RESEARCH OF SELECTED MECHANICAL PROPERTIES OF THE RECYCLED PLASTIC

LYDIA SOBOTOVA, MIROSLAV BADIDA, TIBOR DZURO, MAREK MORAVEC, PAVOL LIPTAI

Technical University of Kosice, Faculty of Mechanical Engineering, Department of Process and Environmental Engineering, Kosice, Slovak Republic

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e-mail : lydia.sobotova@tuke.sk, miroslav.badida@tuke.sk, tibor.dzuro@tuke.sk, marek.moravec@tuke.sk, pavol.liptai@tuke.sk

Plastics are relatively new materials used in almost all areas of human activity, and also in various branches of live and industries. Given the annually growing produce of plastics, their volume are evenly growing up also in the waste, therefore it is necessary to solve the waste from the increasing volume of waste plastic. The contribution deals with the using and testing of sorted plastic waste. From the plastic waste as a semi-product is prepared the plastic plates by extruding technology, it means recycled plastics processing and verifying of their selected mechanical properties. It also deals with testing of selected plastic shaped plates. There are mentioned also the most usual impurities in the testing samples, created during the production. Contribution was originated as collaboration with TOPlast, Inc. Kosice.

KEYWORDS

plastics, recycling of plastics, mechanical testing, waste, material

1 INTRODUCTION

Plastics, however, with increased production bring also no small ecological problems, because plastic waste under normal conditions in nature decomposes several tens or even hundreds of years. In the context with this problem, there is a question of secondary use - recycling of waste material. The possibility of plastic using, as well as the verifying of specific mechanical properties of products from recycled plastics are solved in the contribution.

A means to minimize plastic waste stream is the secondary use (recycling, thermal treatment or other uses). To greater exploitation of the plastics waste is used sorting, collection of plastics, but also his post-sorting in the separated lines on the desired types of plastics. Sorting of plastics is important because of the functionality of recycling technologies. [Varkoly 1995]

2 PLASTICS RECYCLING

Production, consumption and subsequent disposal of waste are a natural part of the "life cycle" of all things, Fig. 1. In connection with the sorting of waste, it is a key a part of disposal of waste, for which we have an opportunity to dispose of waste in the most common ways - landfilling, incineration and storage at the present time. But there are other "green" disposal options. From many aspects, more acceptable methods of disposing of waste are the re-using and recycling.

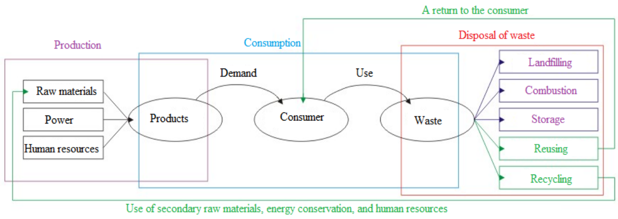

Figure 1. Product lifecycle [Varkoly 1995]

It remains the fact that surveys show that 70 – 80 % of the total quantity of produced waste can be used again or recycled. The mass composition of the average plastics waste was 12 % according to [Varkoly 1995] and not changed to 2014 according to European Commission, which expressed the need to bring residual waste close to zero by 2020 [EP 2014], Fig. 2.

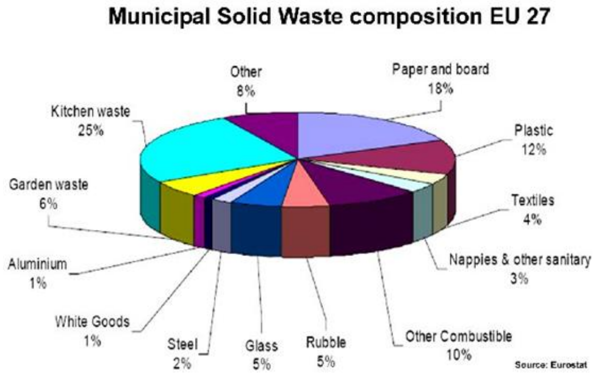

Figure 2. Waste cake [EP 2014]

According to the annually growing produce of plastics, their volume is evenly ramped in waste, too. Where, the amount and small biodegradation image at present production volume the threat, on which is required to respond. Plastic waste ends up in landfills in incinerators, oceans and seas. However, the plastic waste can be considered as a source of secondary cheap and available raw material. This intelligent solution is known under the concept of recycling plastic. Recycling of plastics is generally understood as re-use of plastic in both ways during the production as production waste and in the end of life, with the aim of the investigation of primary raw materials. The recycling of plastic is used, either material alone, or for creating of the energy, which is obtained in plastics. [Soos 2016]During the production arises technological waste what are for example defective products or remnants of gating systems for injection moulding. This waste is most often processing by the recycling of technological waste, which consists of its grinding, optionally followed by a possible recycling. As well as grit and regrind are usually used back in production. The addition of such regrind in an amount of 5 - 15 % strongly does not affect the properties of the final product. [Dulebova 2011], [Sobotova 2011]

