FIELD SURVEY AND LABORATORY TESTS ON COMPOSITE MATERIALS CASE OF GRP (GLASS FIBER REINFORCED POLYESTER) TUBES FOR WATER SUPLY

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Abstract. In the Moldova land, were made two lines of water adduction, having 6000 m length and 40 m slope, or 1/150 slope. The water supply component tubes were disposed under the plant: The tubes are made of glass – reinforced thermosetting plastics (GRP). After about 180 days of operation, one of the lines showed severe deterioration of the quality pipe components.
This paper deals with some laboratory tests in order to detect the failure cases of the pipelines components.

Key words: GRP, supply pipes

1. Introduction

The GRP - tubes market has tremendous growth opportunities across the globe, because it has extensive applications in areas like chemical, oil & gas, offshore, sewage and retail fuel.

A proper case study, concerning the severe deterioration of the quality pipe tubes, is presented.

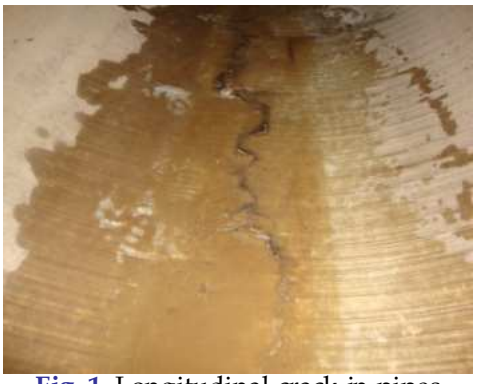

Fig. 1. Longitudinal crack in pipes

Fig. .2. Longitudinal crack in pipes

Fig. 3. Longitudinal crack in pipes

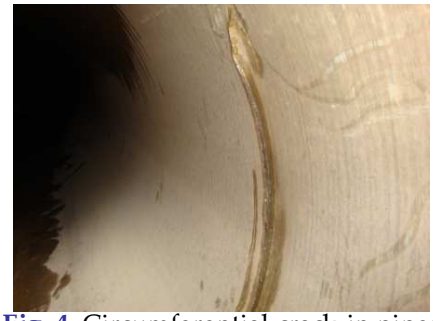

Fig. 4. Circumferential crack in pipes

After about six month of operation, one of the lines showed severe deterioration, as shown in Fig. 1 ... Fig. 4.

Therefore, the investor company requested tests concerning both of the quality strength and the deformability of the pipe material, following the standards (SR EN 1796 + A1, 2009; EN 1393 and 1394, 2003). Determination of initial longitudinal tensile properties, respectively determination of the apparent initial circumferential tensile strength, follows. Were presented on samples from the damaged pipes, called DGI, which is the subject of this analysis.

2. Test Case

2.1. Determination of initial longitudinal tensile properties for DGI pipes (SR EN 1796 + A1, 2009; EN 1393, 2003; Hariga and Duță, 2012)

Plastics piping systems for water supply- Glass reinforced thermosetting plastics (GRP) pipes based on unsaturated polyester resin (PN).

2.1.1. Specimens tested

a) Description of the test pieces:
Prismatic test specimens consist of segments with dimensions l * b * h = 250 * 50 * 20 mm, cut from the tube type III (DGI 106) DN 1300 mm nominal diameter and nominal pressure PN 6.

The size of the test pieces was according to the (SR EN 1393, 2003) specifications, page 7, section 5.2, section 5.2.1 (b) Section 5.2.2.3, page 8-9, Method A.

b) Method of conditioning: The conditioning of the test pieces was performed in standard laboratory conditions, with average temperature of 20 ± 2 ° C and average humidity of 65 ± 5%.

2.1.2. Method of test

It is identified in Section 8, page 12, of the standard (SR EN 1393, 2003).

a) The method consists of: The test pieces are subjected under constant tensile load during 1...3 min. Power failure is recorded in N.

Table 1. Determination of initial longitudinal tensile properties. SPECIMENS P 3.1 ... P 3.6 DGI

b) Temperature and relative humidity at the time of testing: Average temperature of 20 ± 2 ° C and average humidity of 65 ± 5%.

