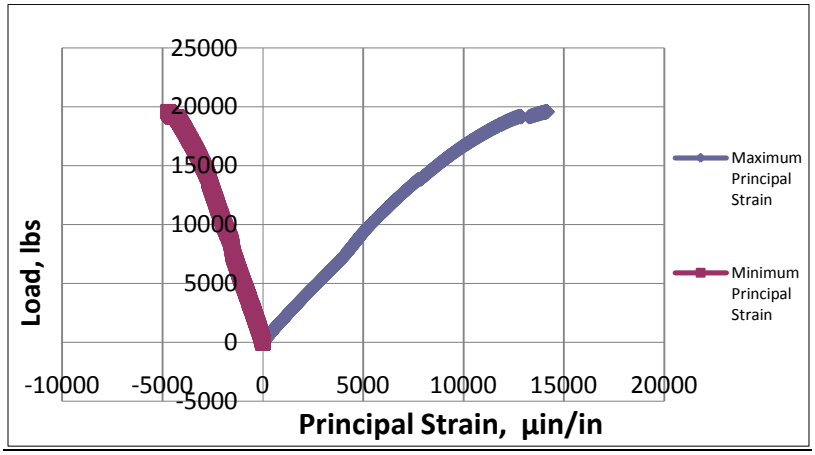

Figure 11: Principal Strain Curve – Spigot End for Specimen 1

6.2 Specimen 2

Joint of the specimen 2 failed at the spigot of the pipe assembly as shown in Figure 12.

Figure 12: Failure of Specimen 2

The load at the time of failure was 21,237 lbs (see Figure 13 for load curve) while the displacement was 2.48 inches (see Figure 14 for displacement curve). Figure 15 shows load-displacement curve for specimen 1. Strain recorded on the center strain gages (longitudinal) of rectangular strain gage rosettes at the bell end and the spigot end at the time of failure read 14,044 µin/in and 3,001 µin/in respectively (see Figure 16 for longitudinal strain curve). Maximum and minimum principal strains recorded at bell end at the time of failure were 14,029 µin/in and -5,224 µin/in respectively at angle of 44 degrees counter-clockwise of the first (R) strain gage. Maximum and minimum principal strains recorded at spigot end at the time of failure were 3,023 µin/in and -1,560 µin/in respectively at angle of 41 degrees counter-clockwise of the first (R) strain gage. This showed that the principal strains were in the longitudinal direction of the pipe assembly. Figure 17 and Figure 18 shows principal stresses curves for Bell and Spigot ends respectively.

