Progress Report

on

Phase II of Long-term Properties of Corrugated HDPE Pipes

to

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by

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1. INTRODUCTION

The full specification of 100-year corrugated HDPE pipes is currently pending on the conformation of long-term properties. Three standard tests which are FM 5-575 (creep rupture of the pipe liner), FM 5-576 (long-term tensile strength), and FM 5-577 (long-term modulus) were initially proposed to evaluate the long-term properties of the corrugated HDPE pipe. Due to results of recent studies, modifications have been made on these three test methods. In this progress report, the modifications of the test methods and the determination of long-term tensile strength and long-term modulus are described.

2. LONG-TERM TENSILE STRENGHT

A draft report on the determination of long-term tensile strength was submitted to FDOT dated December 21st, 2010. The report presented the technical reason to eliminate both FM 5-575 and FM 5-576, and adaptation of FM 5-572, procedure B to determine the long-term tensile strength. The report is summarized as follows:

For determination of 100-year tensile strength, tests should be performed on specimens taken from the finished pipes. Two test methods (FM 5-575 and FM 5-576) were developed to assess the long-term tensile strength of corrugated pipe; FM 5-575 describes the test procedure to determine the ductile-to-brittle curve using pipe liner material, and FM 5-576 describes the analytical method to predict the long-term tensile strength. Since stress cracking is most likely occurring at the pipe junction, the creep rupture test should be evaluated using the junction specimens instead of liner specimens. Therefore, the test shall be performed according to FM 5-572, procedure B. Using test conditions and required failure time values specified in Section 948, the 100-year tensile strength is predicted to be 800 psi. This strength value is a conservative prediction because the 100-year approval pipes exhibit failure times well exceed the specified minimum failure time at all three test conditions.

The report also recommended that *"if industry would like to increase the 100-year tensile strength value, an interlaboratory test program should be carried out using slightly higher applied stresses defined in Section 948. All tests must be carried out to failure."*

3. LONG-TERM MODULUS

A draft report on the evaluation of long-term modulus of corrugated HDPE pipe was submitted to FDOT dated December 21st, 2010. The report presented the technical reason for adopting ASTM D6992, "Standard Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method (SIM)" to determine

the long-term creep modulus of corrugated HDPE pipe. The test standard, FM 5-577, was modified by incorporating the SIM test procedure. A series of round robin programs have been organized to ensure the test being properly performed by the participating labs. The first round robin (RR) program (RR #1) took place in January 2011 with four participating labs. The third RR program (RR #3) is on-going and should be completed in the early of August. It is anticipated that results of the fourth RR program (RR #4) will be used to determine the long-term modulus value with 95% confidence. The RR programs and the available test results are presented in this report.

3.1. RR #1 Program

The purpose of the RR #1 program is to identify the discrepancy of the test procedure and apparatus among the four participating labs. In addition, the appropriate method to measure the creep strain was investigated (cross-head movement of the tensile machine vs. strain gauge). Prior starting the RR program, decisions were made regarding the test specimen and the gauge length. Two types of test specimen, dumbbell and strip specimens, were included in the program dependent on the method used to measure the creep strain, as shown in Table 1. Most importantly, the test specimen shall have a relatively uniform thickness within the gauge length region. Therefore, the test specimen shall be taken from the liner portion of the pipe, as depicted in Figure 1.

Table 1. The test parameters of SIM implemented in RR#1

Strain Measurement Method	Strain Gauge	Cross-head Movement
Test Specimen	ASTM D 638, Type IV (Dumbbell specimen)	ASTM D 882 (1-inch strip specimen)
Gauge Length	1-inch	2-inch
Grip Distance	2.5-inch	2-inch

Form the results of RR#1 program, two important findings were identified:

- Strain gauge must be used to measure the creep strain. Figure 2 shows that the measured creep strain is higher using the crosshead of the machine than strain gauge for 1-in strip test specimen.

- The duration to reach temperature equilibrium at each step is critical in achieving a smooth transition between two adjacent strain segments, as illustrated in Figure 3. It is recommended that the duration to reach equilibrium at each temperature step should be within 15 minutes.

