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Serviceable life of geotextiles in various environments

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ABSTRACT: The use of geotextiles in engineering works depends on the maintenance of stable, or changing within permissible limits, values of mechanical and hydraulic parameters. In the paper, results of experiments carried out with samples of geotextile materials subjected to the influence of natural seacoast and of industrial waste environments, and to the influence of long term action of light, low temperature and loading produced in laboratory conditions are discussed.

INTRODUCTION

At the Maritime Institute in Gdańsk are carried out investigations of changes of the mechanical parameters occurring in geotextile materials exposed to the influence of various environments: of the coastal zone, and of industrial wastes. In order to obtain more quickly results concerning the influence of ultraviolet radiation and of low temperature, a part of the tested materials was exposed in artificial laboratory conditions to quartz lamp light and to freezing in low temperatures. Information obtained from the investigations allows to predict the degradation of the various tested materials when used in engineering structures. Basing on the results, it is also possible to evaluate the risk of damage or destroyal of a structure if it is improperly used or exploited otherwise than it was assumed at the design phase. The obtained information allows also to carry out technical analyses for selecting such materials, from the range available on the market, which will be best suited to specific environmental conditions. Besides maintaining their initial mechanical parameters, geotextiles fabrics should also be resistant to long term loading.

1. EXPERIMENTAL CONDITIONS

Samples of each type of fabric were subjected to marine environment action on the seacoast. Samples used for testing the influence of strongly alkaline industrial waste environment were placed in containers filled with sediment and near-bed liquid taken from industrial settling tanks. Laboratory conditions allowed to accelerate the processes of fabric degradation caused by UV radiation and freezing in -12° C.

Geotextile fabric samples tested for influence of marine environment were placed under water, at a depth of 2 m below water surface, in a specially prepared container which allowed free flow of water and sediments with grain sizes smaller than 3 cm. Therefore the samples were subjected to all processes which proceed in structures in their underwater part.

Laboratory conditions in which were kept samples placed in industrial waste, were quite similar to conditions in the industrial settling tanks, therefore the time of their exposition was exactly as long as in the field.

With respect to exposition to sunlight, the time difference between nature and quartz lamp was very large. The lamp FAMED 1 No. 190/2/56/LKB-ZN/MPD/A7-F1 was used, which has the following characteristic: 220 V, 2.6 A, 50 c/s, gas radient element of quartz glass emitting uv radiation. About 1 minute of irradiation with the lamp corresponded to 1 hour of exposition to strong sunlight. UV exposition was performed in such a way that each of the samples was subjected to the same radiation (the samples were systematically shifted to consecutive places of exposition with varying distance from the source of light). The average distance from radient element to each of the samples was 1.0 m.

With respect to freezing - samples were kept frozen in a freezer for the whole time of exposure.

In order to evaluate the resistance of some of the fabrics to long term loading, tests were carried out in laboratory measuring the strength of samples fresh from manufacturer, then samples taken from the same series of fabrics were subjected to a loading equal to 20, 50 and 80% of the average value of breaking force, and duration of load action until sample breaking was recorded.

Table 1. Properties of geotextiles in their initial state and after exposure to the marine environment, UV radiation and to low temperature

