The manufacture and properties of nonwoven composites from fibres mix

Bernava A¹, Reihmane S² and Merijs – Meri R³

¹ Institute of Polymer Materials, Riga Technical University, Paula Valdena 3/7, Riga, LV-1048, Latvia, aina.bernava@rtu.lv
² Institute of Polymer Materials, Riga Technical University, Paula Valdena 3/7, Riga, LV-1048, Latvia, skaidrite.reihmane@rtu.lv
³ Institute of Polymer Materials, Riga Technical University, Paula Valdena 3/7, Riga, LV-1048, Latvia, remo.merijs-meri@rtu.lv

Abstract. The application of nonwoven composites expands each year. The heat-bonded nonwovens (NW) are used for geotextile production due to the simple production cycle and low processing cost. To create the geotextile with desirable properties the mix of fibres are used. The aim of this study is to use recycled hemp, polyethylene terephthalate and polypropylene fibres for the development of new materials and technologies for nonwoven material composites (NWC) production. The series of NWC from mix of natural and synthetic fibres and series with one or two sides thermoplastic net reinforcing are manufactured. The NWC characterization parameters, water penetration, air permeability and results of physico-mechanical properties are presented.

1. Introduction
The nonwoven (NW) textile industry has grown as a broad array of engineered fibers and polymer-based products by high-speed, low-cost, innovative, value-added, fully automated processes and the ability to recycle textile products into useful products [1]. The common thermoplastic composites market is projected to grow up for 8.34% between 2017 and 2022. Increased use of thermoplastic composites in the transportation and aerospace & defence applications due to various properties offered by them, which include ease of recyclability, low curing time, high strength, and increased rigidity, among others are the factors driving the growth of the thermoplastic composites market across the globe [2]. The nonwoven composite (NWC) geotextiles are fibrous three-dimensional structures, used for different applications such as reinforcement, separation, filtration and drainage instead of coarse-grained soil due to their easy installation and gain [3]. Geotextile are generally made from a limited number of polymers (polypropylene, polyethylene and polyester). The three main properties which are required and specified for geotextile are its mechanical responses, filtration ability and chemical resistance [4]. The Rural Support Service of Latvia has planned financial support for the rebuilding and restoration of melioration systems, as well as for the construction or conversion of areas at production facilities [5, 6]. The 147 km long single water supply system in Riga City also requires continuous maintenance and construction of new facilities, according to the rules for the use and maintenance of the Riga City Hydrographic Network [7].
In view of the above facts, the development of new materials for geotextile is up to date. In the previous studies the optimal composition of fibres mix and the production condition of nonwovens’ composites was identified [8, 9].

The aim of this research is to investigate the properties and the factors affecting NWC from fibers mix without and with reinforcing. The NWC series of the local hemp fibres variety “Bialobrzeskie” of Kraslava district, recycled polyethylene terephthalate and polypropylene fibres mix as well as series of composites with one or two side thermoplastic net reinforcing is manufactured and properties tested.

2. Materials and Methods

For NW web production the local hemp fibres variety “Bialobrzeskie” (HF; length 50-60 ± 2 mm, Ø 15 - 50 nm, linear density 30 tex) [10], recycled polyethylene terephthalate fibres (PET; length 64 ± 1 mm, linear density 6.7 dtex, producer Starlinger & Co. Gesellschaft m.b.H., Uzbekistan [11]) and polypropylene fibres (PP; length 12 ± 1 mm; Ø 18.7 nm, linear density 7.7 dtex; producer Bautech [12]) are used. The thermoplastic PP net (mesh size 20 × 20 mm, thickness 0.37 mm, producer Tenax SPA, Italy) is applied for NW web reinforcement.

2.1. Methods of Production

The untreated hemp fibres are stiff and on the used laboratory carding machine it is not possible to produce a satisfactory NW web [6]. Therefore, after tests, alkali treatment method of hemp (100 g/L at 20±1°C temperature for 2 min) is selected [8, 9]. A neutralization of pre-treated fibres with acetic acid (2 g/L) at 19 ± 1°C temperature for 15 min is done.

The NW web (Table 1) is made from fibrous blend (HF- 59 %; PET- 23 %; PP- 18 %) using laboratory carding machine MESDAN 337A (delivery velocity 10-15 m/min). After NW web formation the samples (160 x 160 mm; mass 2.6 g (designation of sample A) and 3.8 g (designation of sample B) are cut out and prepared for NWCs production in a frame without and with PP net reinforcement from one side (designation of samples A1, B1,) and both sides (designation of samples A2, B2). For thermal bonding of NWC the laboratory press Labtech Engineering ASTM LP-S-50/S at the required pressure 26 ± 1 MPa and temperature 160 ± 2°C is used.

