Investigation of Tensile Strength of Naturally Aged PE100 Irrigation Pipes after Butt Welding

Mehmet ŞAHBAZ[1]*, Erkin AKDOĞAN[1],
[1]*Karamanoğlu Mehmetbey University, Department of Mechanical Engineering, Karaman, Turkey,*
**mehmetsahbaz1@gmail.com*

Abstract

This study investigated the tensile strength properties of three-walled high-density polyethylene (HDPE) irrigation pipes with 85% recycled material added. An important factor limiting the use of polyethylene materials is that they age and lose their strength properties when exposed to environmental conditions. Another negative factor is that the weld locations in these pipes reduce their overall strength. Tensile tests were performed on specimens obtained from naturally aged pipes for one year, butt welded pipes, and unused pipes. As a result of the tests, different results were obtained for the three different cases. As expected, the highest properties were observed in the unused pipe, while elongation and consequently toughness values decreased in naturally aged specimens. In the welded specimens, on the other hand, sudden fracture occurred at the welding points, and accordingly, both strength and strain values were observed at lower values.

Keywords: PE100 pipe, HDPE, tensile test, elongation, burr welding

1. Introduction

High-Density Polyethylene (HDPE) materials are found in many places in everyday life. The fact that it can be produced in different specifications depending on the application increases the use of these materials. One of the advantages of HDPE materials is their high chemical resistance compared to metals. However, as a result of thermal effects, some changes in mechanical properties can be observed. It is also important to determine and reveal these properties [1].

Also, HDPE or PE 100 pipes are widely used today for liquid and gas transportation. Compared to metal pipes, features such as lightness, corrosion resistance, easy applicability, and cost make polyethylene pipes preferred [2,3]. Polyethylene pipes are also frequently used in agricultural irrigation systems in the agricultural sector. While these pipes are applied above ground in portable systems, the permanent ones are buried underground. The fact that polyethylene materials age and lose their strength properties when exposed to environmental conditions is an important factor limiting their use. Whether direct sunlight or underground factors reduce the service life of these pipes. It has been observed that the effect of aging is faster, especially in pipes with recycled material additives. It was observed that both tensile strength and elongation at break decreased especially as the recycling number of materials increased [4]. Another negative factor is that the weld locations in these pipes reduce the overall strength [2,3]. In this study, specimens obtained from pipes naturally aged for one year, butt-welded pipes, and unused pipes were subjected to tensile tests. Different results were obtained for the three different cases.

2. Materials and Methods

Irrigation pipes made of HDPE in three different conditions (unused, aged, butt-welded) were used as test materials. These pipes were produced on an injection molding machine with three layers: inner, middle, and outer. While original granular raw material was used in the inner and outer layers, high-quality recycled material was used in the middle layer. SABIC brand P6006 was used as the original material. P6006 is a black compound high-density polyethylene (MRS 10 - PE 100 class) with multimodal molecular weight distribution. It has been specially developed for use in pressure piping applications. It offers very good long-term hydrostatic strength combined with excellent stress crack resistance (ESCR) properties. The ratio of recycled material by weight is 85%, which contributes positively to the environment and production cost.

The most widely used tensile test was used to determine the mechanical properties of the materials. Tensile tests were performed using the Shimadzu brand, AGS-X model, and 100kN capacity electromechanical tensile compression tester. The test results were accurately recorded by Trapezium-X software and the relevant graphs and values were obtained from there. Tensile test specimens were prepared according to ASTM E8 standards and the tests were performed in accordance with the same standard at a speed of 1mm/min. As a result of the test, information about many mechanical properties was obtained.

2. Results and Discussions

Specimens prepared from materials in three different states were subjected to tensile tests with unidirectional tension at constant speed until rupture. Figure 1 below shows the specimens in three different states and the butt-welded specimen before the tensile test.

