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Influence of Adding Polypropylene(PP) into Polyethylene(PE) on Mechanical Properties of Geocells

Sabi Sabev
Technical University of Sofia, Branch Plovdiv
Plovdiv, Bulgaria
sabi_sabev@tu-plovdiv.bg

Plamen Kasabov
Technical University of Sofia, Branch Plovdiv
Plovdiv, Bulgaria
plamen.kasabov@abv.bg

Konstantin Chukalov
Technical University of Sofia, Branch Plovdiv
Plovdiv, Bulgaria
konstantin_chukalov@abv.bg

Valeri Bakardzhiev
Technical University of Sofia, Branch Plovdiv
Plovdiv, Bulgaria
bakardzhiev@tu-plovdiv.bg

Abstract. **In the article, it will be considered what is the influence of the addition of 10% PP into a polyethylene mixture compared to a mixture of polyethylene on the main mechanical characteristics of geocells - hardness, maximum tensile strength, strength of the internal structural junctions (welds). It will be analyzed the interrelationships between the measured mechanical parameters**

Keywords: geocells, PE/PP blends.

I. INTRODUCTION

Geocells (fig.1) are a network of plastic strips that are ultrasonically welded. The most common material for geocells is PE, but due to the expanding application of these products, requirements for higher strength characteristics are also increasing especially for loading applications. One of the directions for increased strength characteristics is adding a harder material into mixture of PE such as PP. This is a rational option for increasing the strength characteristics due to the unreduced productivity during extrusion as well as easy access and cost of PP. Although the combination of PE and PP has been studied in the literature, the studies on mechanical properties of the relatively new product geocells are not many and researches about them may lead to new applications. One of the big disadvantages of geocells application is the weak strength properties.

Fig. 1. Geocells.

II. MATERIALS AND METHODS

Strips of perforated high-density polyethylene sheets, also known as cell-walls, are welded together at locations known as junctions [1]. Geocells are used both in industrial practice mainly in construction infrastructure - highways, railways, dam walls, etc., as well as in consumer use - as a basis for various types of flooring and various garden applications [2] - [5]. Their use is increasing due to regulatory requirements for their application in first-class roads, as well as their engineering advantages - lightness, durability, possibility of occupying large roof areas, easy installation, individual sizes, etc. however, its applications

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are limited because of the sizeable long-term deformation under constant loading and poor tensile strength [6] - [9].

The most common used material for geocells offered by manufacturers is polyethylene with high density. This is due to the good mechanical and physical characteristics of polyethylene - hardness, elasticity, dielectric strength, moisture resistance, high chemical resistance [10].

The main disadvantages of polyethylene are the weak resistance to light and heat, but due to the specifics of its application, geocells are not exposed to direct light and high temperatures, which also predisposes to its use. From an economic point of view, there are also prerequisites for its use, because on one hand, primary polyethylene has a low cost and is widely available, and also the fact that High-density polyethylene (HDPE) is one of the most popular plastics used in industry [11], [12].

The additives that are traditionally used for geocells are different colorants, depending on the application of the product, as well as-UV stabilizer that improves the product's resistance to light [13].

Other anti-aging additives can be used to improve the technological qualities, fillers and plasticizers, etc. depending on the specific application of the product. In general, polyethylene has established itself as the main material due to the very good combination of technical and economic characteristics.

On another hand PP is a polymer with good mechanical properties-chemical resistance, weldability, stiffness, economical-easy access, low cost, ecological-recyclability.Generally polypropylene is a promising plastic by showing its great chemical, physical and mechanical properties PP applications include, but not limited to, fabrics, films, bottles, sheets and automotive products [14].

Blends of PE/PP have been largely studied because they make up 2/3 of the world's volume of plastics and are fully recyclable. For example, blow molding grade of HDPE as a bottle and injection molding grade of PP as a cap are often used to produce detergent bottles [15]. The proportions used in the article is 50/50 between virgin materials and recycled materials, because the production of geocells is associated with a large technological waste, which is reused.

The investigated properties are the major mechanical properties of geocells-hardness according to Shore D(according DIN 53505, maximum tensile strength(according ISO 10139, strength of internal structural junctions (welds) - according ISO 13426, method B. 10 samples were tested according every selected standardized method.

All tests are in accordance with the relevant test standards (fig 2), being observed the test conditions for the dimensions of the specimens, the range, the rate of deformation and the geometry of the testing machine and of the gripping jaws, as well as the surrounding environment.