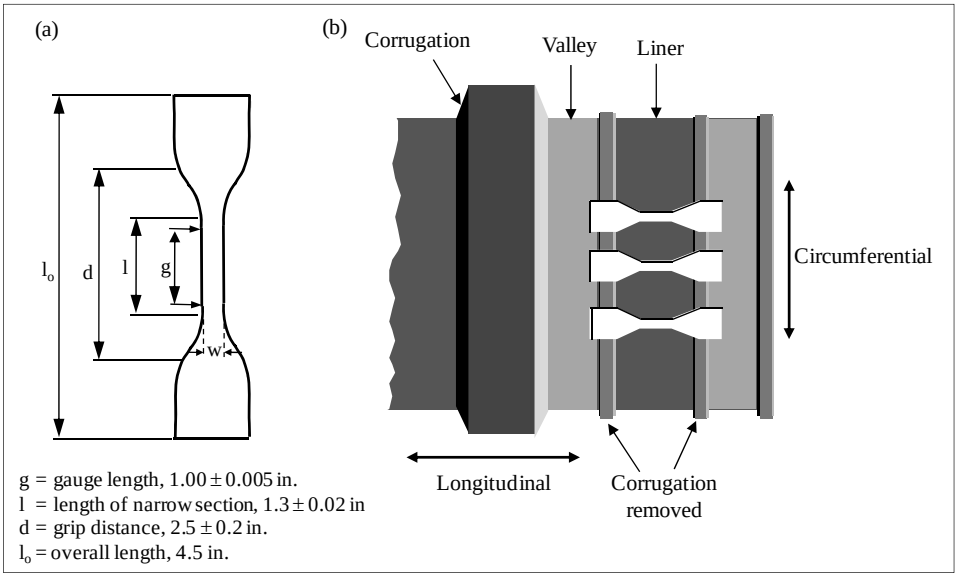


Figure 1 – ASTM D 638 type IV specimen used for the SIM test to measure creep modulus