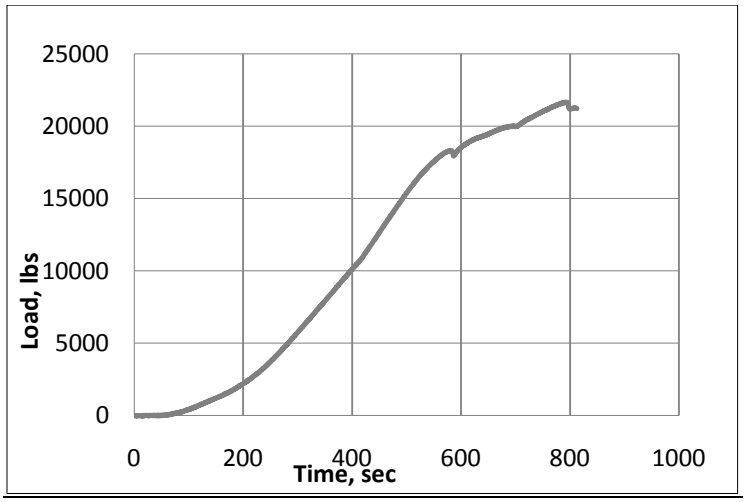

Figure 13: Load Curve for Specimen 2

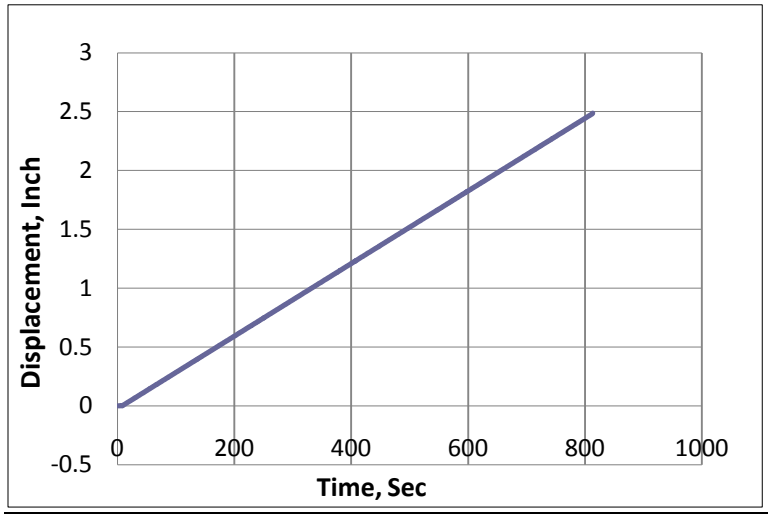

Figure 14: Displacement Curve for Specimen 2

Figure 15: Load Displacement Curve for Specimen 2

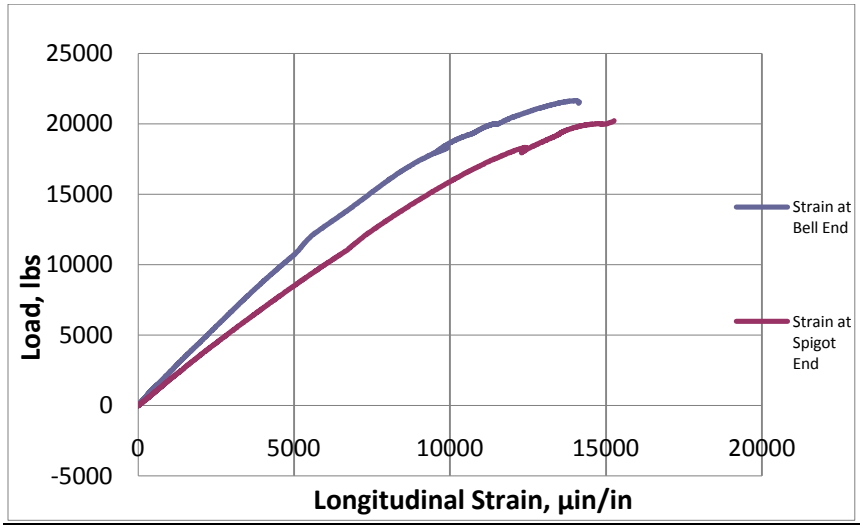

Figure 16: Longitudinal Strain Curve for Specimen 2

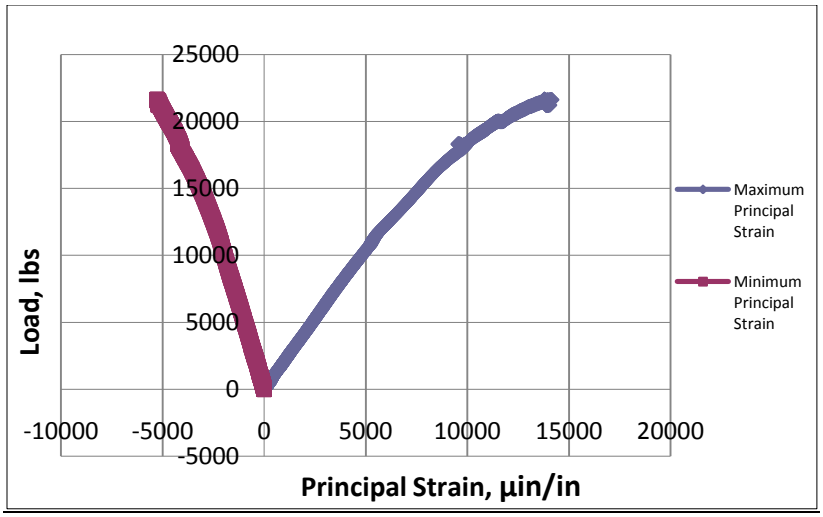

Figure 17: Principal Strain Curve – Bell End for Specimen 2

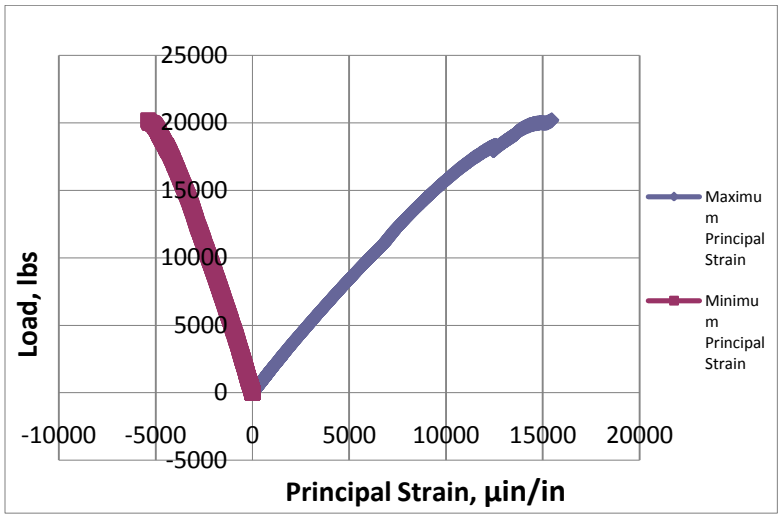

Figure 18: Principal Strain Curve – Spigot End for Specimen 2

6.3 Specimen 3

Joint of the specimen 3 failed at the spigot of the pipe assembly. Crack initiated from the joint and resulted in failure at two locations of the pipe spigot end as shown in Figure 19.

Figure 19: Pipe Piece after Failure of Specimen 3

The load at the time of failure was 54,249 lbs (see Figure 20 for load curve) while the displacement was 1.37 inches (see Figure 21 for displacement curve). Figure 22 shows load-displacement curve for specimen 1. Strain recorded on the center strain gages (longitudinal) of rectangular strain gage rosettes at the bell end and the spigot end at the time of failure read 4,315 μin/in and 10,001 μin/in respectively (see Figure 23 for longitudinal strain curve). Maximum and minimum principal strains recorded at bell end at the time of failure were 4,336 μin/in and -5,017 μin/in respectively at angle of 43 degrees clockwise of the first (R) strain gage. Maximum and minimum principal strains recorded at spigot end at the time of failure were 10,012 μin/in and -4,106 μin/in respectively at angle of 43 degrees clockwise of the first (R) strain gage. This showed that the principal strains were in the circumferential direction of the pipe assembly. Figure 24 and Figure 25 shows principal stresses curves for Bell and Spigot ends respectively.