2.1 *Classification of plastic recycling*

Recycling of plastics - polymers are divided into four groups [Dulebova 2011]:

- primary recycling focuses on processing of pure homogeneous polymer waste – waste, which is generated directly in the processing,

- secondary recycling deals with the processing of contaminated heterogeneous polymer waste - consumer waste,

- tertiary recycling deals with chemical and thermal non-polymerization procedures, by which may be prepared variety of low-molecular products or basic hydrocarbon fractions, used in the manufacture of new polymers,

- quaternary recycling is energy assessment of plastic waste by incineration.

3 EXPERIMENTAL PART

After conditioning of the test specimens, there were performed the bending tests according to Standard EN ISO 178.The experiment was made in the laboratory of mechanical and technological tests at the Department of Technologies and Materials and Department of Process and Environmental Engineering, Faculty of Mechanical Engineering, TUKE. Bending tests were performed on the machine TIRA Test 2300, produced in Germany.

On the bending machine were set in advance recommended parameters Fig. 3:

- The roller was fitted on the load tip with a radius of 5 mm,
- 2 rollers were put on supports with a radius 5 mm,
- Setting longitude of support was L = 64 mm according to Standard EN ISO 178,
- Testing speed was set on 50 mm / min by using of program.

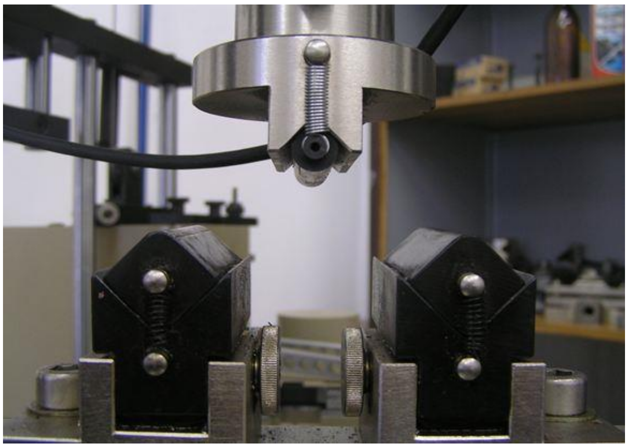

Figure 3. The bending tool in the a basic position

The test specimens were subjected to bending test according to standard ISO 178. The density of the test plate is different for place of the sprue (the longitudinal centre of the plates) and also at the edges of plates, therefore, specimens were taken in all of these places. We also took specimens in the longitudinal and transverse direction to the direction of inflow of molten regrind. Standard EN ISO 178 allows you to use the type of bodies, which must be approved by the stakeholders. By mutual agreement and the requirements of firm TOPlast, Inc. Kosice was determined following type of test materials: the shape of the test specimens: a rectangular prism, the dimensions the test specimen: length l = 80 mm, width b = 35 mm, thickness h = 15 mm, Fig. 4.

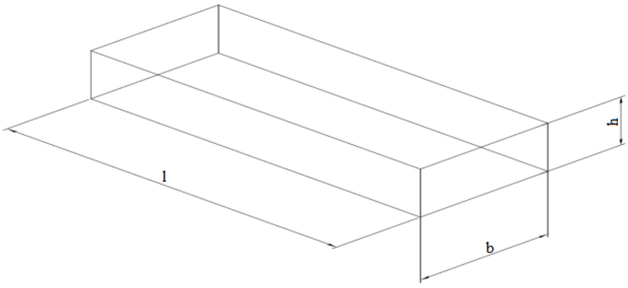

Figure 4. The shape of the test body

Here were created six groups of specimens divided by the sampling sites and orientation relative to the inlet:

- Margin, centre, second margin - longitudinally to the sprue,
- Margin, centre, second margin - transversely to the sprue region.

After conditioning of the test specimens were performed bending tests according to Standard ISO 178. Materials for experiments were supplied by TOPLAST a.s. Kosice, which were made of the recycled plastics from technology plastic waste from production, Fig. 5 and separated plastic waste, Fig. 6. Plastic waste was processed by crushing, Fig. 7 and Fig. 8. By adding of additives are produced plastic sheets, named as TOeco, by extruding, Fig. 9.