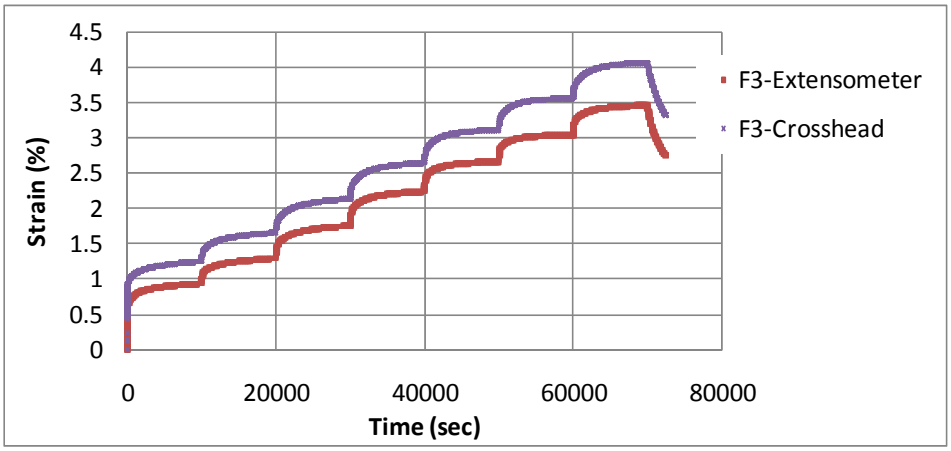
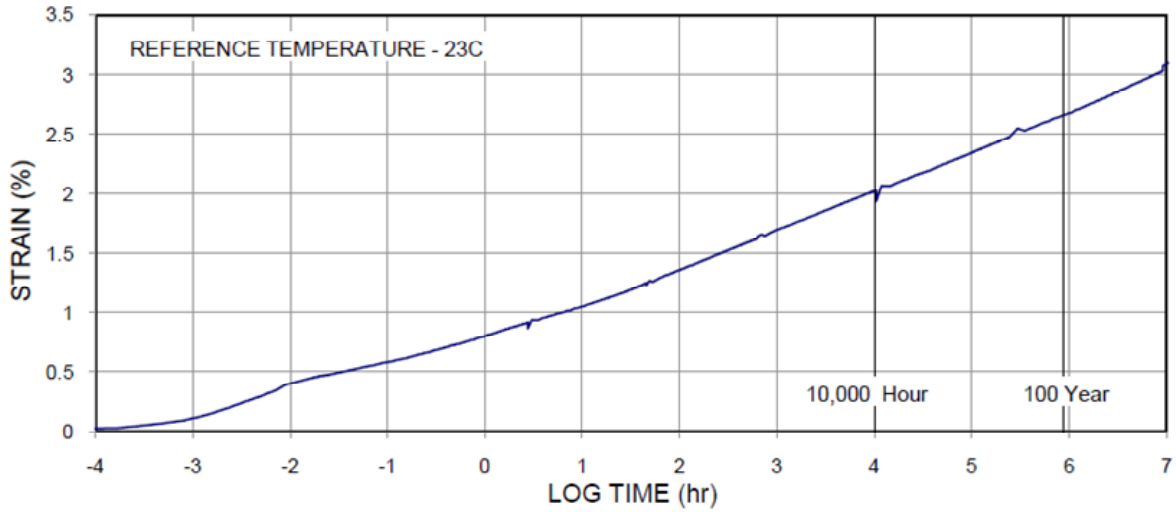
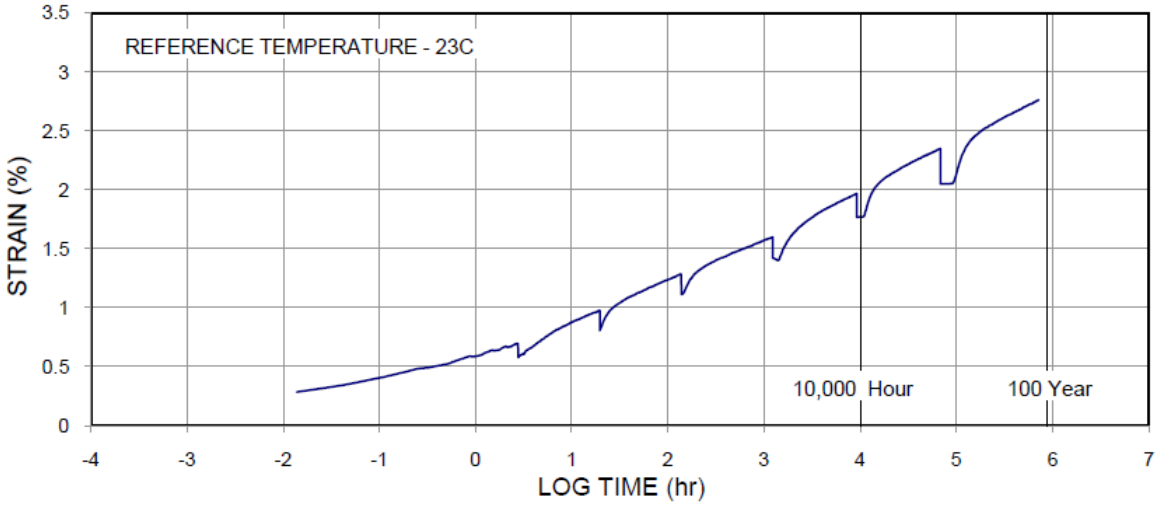


Figure 2. Comparing creep strain measurement between extensometer and crosshead



(a) Short equilibrium temperature time yielding smooth joining between adjacent strain segments



(b) Long equilibrium temperature time yielding poor joining between adjacent strain segments

Figure 3. Effect of time interval to reach equilibrium at each temperature step

3.2. RR #2 Program

Based on the findings of RR#1, the RR#2 program was organized to investigate the variability of temperature control and strain gauge. Furthermore, the test specimens were taken from the "top-hat" at the pipe end instead of the pipe liner portion of the pipe. The benefit of using the top-hat material is due to the uniformity of thickness. A longer test specimen, ASTM D 638 Type I, was used in comparison to ASTM D 638 type IV. The gauge length of the Type I specimen is 2-in, while it is 1-in for the Type IV specimen, making it easier to attach the strain gauge. Figure 4 shows the configuration of the Type I dumbbell specimen.