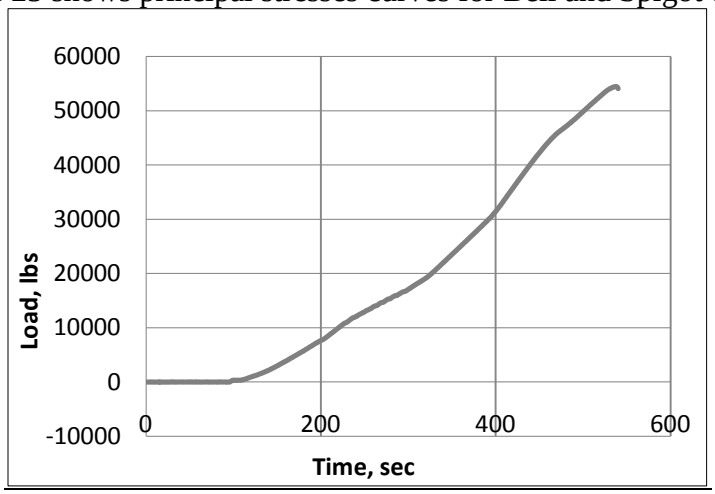

Figure 20: Load Curve for Specimen 3

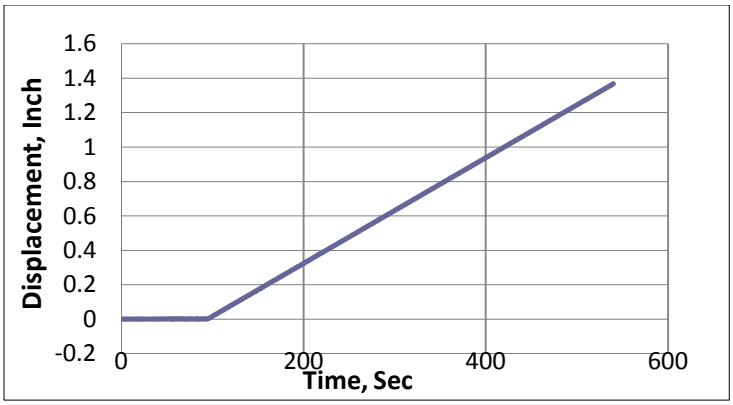

Figure 21: Displacement Curve for Specimen 3

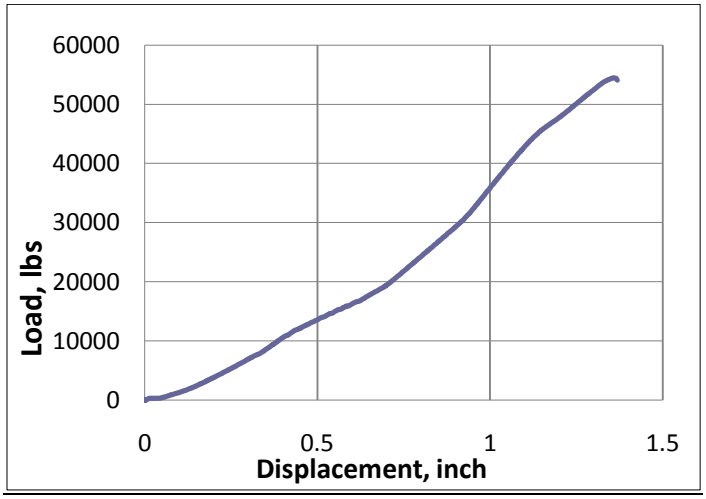

Figure 22: Load-Displacement Curve for Specimen 3

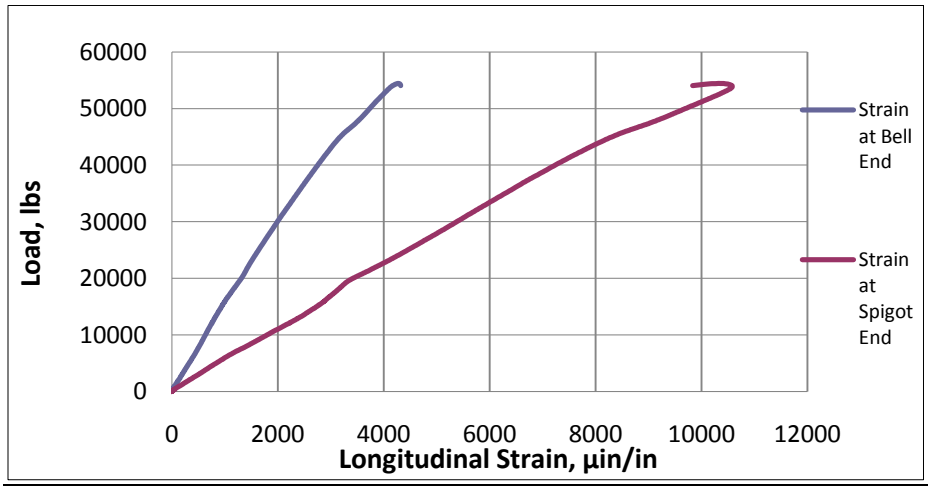

Figure 23: Longitudinal Strain Curve for Specimen 3

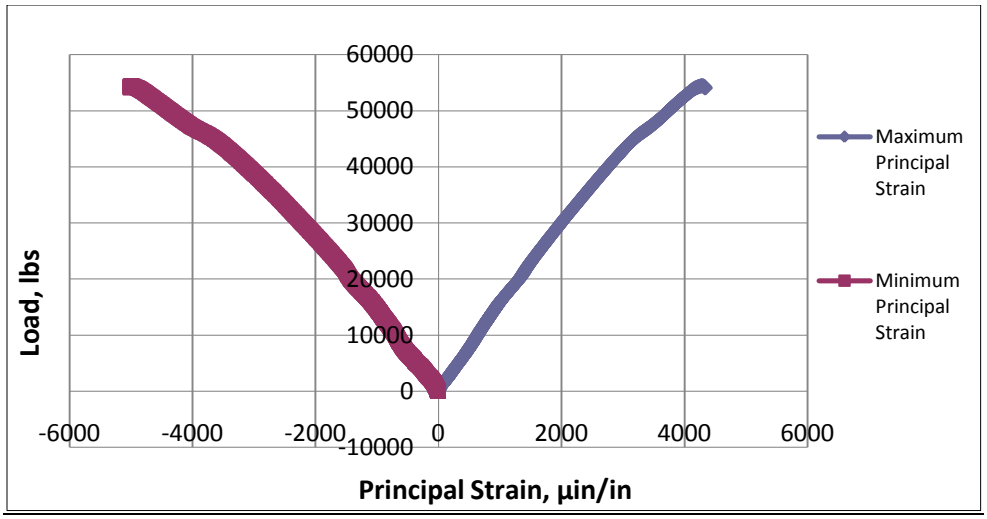

Figure 24: Principal Strain Curve – Bell End for Specimen 3

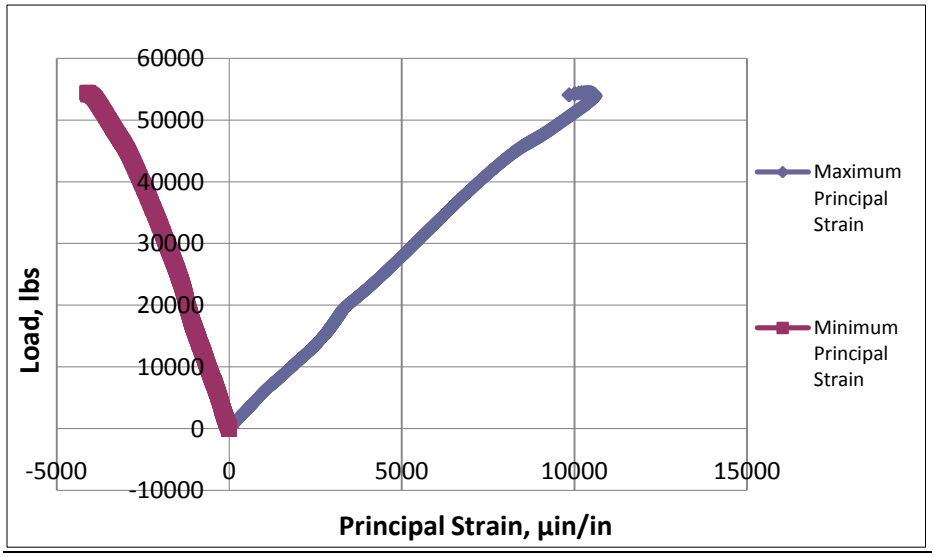

Figure 25: Principal Strain Curve – Spigot End for Specimen 3

6.4 Specimen 4

Joint of the specimen 4 failed at the spigot of the pipe assembly. The load at the time of failure was 54,181 lbs (see Figure 26 for load curve) while the displacement was 1.24 inches (see Figure 27 for displacement curve). Figure 28 shows load-displacement curve for specimen 1. Strain recorded on the center strain gages (longitudinal) of rectangular strain gage rosettes at the bell end and the spigot end at the time of failure read 4,355 µin/in and 10,175 µin/in respectively (see Figure 29 for longitudinal strain curve). Maximum and minimum principal strains recorded at bell end at the time of failure were 4,359 µin/in and -5,631 µin/in respectively at angle of 44 degrees clockwise of the first (R) strain gage. Maximum and minimum principal strains recorded at spigot end at the time of failure were 10,181 µin/in and -3,549 µin/in respectively at angle of 43 degrees counter-clockwise of the first (R) strain gage. This showed that the principal strains were in the circumferential direction at the bell end of the pipe while longitudinal at the spigot

end of the pipe assembly. Figure 30 and Figure 31 show principal stresses curves for Bell and Spigot ends respectively.