2.2. Methods of Testing

Mass per unit area and thickness of NWCs are calculated according LVS EN 12127:2001 [13] and LVS EN ISO 9073-2:2001 [14] respectively.

The tensile strength and elongation at break at maximum force is determined on universal testing machine Zwick/Roell BDO-FB020TN, according LVS EN ISO 13934-1-2001 [15]. Ten samples of NWC (50 x 150 mm) are tested, based on the experience gained in previous research [8, 9]. The resistance to water penetration of NWC is verified by hydrostatic pressure test according LVS EN ISO 9073-16:2009 [16]. For determination of the air permeability LVS EN ISO 9073-15:2008 [17] is applied. Ten NWC samples are tested from both sides and the average values of water penetration and air permeability are calculated.

3. Results and Discussion

Series of composites without netting and with one or both sides net reinforcing were manufactured and tested. The results of NWC parameters are summarised in the Table 1. Before explaining the obtained results, it must be mention, that NW samples have free arrangement of fibers and they are made manually, therefore irregularity in fibers location of further NWC is observed which can an influence on the obtained results of examined properties.

3.1. NWC characteristic and properties

The NW thickness and mass without netting (Table1; samples A, B), depends on mass of the NW. The use of reinforcement decreases the thickness of one side reinforced NWC – about 16 % (A1) and 10 % (B1) due to additional influence of thermoplastic PP net on NW web bonding. Both sides reinforcement in comparison with one side is not significant. As expected, the use of reinforcing net increases the mass per area of NWC and depends on reinforcing net amount (one side, both sides).
Table 1. Mass of NW web, number of reinforcement layers, characterization parameters, water penetration and air permeability of NWC

| Sample | Mass of NW web | Layers of net | NWC characterization parameters | Water penetration, L/min | Air permeability, mm/s |
|--------|----------------|---------------|---------------------------------|-------------------------|-----------------------|
|        | 2.6±0.01 g     | 3.8±0.01 g    | 1                               | 0.38                    | 108.9                 | 61.0                  | 9.5                  |
| A      | x              |               |                                 |                         |                       |                       |                      |
| A1     | x              | x             | 2                               | 0.32                    | 115.6                 | 55.9                  | 16.0                 |
| A2     | x              |               |                                 | 0.34                    | 122.7                 | 71.7                  | 14.9                 |
| B      | x              |               |                                 | 0.40                    | 153.5                 | 79.0                  | 3.9                  |
| B1     | x              | x             |                                 | 0.36                    | 164.4                 | 66.3                  | 5.0                  |
| B2     | x              |               |                                 | 0.35                    | 176.0                 | 75.0                  | 5.4                  |

3.2. Water penetration and air permeability

The water penetration - significant property for geotextiles (Table 1) for examined NWC without reinforcing is higher for samples with higher initial mass of web (A, B samples). With one layer netting, the water penetration decreases for both series samples. It can be explained with NWC thickness decrease and fibers crowding in the NW web after reinforcing. The double side netting (samples A2; B2) causes increase of water penetration in comparison with one-sided reinforcement (A1, B1). The wetting processes influence on water penetration is possible.

The air permeability (Table 1) is higher (59 %) for samples with lower web initial mass and mass per area (A series). The reinforcement of NWC increases the air permeability in all cases.

The expected correlation between the water penetration and air permeability is not confirmed.

3.3. Mechanical properties

![Figure 1. Tensile strength of NWC](image1)

![Figure 2. Elongation at break of NWC](image2)
The physico-mechanical properties of NWC are important for starting an application of NWC. The influence of thickness and mass per area of NWC on tensile strength (Figure 1; samples A, B) without reinforcing is not significant. The significant increases of tensile strength, after reinforcement is observe for B series - 33 % for one-sided (sample B1), 70 % for double-sided (sample B2).

The elongation characteristics grow remarkably (60 - 66 % for A series and 81 % for B series) in all cases due to use of reinforcement (Figure 2). The influence of reinforcing method (one or both sides netting) on the elongation at break is smaller -15 % (A series) and 2 % (B series).