Figure 5 shows four sets of SIM data obtained from the participating labs. One of the labs. exhibits a much higher creep strain than the others. This lab is only one used an Instron tensile machine to perform the SIM test, and the applied force was controlled by a load cell. It is believed that the applied force imposed onto the test specimen increased with test temperature due to thermal expansion of the metal rods and grips (a compressive force was experienced by the load cell as metal expanded). The other three labs used dead-load for their SIM tests.

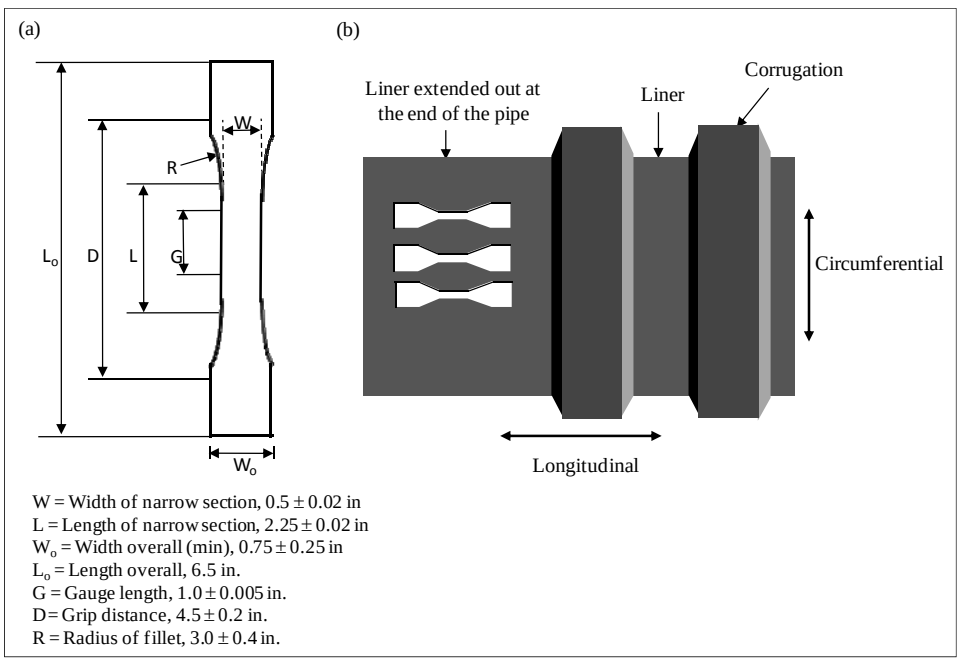


Figure 4. ASTM D 638 type I specimen used for the SIM test to measure creep modulus