Item	Kind of geotextile	Raw material	Time of exposure	Type of exposure	PROPERITES						
					Unit weight	Thickness	Tensile strenght		Elongation		Permeabi lity coefficient
							L - longitudial		T - transverse		
							L	T	L	T	k_n
-	-	-	months or hours	-	g/cm^2	cm	kN/5cm	kN/5cm	-	-	$*10^{-3}$ m/s
-	1	2	3	4	5	6	7	8	9	10	11
1	nonwoven fabric	PES	0 m	initial state	490	0.600	0.72	0.52	85	115	0.78
			12 m	marine environment			0.89	0.60	75	100	1.09
			27 m				0.91	0.73	65	90	0.20
			51 m				0.65	0.58	58	76	-
			370 h	UV radiation			0.75	0.58	91	110	-
			4000 h	low temp.			0.71	0.62	83	102	-
2	nonwoven fabric	PP	0 m	initial state	450	0.690	0.56	0.35	95	150	7.35
			12 m	mar. env.			0.80	0.48	65	80	4.50
			370 h	UV radiation			0.27	0.06	74	99	-
			4000 h	low temp.			0.69	0.33	92	134	-
3	nonwoven fabric on woven fabric	PP/ PES	0 m	initial state	430	0.400	0.60	0.43	11	9	0.25
			12 m	marine environment			0.56	0.46	10	10	0.32
			27 m				0.59	0.33	10	10	0.89
			51 m				0.55	0.48	10	9	-
			370 h	UV radiation			0.54	0.40	11	10	-
			4000 h	low temp.			0.51	0.45	12	10	-
4	nonwoven on spun fabric	PA/ PP	0 m	initial state	670	0.640	1.17	1.45	30	26	6.80
			12 m	marine environm.			0.92	1.64	35	30	0.70
			36 m				1.01	1.54	34	22	-
			370 h	UV radiation			-	-	-	-	-
			4000 h	low temp.			1.19	1.42	31	27	-
5	nonwoven on spun fabric	PA/ PP	0 m	initial state	515	0.490	1.17	2.27	33	28	6.10
			12 m	mar. env.			0.98	2.41	45	35	1.45
			370 h	UV radiation			-	-	-	-	-
			4000 h	low temp.			-	-	-	-	-
6	woven fabric	PA	0 m	initial state	485	0.090	6.16	4.13	43	35	0.05
			51 m	marine environm.			4.91	3.80	49	30	0.04
			88 m				2.71	2.14	34	23	0.07
			370 h	UV radiation			-	-	-	-	-
			4000 h	low temp.			7.32	4.41	49	41	-
7	Malliwatt technic	cotton fibre with PES	0 m	initial state	270	0.160	0.43	0.38	33	90	0.89
			12 m	marine environm.			0.33	0.61	26	53	0.18
			36 m				0.43	0.65	28	46	-
			370 h	UV radiation			-	-	-	-	-
			4000 h	low temp.			-	-	-	-	-
8	woven fabric A	PP	0 m	initial state	590	0.160	9.86	5.31	31	26	5.4
			24 m	mar. env.			9.51	5.53	29	25	5.2
		with stabilizator	1000 h	UV radiation			2.11	1.35	11	7	
		without stabilizator	1000 h	UV radiation			0.78	0.28	8		
9	woven fabric B	PP	0 m	initial state	330	0.090	4.48	3.15	27	20	0.84
			24 m	mar. env.			5.10	3.00	28	19	-
		with stabilizator	1000 h	UV radiation			1.18	0.40	8	6	-
		without stabilizator	1000 h	UV radiation			0.20	-	6	-	-

It was assumed that the best indicator for comparisons of changes in the geotextile fabric during exposition in given conditions will be the difference of resistance between fresh samples and samples exposed to natural and simulated environmental conditions.

2. EXPERIMENTAL RESULTS AND THEIR ANALYSIS

In Table 1 are shown results obtained in experiments in the coastal environment and during UV exposition and low temperature experiments performed in laboratory.

Comparison of strength parameters after exposing the geotextiles for 3.5 years to sea environment allows to state that tensile strength is only insignificantly changed. Differences in values for fabrics made of polypropylene and polyester result rather from nonuniformities of the products than from degradation in marine environment. Often tensile strength is even higher after exposing in the sea. During additional tests it was observed in some cases that these changes are connected with shrinkage of the fabric in water environment, during which the samples become thicker.

With respect to fabric It. 6 in Table 1, made of polyamide, its strength in water environment visibly decreases because it is a uniform fabric (due to technique of production and significant uniformity of strength of the fibres and made from them thread). Carried out experiments confirm found in literature information that water has a negative influence on polyamide fibres.

Because fabrics have higher strength though lower permeability, a new type of fabric made from polypropylene fibres (Table 1, It. 8, 9) was made for use in structures. Polypropylene fabrics were used in marine environment both above and below water surface. This fabric was used for the located below water surface core of the coastal breakwater in the North Harbour in Gdańsk. The core was made in the form of multi-chamber geotextile segments filled with sand, Fig. 1 replacing the inner part of the breakwater's rubble mound. After two years of exposure in the sea, fabric taken from the structure for testing had unchanged strength parameters.

Fabrics used in structures located on the beach to protect dunes against running up storm waves (Fig. 2), were made using stabilisers which prevented degradation of the fabric when exposed to UV radiation. After two years the fabric did not change its strength parameters, even though during storms a large part of the structure became uncovered and was exposed to sunlight.