The used machine equipment is calibrated according the metrology requirements. The test samples have an average thickness of 1.4 mm (deviation of maximum 5%, width of 100 and 150 mm], the results of samples composed of 100% PE and additives for color and anti UV agent were compared, as well as samples with 90% PE and 10% PP with the same additives.

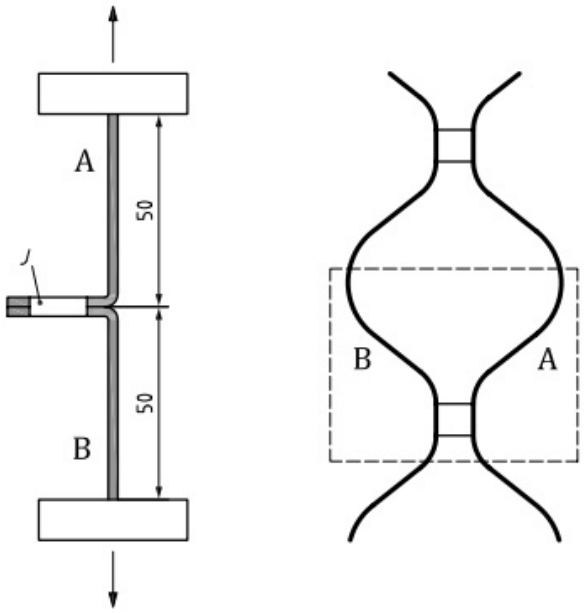

Fig. 2. Dimensions and place to take the sample (ISO 13426, method B) [16].

III. RESULTS AND DISCUSIION

The results are statistically processed. the trends in the mechanical indicators are shown, which may be used for other ratios as well. The numbers of tested samples is sufficient for statistical sampling,

The research can be used for other products from the same materials and additives and is not limited to geocells:

- Maximum tensile strength = Rm(kN/m)
  Rm = F/b

Where
F - maximum applied force (kN)
b - width of the sample (m)

The standardized dimension unit is kN/m.

Measured maximum tensile strength of 10 samples of both mixtures - fig 3, fig, 4. PE mixture results Rm{kN/m): 26.5, 27.7, 27.1, 27.3, 25.7, 26.9, 26.7, 27.7, 24.7, 27.3.

PE/PP mixture results Rm{kN/m): 29.6, 27.7, 26.4, 28.7, 27.8, 28.7, 26.6, 28.4, 27.2, 28.1

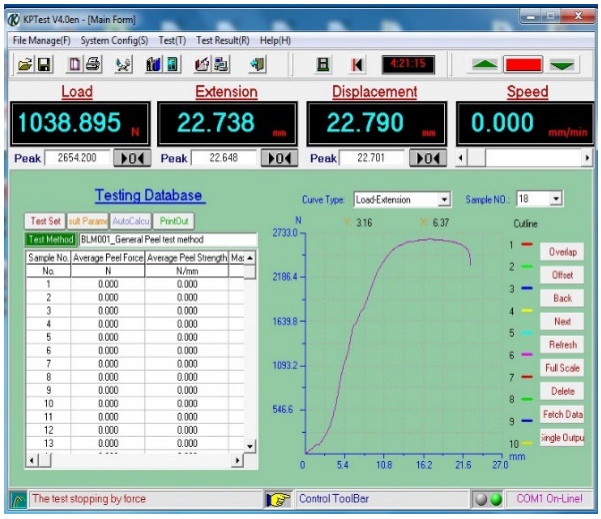

Fig. 3. Test result,sample No1,Force-1.65 kN,width of the sample-100mm,mixture PE.

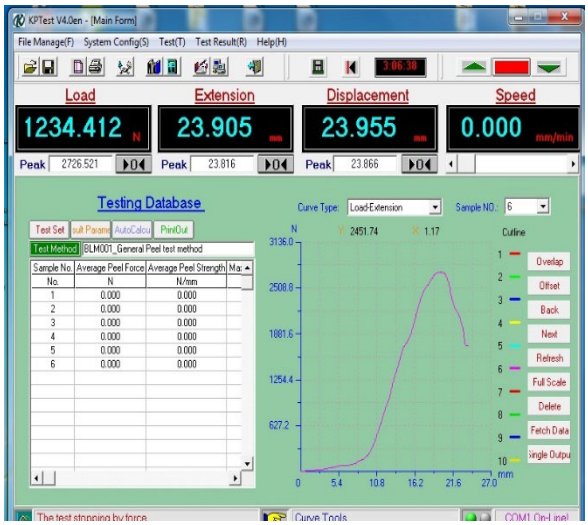

Fig. 4. Test result, sample No9, (mixture PE/PP).