Table 1. Determination of initial longitudinal tensile properties. SPECIMENS P 3.1 ... P 3.6 – DGI 106

GEN INF tube defects. - DGI SPECIMEN	**bi, bi' [mm]**		**ei, ei' [mm]**		**F [N]**	$\sigma_1 A,i^*$ **[N/mm]**	σ_{min} **[N/mm]**
P 3.1 DGI IMMS 84/E31/12.11	bi	55.60	ei	21.00			
	bi'	56.90	ei'	21.00			
MEAN	**	54.70	**	21.00	20200	369.29	**275.00**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]		ei, ei' [mm]				
P 3.2 DGI IMMS 84/E3-2/12.11	bi	54.70	ei	21.00			
	bi'	56.20	ei'	21.00			
MEAN	**	55.45	**	21.00	23300	420.20	**275.00**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]		ei, ei' [mm]				
P 3.2 DGI IMMS 84/E3-2/12.11	bi bi'	54.70 56.20	ei ei'	21.00 21.00			
MEAN	**	55.45	**	21.00	23300	420.20	**275.00**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]		ei, ei' [mm]				
P 3.4 DGI IMMS	bi	51.70	ei	20.50			
84/E3-4/12.11	bi'	52.80	ei'	20.50			
MEAN	**	52.25	**	20.50	22900	438.28	**275.00**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]		ei, ei' [mm]				
P 3.5 DGI IMMS	bi	53.30	ei	21.00			
84/E3-5/12.11	bi'	54.10	ei'	21.00			
MEAN	**	53.70	**	21.00	24500	456.24	**275.00**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]		ei, ei' [mm]				
P 3.6 DGI IMMS	bi	52.30	ei	20.50			
84/E3-6/12.11	bi'	53.70	ei'	20.50			
MEAN	**	53.00	**	20.50	22700	428.30	**275.00**
MEAN TUB VALUE =						424.06	**275.00**

Where:

ei, ei'= measured thickness of the specimen wall on opposite sides; [mm]

bi, bi' = measured width of the specimen, in the middle, on opposite sides [mm]

F = breaking strength of the specimen [N];

$\sigma_1 A,i^*$ = initial tensile strength, longitudinal [N / mm].

σ_{min} = initial tensile strength, minimum longitudinal [N / mm] under SR EN 1796+A1:2009 provisions, section 5.2.5.1, Table 13, for DN =1300 and PN=6.

The calculated value for was performed under the SR EN 1393:2003 provisions, page. 13, section. 9.1, with the formula:

$$\sigma_1 A,i^* = \frac{F}{b}$$

c) Description of the test equipment:
ZD type hydraulic press UNIVERSAL TESTING MACHINE 400 kN, caliper measurement precision of 0.1 mm.

2.1.3. Test Resuls

The size specimens tested on initial longitudinal tensile is presented in the results table (Table 1). Allure of the test specimens is shown in Fig. 5.

Fig. 5. Test specimens type III (DGI 106)

2.2 Determination of the apparent initial circumferential tensile strength, of DGI pipes (SR EN 1796 + A1, 2009; EN 1394, 2003; Hariga and Duță, 2012)

Plastics piping systems for water supply- Glass reinforced thermosetting plastics (GRP) pipes based on unsaturated polyester resin (PN).

2.2.1. Specimens tested

a) Description of the test pieces:
The prismatic test specimens consist of segments with dimensions l * b * h = 250 * 50 * 20 mm, cut from the tube type III (DGI 106) DN 1300 mm nominal diameter and nominal pressure PN 6. The size test pieces was as specified in (SR EN 1393, 2003), page 7, section 5.2, section 5.2.1 (b) Section 5.2.2.3, page 8-9, Method A.

b) Method of conditioning:
The conditioning of the test pieces was performed in standard laboratory conditions, with average temperature of 20 ± 2 ° C and average humidity of 65 ± 5%.