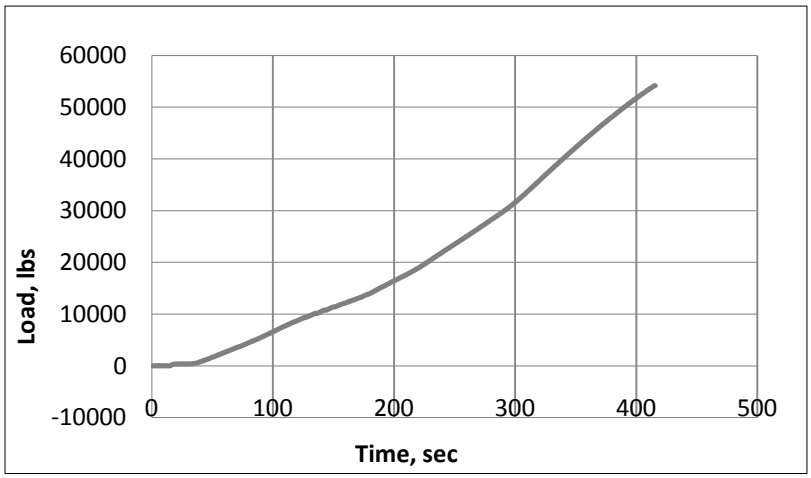

Figure 26: Load Curve for Specimen 4

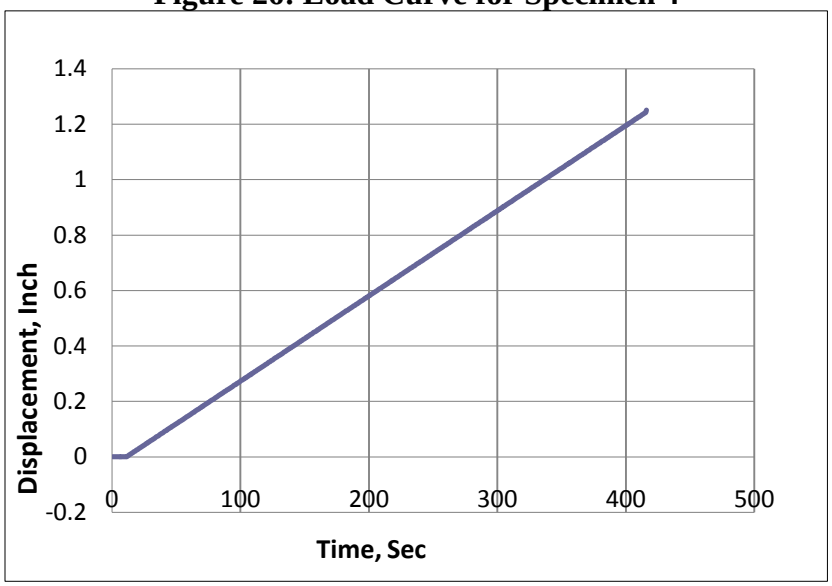

Figure 27: Displacement Curve for Specimen 4

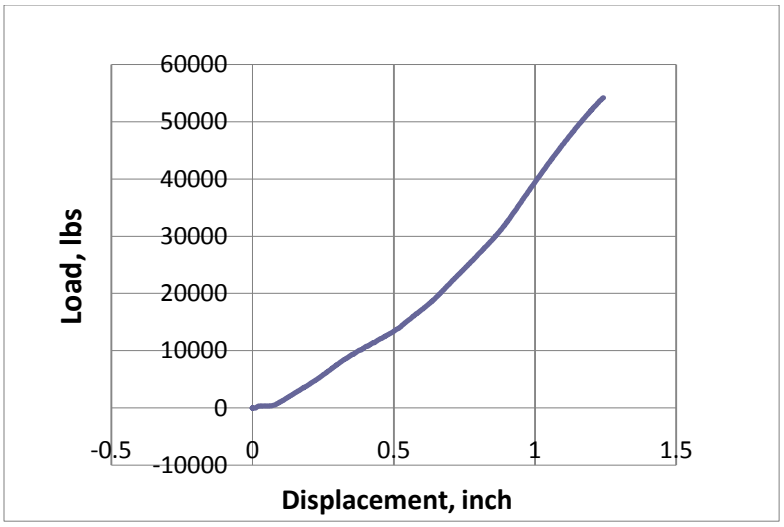

Figure 28: Load Displacement Curve for Specimen 4

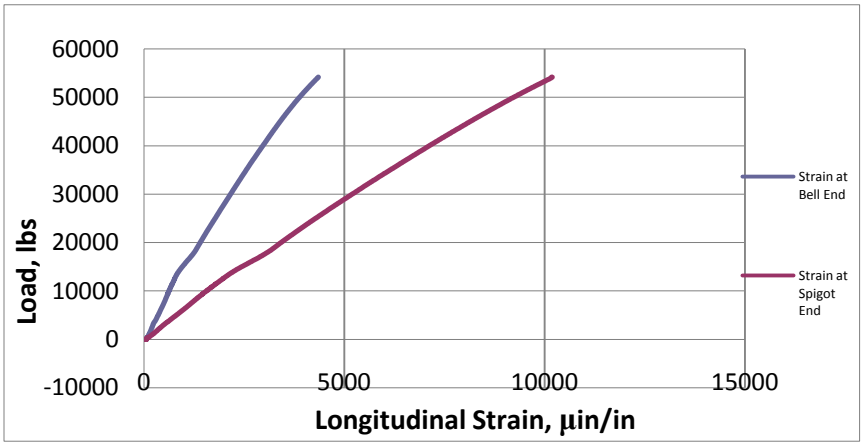

Figure 29: Longitudinal Strain Curve for Specimen 4

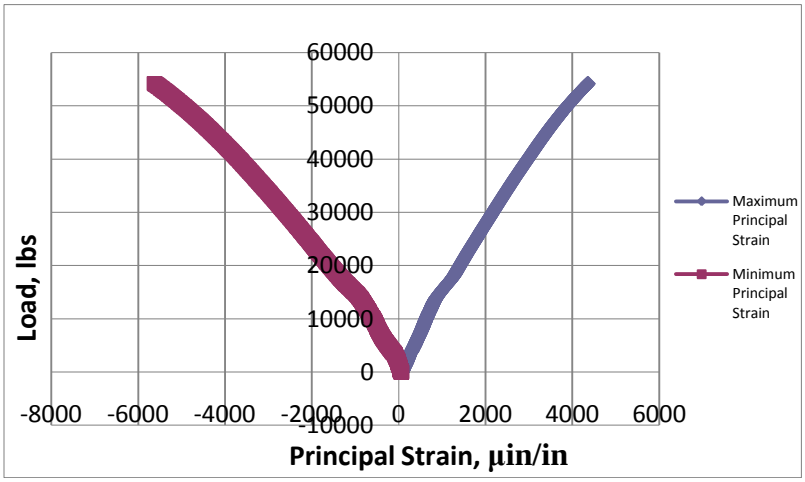

Figure 30: Principal Strain Curve – Bell End for Specimen 4

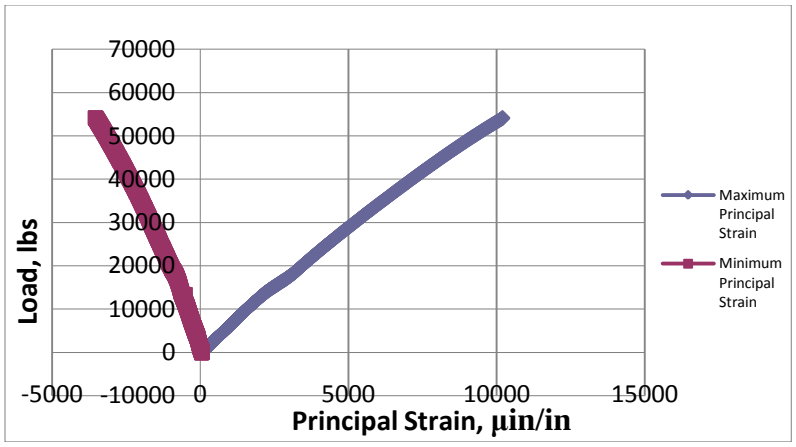

Figure 31: Principal Strain Curve – Spigot End for Specimen 4

6.5 Specimen 5

Joint of the specimen 5 failed at the spigot of the pipe assembly. The load at the time of failure was 29,895 lbs (see Figure 33 for load curve) while the displacement was 1.8177 inches (see Figure 32 for displacement curve). Figure 34 shows load-displacement curve for specimen 1. Strain recorded on the center strain gages (longitudinal) of rectangular strain gage rosettes at the bell end and the spigot end at the time of failure read 8,358 µin/in and 8,809 µin/in respectively (see Figure 35 for longitudinal strain curve). Maximum and minimum principal strains recorded at bell end at the time of failure were 8,605 µin/in and -3,200 µin/in respectively at angle of 37 degrees clockwise of the Right strain gage. Maximum and minimum principal strains recorded at spigot end at the time of failure were 8,823 µin/in and -3,972 µin/in respectively at angle of 43 degrees clockwise of the first Right strain gage. This showed that the principal strains were in the circumferential direction at both the bell and spigot ends of the pipe assembly. Figure 36 and Figure 37 show principal stresses curves for Bell and Spigot ends respectively.