4. Conclusions
- The thickness and mass per area of NWC without reinforcing depends on initial mass of NW web - 5 % and 30 % respectively.
- The use of reinforcement decreases NWC thickness (one side netting about 16 % (A1) - 10 % (B1); both side netting 11 % (A2) - 13 % (B2)
- The use of netting causes the increase of NWC mass per area; one side netting about 6 % (A1) - 7 % (B1), double-sided netting 12 % (A2) - 13 % (B2).
- The increase of water penetration for NWC with higher web initial mass, 23 % (without netting), 16 % (with 1 play netting) and 5 % (with both sides netting), is observed.
- The air permeability is higher (59 %) for samples with lower web initial mass and mass per area. The reinforcement of NWC increases the air permeability in all cases.
- The physico-mechanical properties depends on NWC characterizing properties and reinforcing method; the increase of tensile strength 70 % for B series double sided NWC is achieved.
- The use of reinforcement causes significant increase of elongation at break; 66 % (A series) and 81 % (B series).

5. Acknowledgements
The Financial Support of NRP of Latvia, project IMIS2, is greatly acknowledged.

6. References
[1] Pourdeyhimi B 2016 *Nonw. Text. World Com.* 3 - 4 32 – 35.
[2] Thermoplastic Composites Market Fiber - Global Forecast to 2022 2017 *Markets and Markets Rep. Code ASDR-432582 Now* (8.12.2017).
[3] Lamy E, Lassabatere L, Bechet B, Andrieu H 2013 Effect of a nonwoven geotextile on solute and colloid transport in porous media under both saturated and unsaturated conditions, *Geot. and Geom.* 36 55 – 65.
[4] *Handbook of technical textiles* 2004 Ed. Horrock A R and Anand S C Woodhead publishing limited 358 - 372.
[5] Lauku attīstības programmas (LAP) investīciju pasākumi 2014 - 2020 4 3 Atbalsts ieguldījumiem infrastruktūrā, http://www.lad.gov.lv/lv/atalsta-veidi/projekti-un-investicijas/lap-investiciju-passakumi/4-3-atbalsts-ieguldijumiem-infrastruktura (30.08.2018).
[6] Latvijas lauku attīstības programa (LAP) 2014. -2020. Zemkopības ministrija, Rēzekne 19.03.2015.,http://www.lad.gov.lv/files/lap_prezentacija_19032015.pdf
[7] Meliorācija,http://mvd.riga.lv/3ozares/vides-parvalde/melioracija (30.08.2018).
[8] Bernava A, Reihmane S, Bitenieks J, Maniņš M 2017 The nonwovens properties made from hybrid fibres, *Key Eng. Mat.* 721, 53 – 57.
[9] Bernava A, Reihmane S, Bitenieks J, Merijs - Meri R 2017 The properties of mesh reinforced nonwoven composites *Solid State Phenom.* 267 63 - 67.
[10] Baltiņa I, Zamuška Z, Stramkale V, Strazds G, 2011, Physical properties of Latvian hemp fibres *Environment Technology. Resources, Proc. of the 8th Intern. Sc. and Pract. Conf* 2 237 -243.
[11] Baucon polypropylene fibres © 2018 http://www.bautech.eu/en/products/concrete-floor/baucon.html (13 11.2018.)
[12] © Starlinger &Co GmbH Recycling line – reco STAR PET (non food)
https://www.starlinger.com/en/recycling/recostar-product-line/recostar-pet-non-food
(13.11.2018.)

[13] LVS EN 12127:2001 Textiles - Fabrics - Determination of mass per unit area using small
samples, https://www.lvs.lv/lv/products/4020, (13.06.2018).

[14] LVS EN ISO 9073-2:2001 Test methods for nonwovens - Part 2: Determination of thickness
https://www.lvs.lv/lv/products/4616 (13.06.2018).

[15] LVS EN ISO 13934-1:2001 Textiles - Tensile properties of fabrics - Part 1: Determination of
maximum force and elongation at maximum force using the strip method
https://www.lvs.lv/lv/products/5094 (13.06.2018).

[16] LVS EN ISO 9073-16:2009 Textiles - Test methods for nonwovens - Part 16: Determination of
resistance to penetration by water (hydrostatic pressure) (ISO 9073-16:2007)
https://www.lvs.lv/lv/products/25312, (13.06.2018).

[17] LVS EN ISO 9073-15:2008 Textiles - Test methods for nonwovens - Part 15: Determination of
air permeability https://www.lvs.lv/lv/products/24642 (13.06.2018).