2.2.2. Method of test

It is identified in Section 8, page 12, of the standard (SR EN 1393, 2003).

a) The method consists of: The test pieces are subjected under constant tensile load during 1 ... 3 min. Power failure is recorded in N.

b) Temperature and relative humidity at the time of testing: Average temperature of 20 ± 2 °C and average humidity of 65 ± 5%.

c) Description of the test equipment:
ZD type hydraulic press UNIVERSAL TESTING MACHINE 400 kN, caliper measurement precision of 0.1 mm.

2.2.3. Test Resuls

The size specimens, tested on apparent initial circumferential tensile, is presented in the results table (Table 2). Allure of the test specimens is shown in Fig. 6.

Fig. 6. Test specimens type III (DGI)

Table 2. Determination of the apparent initial circumferential tensile strength SPECIMENS P 4.1 ... P 4.6 DGI 106

GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]		F_{ult} [N]	$\sigma_c C,i^*$ [N/mm]	dm [m]	ei, m [m]	di, m [m]	P0,c [bar]	σ_l^* [N/mm]
P 4.1 DGI 106 IMMS 84/E4-1/12.11	bi	25.10							
	bi'	25.10							
MEAN	**	25.10	29000	1155.38	1.3135	0.0200	1.2935	17.86	**586.62**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]								
P 4.2 DGI 106 IMMS 84/E4-2/12.11	bi	25.20							
	bi'	25.20							
MEAN	**	25.20	30000	1190.48	1.3133	0.0209	1.2924	18.42	**604.86**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]								
P 4.3 DGI 106 IMMS 84/E4-3/12.11	bi	25.00							
	bi'	25.00							
MEAN	**	25.00	31000	1240.00	1.3128	0.0200	1.2928	19.18	**629.59**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]								
P 4.4 DGI 106 IMMS 84/E4-4/12.11	bi	25.00							
	bi'	25.00							
MEAN	**	25.00	32500	1300.00	1.3136	0.2020	1.1116	23.39	**768.12**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]								
P 4.5 DGI 106 IMMS 84/E4-5/12.11	bi	25.10							
	bi'	25.10							
MEAN	**	25.10	32000	1274.90	1.3125	0.0198	1.2927	19.72	**647.21**
GEN INF tube defects. - DGI SPECIMEN	bi, bi' [mm]								
P 4.6 DGI 106 IMMS 84/E4-6/12.11	bi	25.50							
	bi'	25.50							
MEAN	**	25.50	30000	1176.47	1.3133	0.0194	1.2939	18.18	**597.05**
MEAN TUB VALUE =				1222.9					**638.91**

The calculated value for $\sigma_c C,i^*$ was performed according to SRIThe reference value σ_l^* is calculated as specified EN 1394:2003, pag. 18, section. 9.3, with the formula:

$$\sigma_c C,i^* = \frac{Fult}{b}$$

SR EN 1796+A1:2009, section 5.2.5.2.2 and section. 5.2.6.2.2, as follows:

$$P_{o,C} = 0.02 * \sigma_c C,i^* / d_i;$$

$$\sigma_l^* = 25 * P_{o,C} * d_m.$$

3. Conclusion

In addition to the above, the following conclusions can be drawn:

a) Apparent initial tensile resistances both in the longitudinal and the circular direction, is much higher than the minimum reference values. This confirms the quality of the material put into practice.

b) Studying the breaking of the pipe rings shown in the attached photos, it has been found that the cracks occurs mainly in the pipe wall core, in the middle section, when the maximum normalized deflection ring is achieved.

c) The destruction of the pipe wall is not caused by the poor quality of the material but due to a serious non-conforming aspects, technological point of view, occurred during the manufacturing process.

d) Severe damages shown in Fig. 1 ... Fig. 4 can be explained by the emergence of some accidental forces of high intensity. The mechanism of such forces may be due to an unexpected water hammer.

According the test results, the following advantages of GRP composite tubes can be marked out:

- Long service period with low maintenance costs and high quality product because of the material characteristics.
- High resistance in service at different depth underground installation
- Resistance to constant external forces because of the high rigidity of the tube.
- Disadvantages:
- Vulnerable to the unexpected forces of high intensity.

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