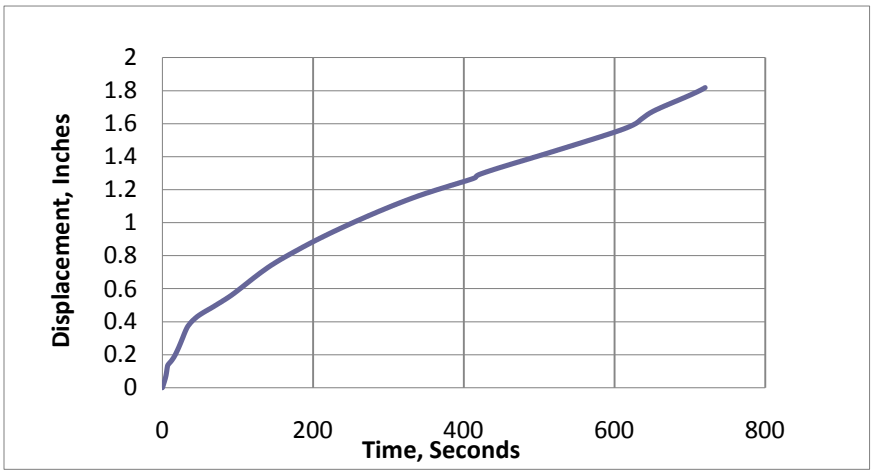

Figure 32: Displacement Curve for Specimen 5

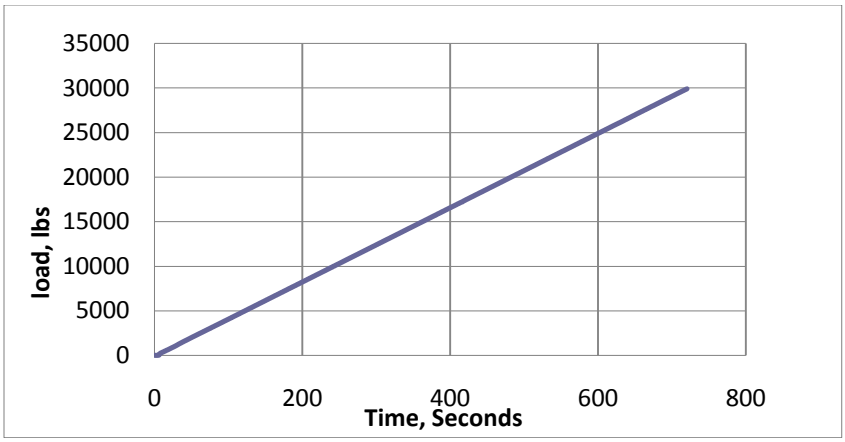

Figure 33: Load Curve for Specimen 5

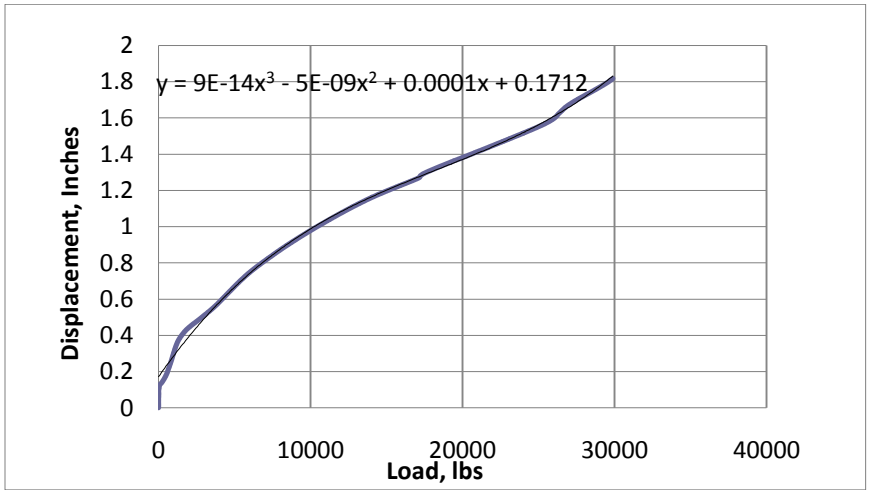

Figure 34: Load-Displacement Curve for Specimen 5

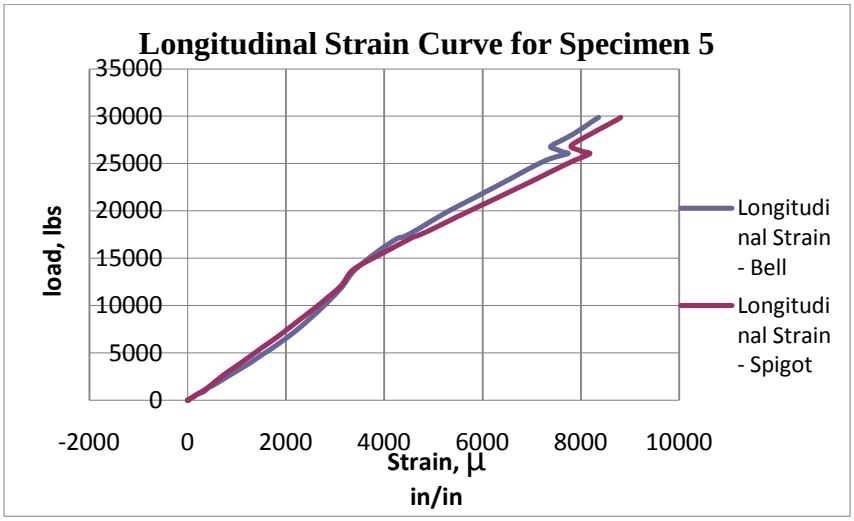

Figure 35: Longitudinal Strain Curve for Specimen 5

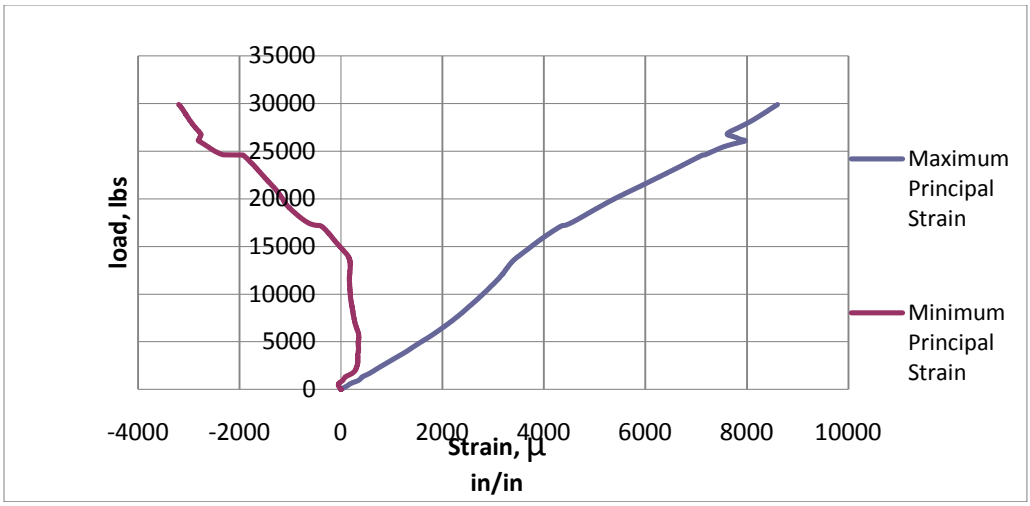

Figure 36: Principal Strain Curve as Bell End for Specimen 5

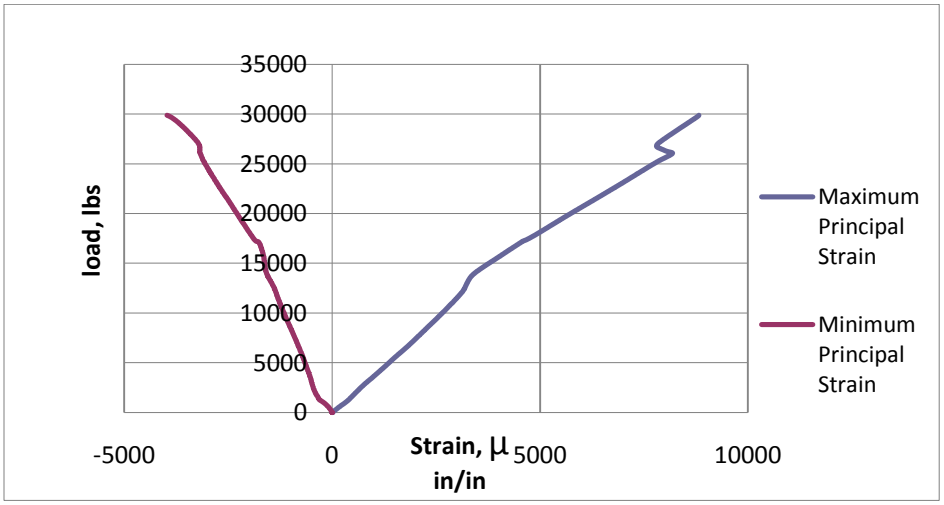

Figure 37: Principal Strain Curve at Spigot End for Specimen 5

6.6 Specimen 6

Joint of the specimen 6 failed at the spigot of the pipe assembly. The load at the time of failure was 27,747 lbs (see Figure 39 for load curve) while the displacement was 1.2856 inches (see Figure 38 for displacement curve). Figure 40 shows load-displacement curve for specimen 1. Strain recorded on the center strain gages (longitudinal) of rectangular strain gage rosettes at the bell end and the spigot end at the time of failure read 6,512 µin/in and 9,435 µin/in respectively (see Figure 41 for longitudinal strain curve). Maximum and minimum principal strains recorded at bell end at the time of failure were 6,554 µin/in and -2,356 µin/in respectively at angle of 41 degrees clockwise of the Right strain gage. Maximum and minimum principal strains recorded at spigot end at the time of failure were 9,447 µin/in and -3,317 µin/in respectively at angle of 43 degrees clockwise of the Right strain gage. This showed that the principal strains were in the circumferential direction at both the bell and spigot ends of the pipe assembly. Figure 42 and Figure 43 show principal stresses curves for Bell and Spigot ends respectively.