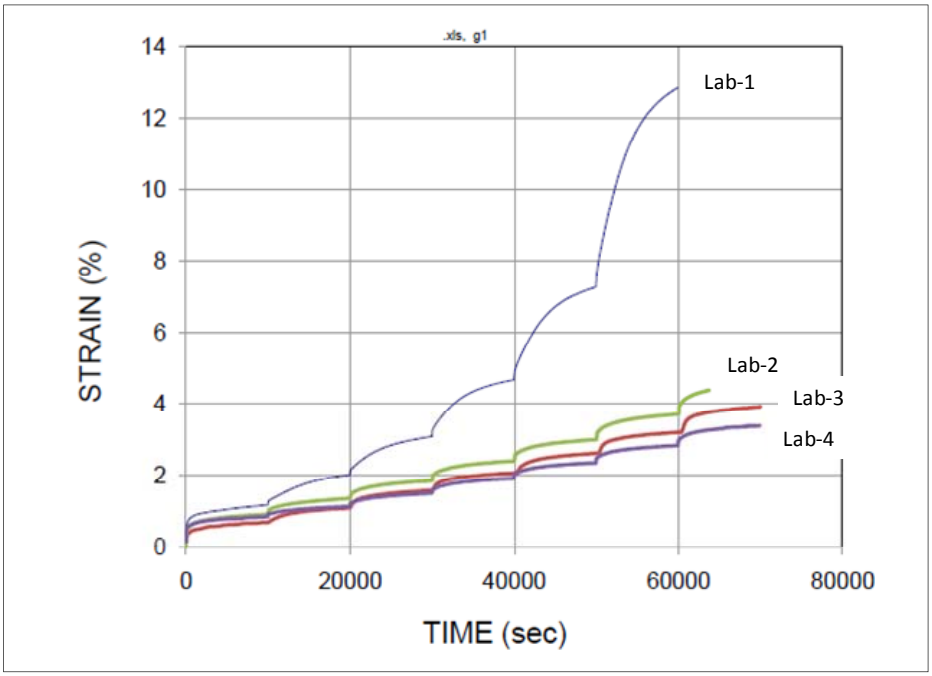


Figure 5. Comparing creep strain test data obtained from four labs

Form the results of RR#2 program, two important findings were identified:

- The top-hat material is too thin to be used for the SIM test. The thickness of this portion of the liner was found to be much thinner than the pipe liner (~ 0.045-in versus ~ 0.07-in). A compressive stress may be introduced by attaching the strain gauge to such thin material subsequently affecting the creep strain.

- Dead-load must be used to apply force to the test specimen in the SIM test.

3.3. RR #3 Program

The purpose of the RR#3 program is to isolate the variability contributed by the test equipments from that by the test specimens. The dumbbell shaped specimen, ASTM D 638, Type IV, was used in this program. The test specimens were taken from the compressive molded plaques instead of the pipe liner to minimize material variability. Figure 6 shows six sets of SIM test data from three participating labs, and they are relatively similar to each other. The master creep curve will be generated once the fourth lab submits the test data.

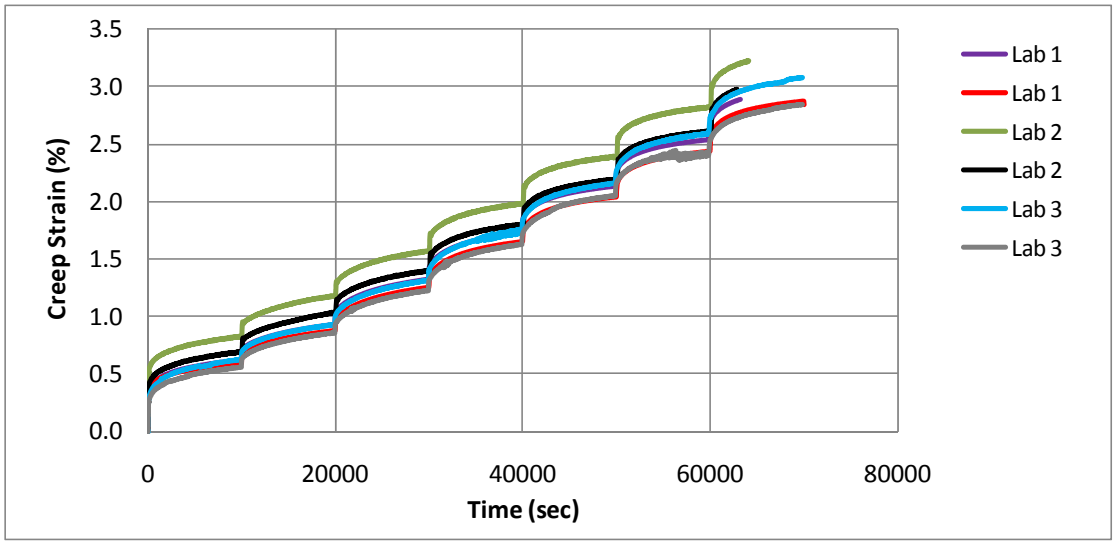


Figure 6. SIM test data from three participating labs of RR#3 program.

3.4. RR #4 Program

The results of RR#4 program will be used to determine the long-term modulus value with 95% confidence. The test specimens will be taken from the liner portion of the pipe using ASTM D638 Type IV die. The target of the program is to assess the effects of HDPE resin and pipe extrusion process. Table 2 shows the pipe samples that will be evaluated in this program. Two replicates will be performed for each sample.

Table 1 – Test samples of RR #4 program

Code	Pipe Manufacturer	Pipe Diameter (in)	HDPE Resin
Sample A	I	24	I
Sample B	I	48	I
Sample C	I	24	II
Sample D	I	48	II
Sample E	II	24	III