Figure 5. Technology plastic waste from production

Figure 6. Sorted plastics waste

Figure 7. Crushed plastic waste

Figure 8. Crushed and sieved plastic waste

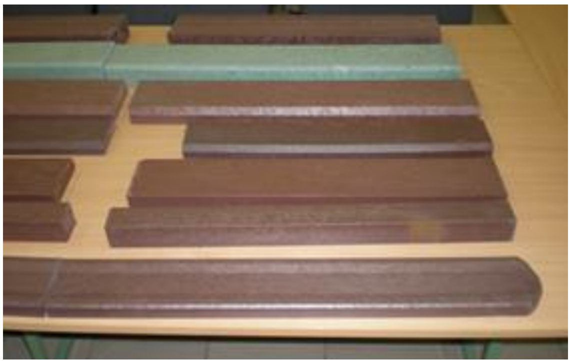

Figure 9. Example of final product – plastic plates

Plastic plates of recycled material from the outer surface create material- workpiece without holes and bubbles. However, after splitting materials they exhibit various problems as bubbles, Fig. 10, the impurities of unmelted plastic packaging parts, the particles of glass, paper, metal and wood. The details the impurities are shown in Fig. 11 and Fig. 12.

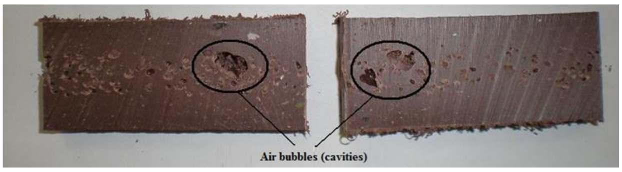

Figure 10. Bubbles in a plastic plate

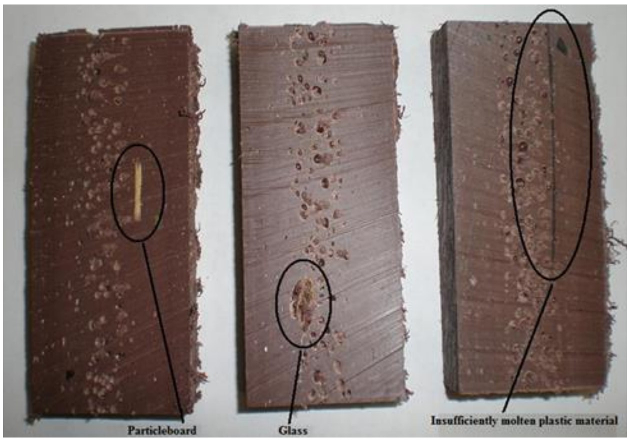

Figure 11. Impurities in plastic boards from recycled plastic

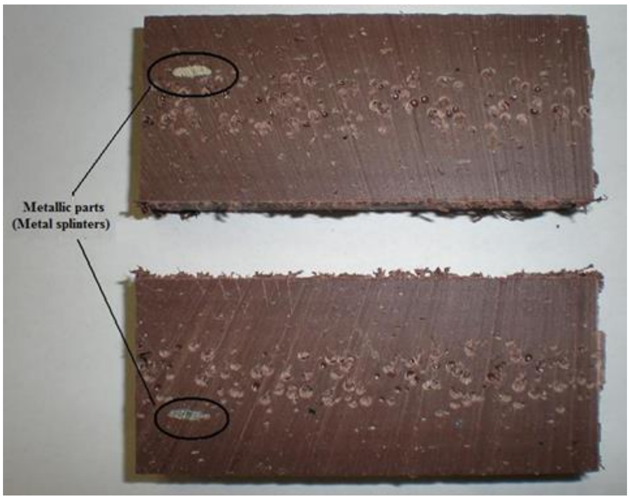

Figure 12. Metal chips in the plastic plate from recycled plastic

3.1 *Visual assessment of bending test and discussion*

The test specimen is placed horizontally on support so that the load tip was applied to the middle of the test body. After setting all parameters in testing machine, as the width and geometrical parameters of material, bend test was performed, the force was applied through a loading tip on the test specimen until it was fractured.

After loading of the test body by a force, created by burdening body, in most cases there were no ruptures in all the cross-section, but only on the outside of the bend specimens, while in the resulting crack of materials were visible fibres (Fig. 13 and Fig. 14). The inner sides of the bend test specimen remained intact. In Fig. 15 was a brittle fracture due to impurities, which act as a debited.