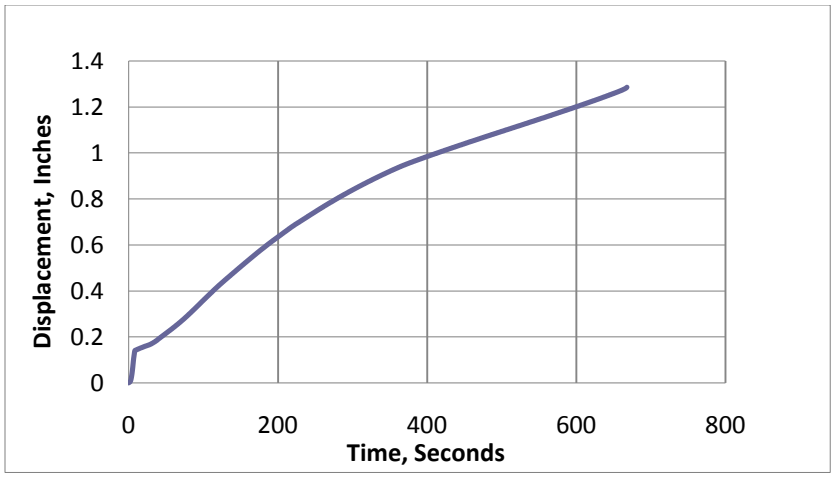

Figure 38: Displacement Curve for Specimen 6

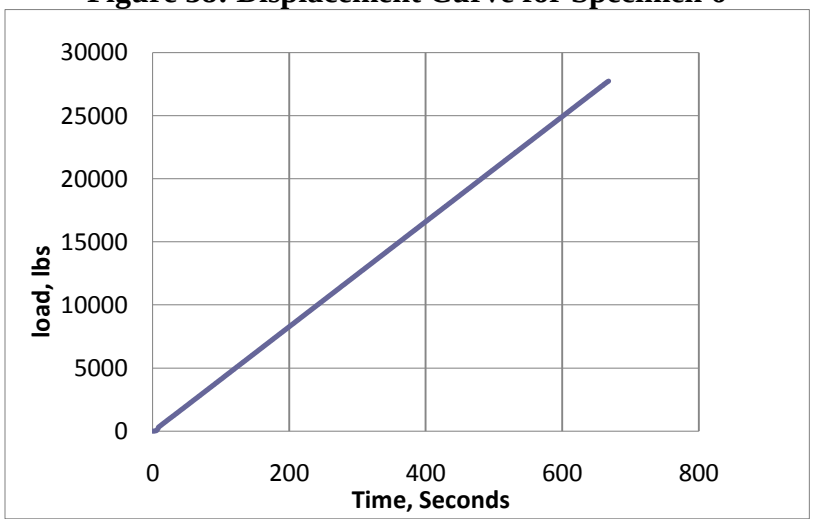

Figure 39: Load Curve for Specimen 6

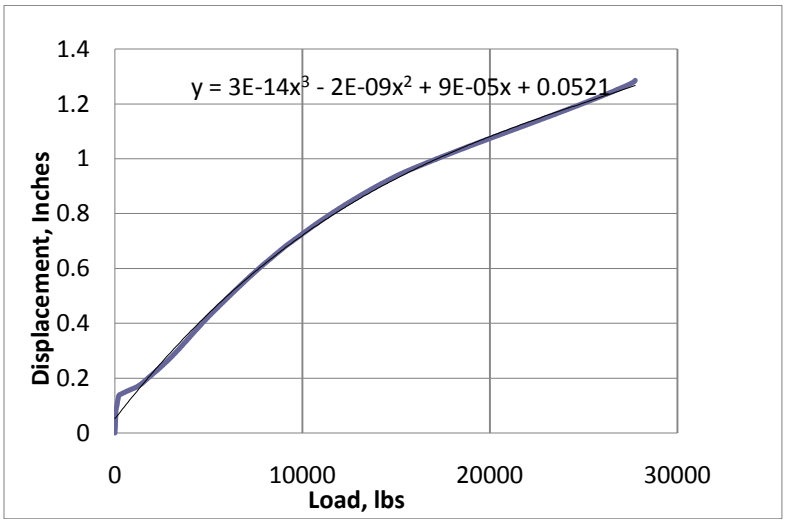

Figure 40: Load-Displacement Curve for Specimen 6

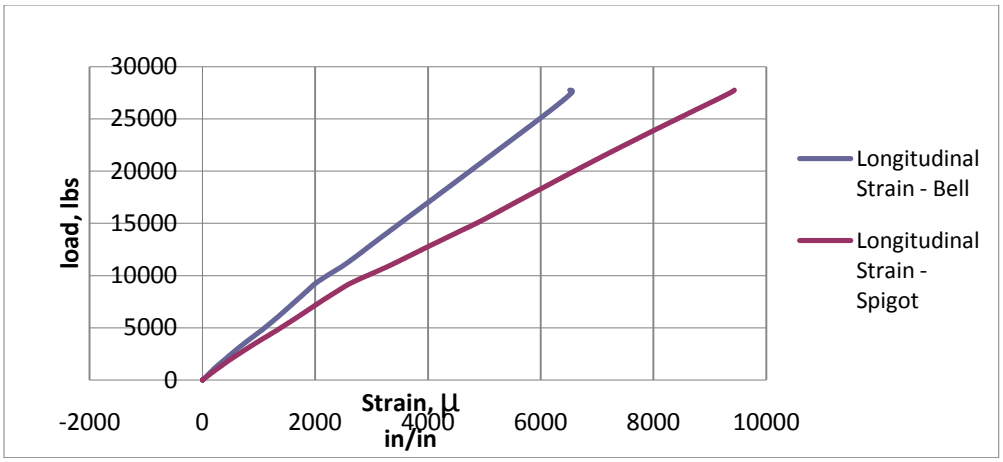

Figure 41: Longitudinal Strain Curve for Specimen 6

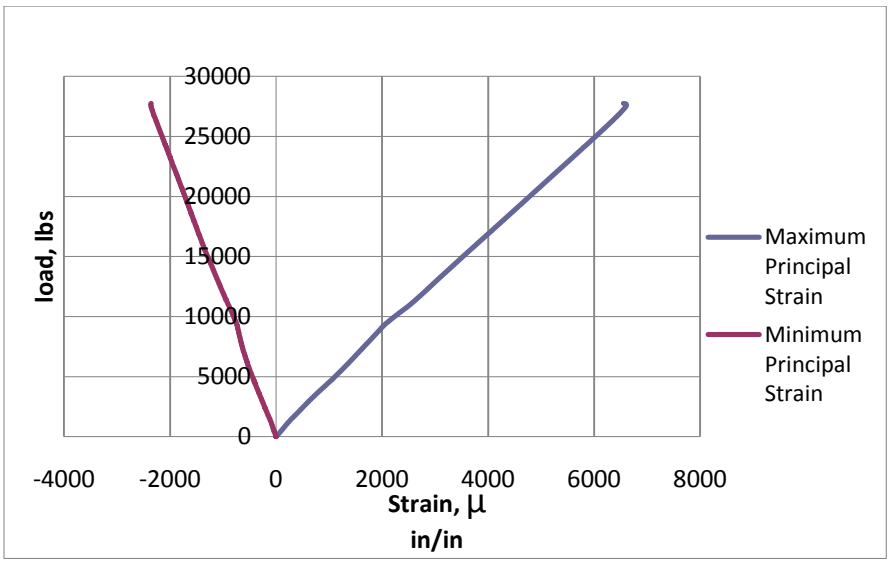

Figure 42: Principal Strain Curve at Bell End for Specimen 6

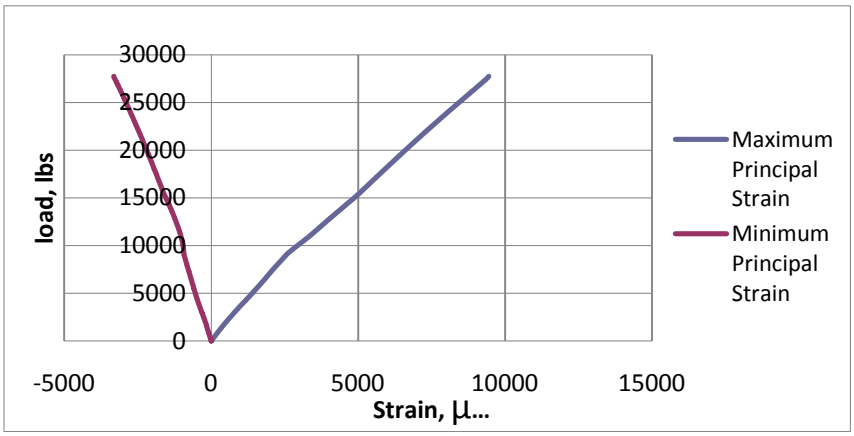

Figure 43: Principal Strain Curve at Spigot End for Specimen 6

7. Discussions

Seventy-five percent of the samples failed at the spigot. Principal stains were in circumferential directions in majority of occasions (seventy-five percent). The reason for spigot failing in majority of occasions may be extra thickness provided to the bell. In case when bell has failed (for 4" and 6" pipes), failure of spigot for same diameter of pipe has been at higher loads. Spigot failures (for 8" pipes) have been observed at similar loads. This indicates that safe load can be predicted on basis of capacity of spigot (within BRJ) to withstand tensile load. However, bell end has to be manufactured to be able to withstand more tensile load within the joint than spigot, because bell-end has more room for increase in thickness.

8. Conclusions

Tensile tests were conducted for 4" and 8" diameter PVC pipe assemblies with Bulldog Restraint Joint System. The test specimens were subjected to constant displacement. Load and strain were measured. The test results are summarized in Table 2 and Table 3.

Maximum allowable tensile load for pipe joint system is essential in planning trenchless installations. Allowable tensile load rating is required for designers to use Bulldog Restraint Joint Systems in trenchless applications.

Table 2: Summary of Results

Specimen No.	Position of Failure	Load at Failure, lbs	Displacement at Failure, inches	Longitudinal Strain at Failure, μin/in	
				Bell End	Spigot End
1	Bell	19,479	1.67	10,259	14,059
2	Spigot	21,237	2.48	14,044	3,001
3	Spigot	54,249	1.37	4,315	10,001
4	Spigot	54,181	1.24	4,335	10,175
5	Spigot	29,896	1.82	8,358	8,809
6	Bell	27,747	1.28	6,512	9,435

Table 3: Principal Strains on Specimens