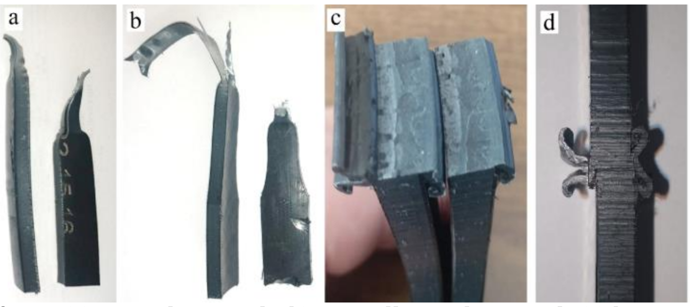

Fig. 1 Tensile test specimens from: (a) unused material, (b) naturally aged material, (c) butt-welded, and (d) butt-welded specimens before the tensile test

The shape changes in the specimens shown in Figure 1 after the tensile tests provide information about the behavior of the materials. Figure 1a shows the specimen obtained from the unused pipe after the tensile test. A homogeneous and long shape change is seen in the material before fracture. In Figure 1b, it is observed that the 15% original material in the inner and outer parts of the specimen produced from naturally aged pipe shows more ductility. Figure 1c shows the surface of the specimen produced from butt-welded (unused and 85% recycled) material after a sudden fracture. Figure 1d shows the butt-welded specimen before the tensile test.

The graph below (Figure 2) shows the stress-strain curves obtained after the tensile tests and confirms the above. Ultimate strength and yield strength values are close for unused and aged pipes, while strain values are almost halved for aged specimens. This situation confirms the literature [5] and shows that aging does not have a negative effect on stress values but decreases the elongation property.

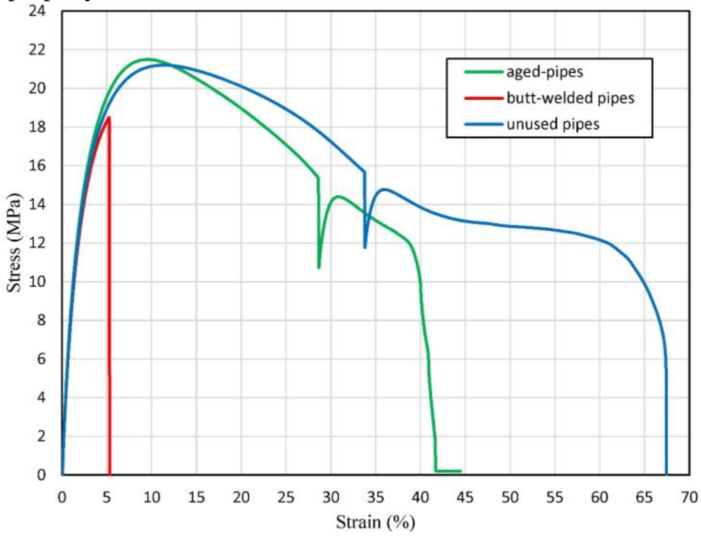

Fig. 2 Stress-Strain curves for three different cases

Table 1 presents some mechanical properties obtained from these curves. When the table values are examined, unused pipe gives the highest values while the lowest values are obtained from the butt-welded pipe. The toughness value calculated according to the area under the stress-strain graph was the lowest in the welded pipe with the lowest elongation and strength values.

Table 1. Mechanical characteristics of pipes from unused, naturally aged, and butt-welded materials

HDPE or PE 100 Irrigation pipe	Ultimate tensile strengths, MPa	Elongation at Break (%)	Toughness (J/mm^3)	Young's modulus *E*, MPa
Unused pipe	21.2 ± 0.3	67.45 ± 1.25	1050.6 ± 13.1	1097 ± 78
Naturally aged pipe	21.5 ± 0.3	41.94 ± 7.87	464.9 ± 129.6	1092 ± 85
Butt-welded pipe	18.5 ± 1.5	5.16 ± 1.87	68.9 ± 20.9	1093 ± 195

4. Conclusions

In conclusion, the highest mechanical properties were observed in the unused pipe. In the naturally aged specimens, the elongation and toughness values decreased. In the welded samples, however, sudden fracture occurred at the weld areas, and as a result, both strength and strain values were observed to be lower.

Tensile strength and elastic modulus values were near to unused material in the aged material. Natural aging has no negative effect on these values. However, toughness was observed to decrease by 55.8% in aged material.

The tensile strength of butt-welded parts showed a 14% decrease. A 95% decrease was observed in toughness and elongation at break values. Mechanical properties can be increased by minimizing the misalignment in the weld zone. As a future study, optimum welding parameters can be determined by changing the welding temperature-pressure values. Thus, the strength of the weld zone can be increased.

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