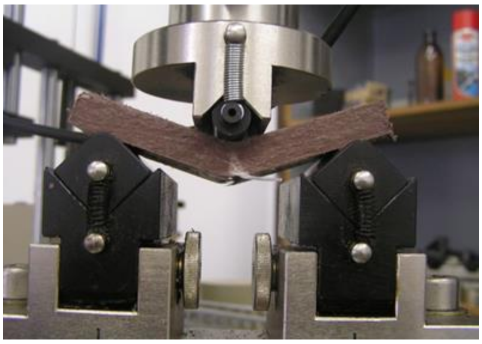

Figure 13. Damage of the test specimen during the bending test, test I

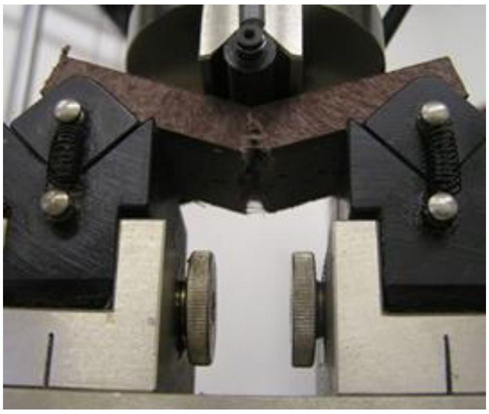

Figure 14. Damage of the test specimen at bending, test II

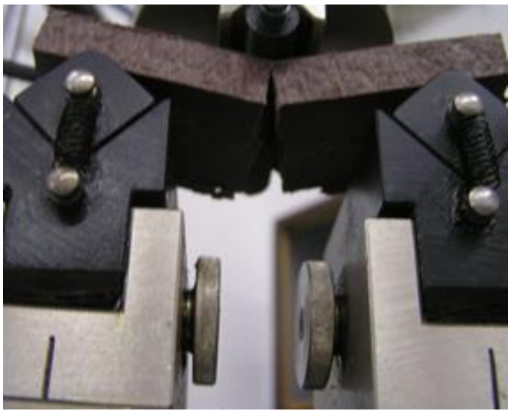

Figure 15. Damage of the test specimen at bending, test III

The average of the measured values was recorded in Tab. 1 and was processed the graph of the average measured values of applied force with respect to a group of the test specimens, Fig. 16.

Group	Fm [N]	s_1 [mm]	s_2 [mm]	σ_{f1} [MPa]	$\sigma_{f2} = \sigma_{fm}$ [MPa]	ε_{f1}	ε_{f2}	E_f [MPa]
I.	1480,35	9,91	12,44	6,53	19,2	0,210627	0,264203	239,98
II.	1108,7	10,09	12,53	5,56	16,2	0,200212	0,252278	218,79
III.	1388,79	10,93	13,33	6,11	17,6	0,236575	0,28272	253,95
IV.	1424,88	13,7	15,98	6,78	19,5	0,278285	0,334591	228,29
V.	1229,42	10,62	12,9	5,63	16,5	0,218916	0,277319	190,61
VI.	1334,56	3,79	6,4	6,79	19,6	0,075044	0,125444	259,7
Average	**1327,78**	**9,84**	**12,26**	**6,23**	**18,1**	**0,203276**	**0,256092**	**231,89**

Table 1. Average measured values of bending test bodies of type A

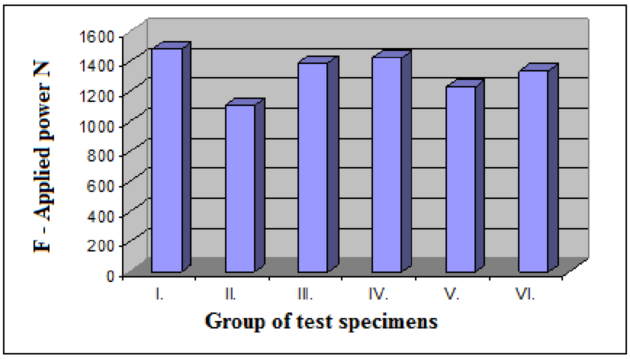

Figure 16. The graph of average measured values of the applied force of the test specimens, type A

In the graph shown in Fig. 16 follows that to rupture of the test specimens during the bending test is needed the highest applied force in test samples of group I. Margin of sample, longitudinally to the sprue and on the other hand the smallest force was applied to the specimens of group II, the centre transverses to the sprue. On the basis of the average values it was also taken graph of deformation in bending, which is shown in Fig. 17.