An important factor, influencing mechanical properties of geotextiles, is UV radiation. In hydrotechnical engineering, geotextiles may be exposed to UV radiation in the underwater zone, in the water surface variation zone, and in the above water zone. In Baltic Sea conditions, due to contamination, UV radiation reaches only 20 cm below water surface. Therefore the UV radiation problem concerns geotextiles used on the coast above water level, during constant exposure and also during periodical exposure when stored on the construction site. In order to shorten the time of testing for changes in mechanical properties of

Fig. 1. Exposure site of the geotextile A and B (Table 1) to the marine environment in the North Harbour in Gdańsk.

Fig. 2. Exposure site of the geotextile A and B to the marine environment (above water) in structures located on beach at Kołobrzeg.

several types of geotextiles caused by UV radiation, tests were performed in the laboratory.

From shown in Table 1 results of laboratory tests of geotextile material degradation under UV irradiation, varying values of strength parameters were obtained, dependent on the type of raw material, type of fibres and method of their connecting, mass per unit of surface, and time of exposure to UV radiation.

After 370 hours of exposure to UV radiation, needled cloth made of PES practically did not change its tensile strength at breaking (It. 1). Differences in the value of strength are within limits determined by standard deviation from mean value, and results from nonuniformities of the material and from measurement errors.

Needled cloth made of mixed PP/PES (50% each) fibres (It. 3), after 370 hours exposure changed strength within 10% of initial value. After 370 hours exposure, strength of PP needled cloth (It. 2) was reduced to about 50% of the initial value.

Made of PP fabrics A and B (Items 8 and 9) made in two versions : with and without an UV stabiliser, were subjected to 1000 hours of irradiation. With respect to initial value, longitudinal tensile strength of material A with stabiliser was reduced by about 79% and without stabiliser by 92%. Transverse tensile strength reduction was 74% for fabric with stabiliser and 95% without stabiliser. This shows that degradation of the fabric in results of UV irradiation, measured by the change of tensile strength, is of similar character for both directions of stretching. In case of fabric B, after irradiation of fabric with stabiliser the decrease in longitudinal tensile strength was about 74%, and in transverse strength - about 88%.

It results that use of stabiliser reduced the loss of strength of fabric made of PP by about 15%. Probably resistance to UV radiation could be improved by increasing the mass of stabiliser during forming of the fibres.

During irradiation, also changes of the surface of tested samples were visually observed. They showed that UV radiation exerts strongest influence of fibres in materials made of PP. Fibres on the exposed surface become brittle, lustreless and break. Thickness of the material has a significant influence on the progress of degradation into the material. Though very brittle and much damaged, the surface fibres provide protection for the deeper lying ones. The greater the thickness, the slower is the progress of degradation into the material. This may explain the observed smaller changes in needled cloth and composites than in fabrics.

Elongation of geotextiles subjected for a long time to marine environment action becomes smaller in case of needled cloth (Table 1, It. 1, 2), while in case of needled cloth on bonded cloth and on fabrics it remains unchanged. Similarly, exposure to marine environment does not cause changes in elongation of fabrics.

After exposing to low temperature, all types of tested geotextile materials retained their initial parameters of elongation within standard deviation from mean value.

Changes in elongation of geotextiles exposed to UV radiation vary depending on the type of material used for fibres, on thickness of the fibres and on thickness of the geotextile itself. After 370 hours of irradiation, needled cloth made of PES (Table 1, It. 1) and PP/PES (Table 1, It. 3) had practically unchanged elongation parameters. Longitudinal elongation of PP needled cloth after irradiation was smaller by 21%, and in transverse direction it was smaller by 51% (Table 1, It. 2).

Large changes in elongation occurred in made of PP fabrics A and B, which were exposed to sunlight for 1000 hours (Table 1, It. 8, 9). Elongation on fabric A, made of PP with stabiliser, after the exposure was reduced in longitudinal direction by 65% and in transverse direction by 74% of the initial value. Fabric B, made of PP with stabiliser, had elongation reduced in both directions by 70%.

Water permeability of the materials was tested only after exposing them to the marine environment. Changes in permeability were determined by comparing coefficients of permeability obtained from samples of fresh material with coefficients obtained for samples of materials after exposure to marine environment. In case of needled cloth and composites (Table 1, It. 1, 2, 3, 4, 5, 7) varying changes were observed, resulting from blocking of flow through the material by grains of fine sand deposited in pores of the material (reduced permeability), or from washing out of fleece from composites (increased permeability). Permeability of fabrics remained unchanged.