The measured results show an average maximum tensile strength of a PE blend of 26.76 kN/m and an average maximum tensile strength of a blend of 90% PE and 10% PP of 27.92 kN/m or an increase in average ultimate tensile strength of 4.3% at addition of 10% PP. The results are statistically processed (fig. 5). Overall, the destruction figures are correct, no deviations are observed, testing conditions are correct, there is repeatability of the results, which is also proven by the regression analysis, although tensile strength testing of elastic materials is very sensitive.

The destruction graphs show no deviation from the test conditions The maximum tensile strength of geocells is an essential technical characteristic in declarations of conformity and is often a leading mechanical characteristic about the standardization of geocells as a productThe increasingly wide application of geocells leads to increasingly higher required results, especially of the essential characteristics depending on their application.

The addition of PP into PE increases the average maximum tensile strength and one of the options for higher requirements of maximum tensile strength according to the specification. No differences were observed in the extrusion performance of the two blends. The current results may be used as a basis for the use of different amounts of PP in PE.

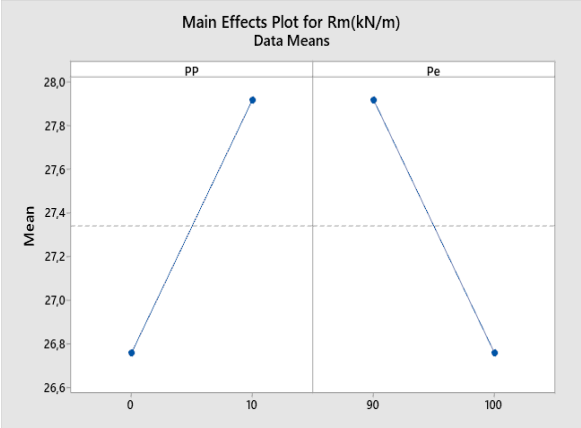

Fig. 5. Main effect plot for Rm.

Fig. 6. Test result, sample 3, mixture PE.

- Hardness

Hardness was measured according to the standardized Shore D testing method for polymers according to DIN 53505, with the range of the hardness indenter consistent with the theoretical results of the two mixtures. hardness measures the hardness of elastomers by measuring the

penetration depth.[17] Geocell testing according Shore D is suitable because of their textured surface. Hardness is not an essential technical characteristic in the declarations of conformity, but the relationship between the results of the measured hardness and other mechanical parameters, the study is important and can be used in engineering practice, since hardness measurement is a nondestructive test. Shore-D hardness gives additional help for tribological analysis of engineering polymers and their composites[18]. Tests according Shore D are measured in dimensionless units.The results are shown in fig. 6, fig7.

Hardness results (PE mixture)-Hsh-45.8, 44.6, 48.2, 46.7, 46.5, 47.8, 44.5, 47.7, 44.5, 45.5.

Hardness results (PE/PP mixture)-Hsh-56, 56, 57.3, 59.4, 58.2, 57.7, 59.5, 57.5, 58, 58.3.

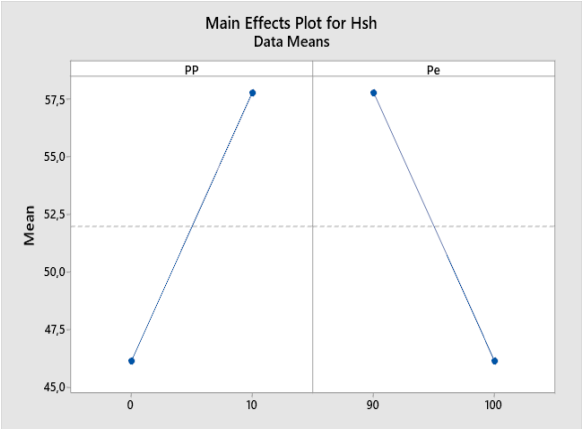

Fig. 7. Main effects plot for Hsh.

The average Shore D hardness values of both mixtures of 46.16 and 57.79 show a significant increase in hardness with the addition of 10% PP by 26.78%. It should not be overlooked that the increased hardness causes technological problems, because it slows down and makes the cutting process more difficult. Cutting is often a finishing operation during manufacturing the product. Also it is possible to get cracks as a result of the increased hardness, during cutting which affects the quality and manufacturing rate of the product.These problems may be solved by choosing technological processes for the manufacturing of the product, in which there are no cutting processes.