Specimen No.	Principal Strain – Bell End, μin/in			Principal Strain – Spigot End, μin/in		
	Maximum	Minimum	Direction	Maximum	Minimum	Direction
1	10,333	-4,103	Circumferential	14,065	-4,690	Circumferential
2	14,029	-5,224	Longitudinal	3,023	-1,560	Longitudinal
3	4,336	-5,017	Circumferential	10,012	-4,106	Circumferential
4	4,359	-5,631	Circumferential	10,181	-3,549	Longitudinal
5	8,605	-3,200	Circumferential	8,823	-3,972	Circumferential
6	6,554	-2,356	Circumferential	9,447	-3,317	Circumferential

9. Limitations

A standard specifically for testing tensile strength of joint was not found. ASTM D 638 – 03 was used as guideline but was not totally followed. ASTM D 638 is standard for testing tensile properties of plastics. The test was performed on a composite joint which consisted of plastic

pipe, steel grip ring and rubber gasket. Hence, the specimen was a composite material. One of the limitations of the tests was that we were not able to adhere strictly to any published Standard for the tests due to lack of a standard that covers this particular test. Thickness of the pipe varied slightly along the length of the pipe. Since the wall thickness variations were not measured, only the load is reported and the tensile stresses were not calculated. While the results presented in this report are intended to be used for practical applications in the field, for research and academic purposes, knowing the tensile stresses would be useful.

10. Recommendations

The data from these tests must be used very carefully while designing for trenchless installations. Joints may behave in different manner in different installation conditions, such as installing the product at temperatures far greater or lower than the temperature at which the tests were conducted. For trenchless applications it is also important to know about behavior of joint under a combination of tensile and bending loads. This test will be the subject of the next phase of research.

References

Bulldog Restraint Systems. (n.d.). *Pipe/Fittings*. Retrieved August 17, 2009, from Bulldog Restraint Systems: http://www.bulldogrestraintsystem.com/pipe.html

Najafi, M., & Gokhale, S. (2005). *Trenchless Technology: Pipeline and Utility Design, Construction and Renewal.* McGraw Hill Companies, Inc.