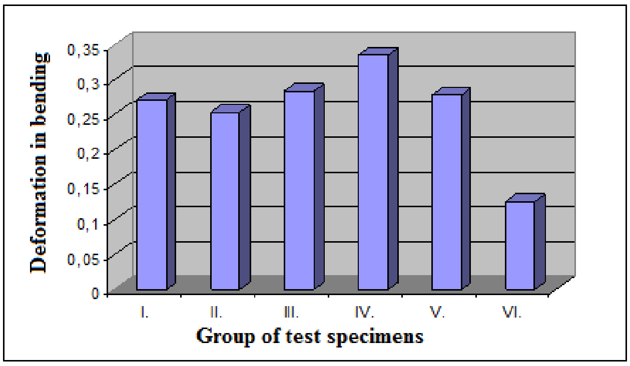

Figure 17. The graph of average measured values of applied force of specimens of type A

The graph displayed on the Fig. 17 shows that the maximum value of flexural deformation was achieved in the group of test pieces IV. Margin longitudinal on the sprue (a), other groups of the specimens were almost comparable to the values except of the specimens VI. The centre-longitudinal to the sprue, deformation was achieved significantly lower.

The graphs of Fig. 18 show the evaluation of values of flexural modulus, depending on the site of sampling, and according to the sampling direction (laterally or longitudinally in the filler).

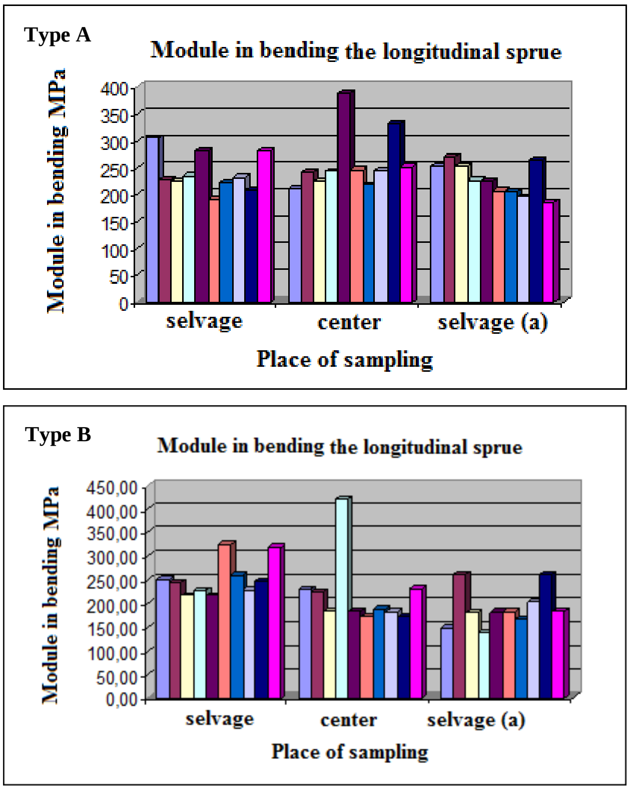

Figure 18. Modulus in flexural test specimen, type A and type B

Those diagrams show that the size of the calculated values of the flexural modulus are varied, not only in a different groups and directions, but the diversity is achieved also at the values of the individual specimens in a group.

4 CONCLUSION

After loading of the test specimen by a force, in most cases there were not destroyed the specimens in all the cross-section, but only on the outside of the bend specimen, while the crack were visible with fibres (Fig. 13, Fig. 14). In Fig. 15 was formed the crack with sharp edges. The inner side of bend of test sample remained intact.

The production of recycled plastic materials has a great usage in the future, but it depends of their material structure and clearness, which in many cases influence on the future material properties and utilization.

The importance of utilization of plastic waste from production and from collection points is very favourable and useful, because this is the way how to reduce the plastic waste, to save the production costs and to protect the environment.

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CONTACTS:

Doc. Ing. Lydia Sobotova, Ph.D.
Dr.h.c. mult. prof. Ing. Miroslav Badida, Ph.D.
Ing. Tibor Dzuro, Ph.D.
Ing. Marek Moravec, Ph.D.
Ing. Pavol Liptai, Ph.D.

Technical University of Kosice,
Faculty of Mechanical Engineering,
Department of Process and Environmental Engineering
Letna 9, 042 00 Kosice, Slovak Republic
Tel.: +421 55 602 2793
e-mail: Lydia.sobotova@tuke.sk
http://www.sjf.tuke.sk/kpaei/
Tel.: +421 55 602 2716
e-mail: miroslav.badida@tuke.sk,
http://www.sjf.tuke.sk/kpaei/
Tel.: +421 55 602 2673
e-mail: tibor.dzuro@tuke.sk,
http://www.sjf.tuke.sk/kpaei/
Tel.: +421 55 602 2482
e-mail: marek.moravec@tuke.sk
http://www.sjf.tuke.sk/kpaei/
Tel.: +421 55 602 3214
e-mail: pavol.liptai@tuke.sk
http://www.sjf.tuke.sk/kpaei/