- Maximum tensile strength for internal structural junctions are shown in fig 8, fig 9, fig. 10.

The connection mode of junctions is crucial to the performance of geocells [19].

Maximum tensile strength for internal junctions {PE mixture}. Results{kN/m) - PE mixture: 12.2, 11.5, 11.6, 11.1, 11, 10.9, 10.6, 11.3, 10.4, 11.2.

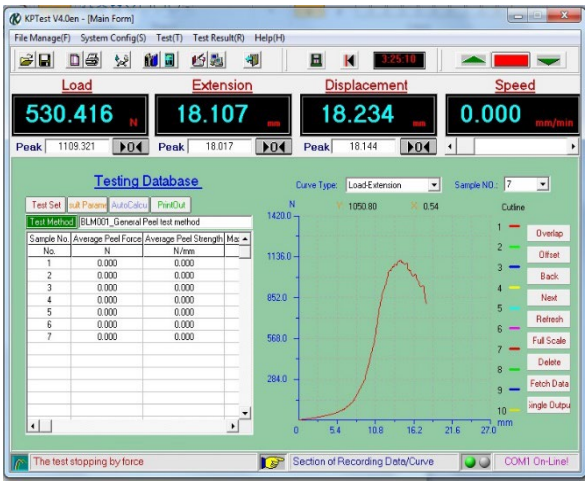

Fig. 8. Test result, sample 5, width 100 mm.

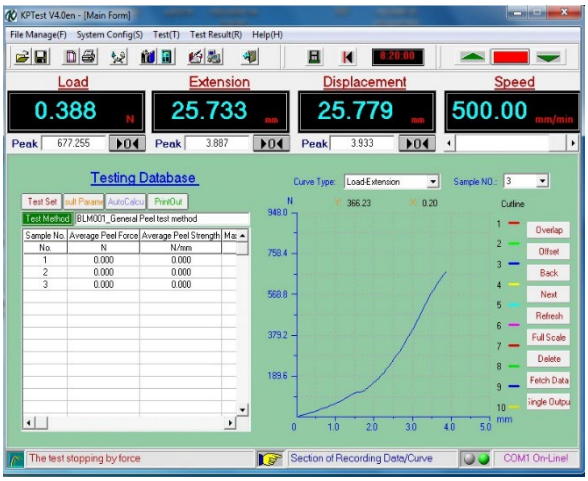

Fig. 9. Test result, sample 4, width 100 mm.

The results show a significant decrease in the strength of the internal structural junctions with the addition of 10% PE into PP. This is expected due to increased maximum tensile strength of strips and hardness with the addition of PP.

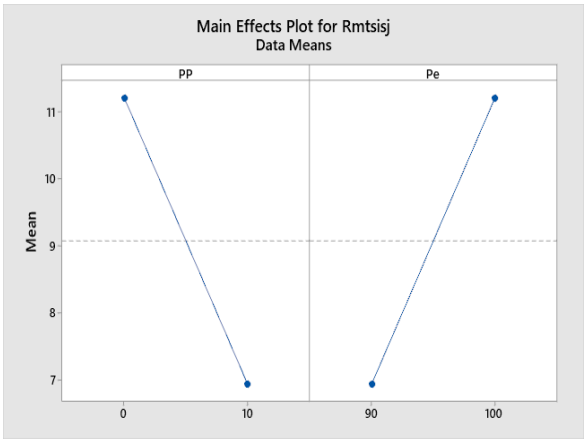

Fig. 10. Main effect plot for Rmtsisj.

The results, compared with other authors [20] - [22], are reliable and no deviations were observed in the regression analyses. They may be used and applied in engineering practice. The statistical error has a negligible impact as the range of results is close.

IV. CONCLUSIONS

The test results showed that the addition of 10% PP in PE increased the stiffness and ultimate tensile strength, but reduced the strength of the internal connections of the structure. Given the wider application of the product and the fact that the ultimate tensile strength is part of a harmonized standard for this product, the addition of PP is justified when higher requirements are set for this property. The addition of PP does not change the productivity of the entire technological process of creating the product. However, the increase in hardness should not be ignored, which can lead to a reduced quality when cutting the product during its final processing. The results may be used as a basis and for other ratios between PP and PE. The increased strength properties may expand geocells application.

V. ACKNOWLEDGMENTS

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