3. CHANGE OF MECHANICAL PARAMETERS OF GEOTEXTILES UNDER LONG TERM LOADING

Information on mechanical change of geotextiles under long term loading is an important element for predicting the behaviour of various types of geotextiles during future use in hydraulic structures.

Information from these investigations is also necessary to evaluate the risk of damage or destroyal of a structure during periodical loading transmitted from varying water level, waves, and pulsatory variations of pressure and caused by them two-directional water flow through the geotextile fabric.

Long term loading may result in structural changes of the geotextile fabric, i.e. in permanent deformations which change mechanical properties of the fabric, and which in turn may cause also changes in hydraulic properties. Changes of hydraulic properties caused by long term loading consist in increasing the filtration pores in the fabric, and in decreasing the thickness of the filtration layer. They are caused by a permanent or periodical elongation of the fibres of the yarn from which the geotextile is made. They depend on the type and properties of the fibres, and on the method of their connecting, in result of which a given type of geotextile fabric is obtained.

Structural changes of geotextile fabrics may result in hydraulic perforation in the layer of protected soil, which in effect may cause loss of stability of the whole structure or of its part. It results that knowledge of changes in mechanical properties under influence of long term loading is a very important element of the general characteristic of geotextiles.

Deformation of stretched geotextiles, built into the subsoil, consists of two parts:

1) part caused by the tensile force,
2) part caused by creep, which is time dependent; creep in this case is the change of length of geotextile under stable tensile force.

In order to determine the changes of parameters, several types of geofabrics, geotextiles and composites were tested. Samples of materials obtained from manufacturers were subjected to loading, and their strength and elongation were recorded. At the moment of breaking obtained results were statistically processed, and mean values of strength at breaking , standard deviation $_{n-1}$, and coefficients of variability were calculated. From obtained mean values, the corresponding 80, 50 and 20% values of loads were determined. Next, samples from the same part of each tested material were taken. Each of these was subjected to loading until breaking. In case of the 20% loads, in some cases after about a dozen months of observation, when no increase of elongation was observed, testing was stopped.

Changes in elongation of materials A and B (Table 1, It. 8, 9), subjected to laoding equal to 20, 50 and 80% of the initial loads at breaking during tensile tests are, shown in Tables 2 and 3.

Presented in Table 2 changes in elongation show that the 20% load generally does not cause flow of material, elongation parameters also remain unchanged in both kinds of material. Stable 50% loading results in increasing secondary elongation, which finally leads to breaking of the samples. Deformation does not proceed systematically in time but is of random character. Time between applying the load and breaking of the samples varied from 6 to 48 days for material A, and 10 to 46 days for material B.

Stable loading, equal to 80% of initial load at breaking, results in quickly growing secondary elongation (often difficult to record), leading to breaking of tested samples. Also in this case progress of deformation, measured by elongation of the samples, is of random character. Times between applying the load and breaking varied from 19 to 33 minutes for material A, and from 10 to 4440 seconds for material B.

4. CHANGES OF GEOTEXTILE PARAMETERS IN INDUSTRIAL WASTE ENVIRONMENT

Investigations of technical parameters of geotextiles exposed to soda works waste were carried out for several years.

Strength parameters and accompanying elongation under breaking load 1 were tested. In Fig. 3 results obtained for five kinds of geotextile materials are presented.

Postsoda deposits are strongly alkaline (PH abt,10) and contain many various components, including large amounts of carbonate. The geotextiles

Table 2. Initial and secondary elongation of fabrics A and B subjected to long term loading equal to 20 and 50% of initial load and breaking (tensile load) - size of samples - 10*1 [cm]

	FABRIC A													
	20% of loading and breaking					50% of loading and breaking								
	longitudinal (warp) = 394 N		transverse (weft) = 212 N			longitudinal (warp) = 986 N				transverse (weft) = 513 N				
time (days)	16	19	12	10	13	6	24	36	48	36	10	23	6	10
initial elong.	1.3	1.3	1.0	1.2	0.9	1.5	0.8	1.5	1.0	1.2	0.9	1.0	1.3	1.0
secondary el.	0.4	0.3	0.0	0.1	0.2	4.6	3.7	3.5	4.0	6.0	2.3	4.7	1.9	3.0
total elong.	1.7	1.6	1.0	1.3	1.1	6.1	4.5	5.0	5.0	7.2	3.2	5.7	3.2	4.0

	FABRIC B												
	20% of loading and breaking					50% of loading and breaking							
	longitudinal (warp) = 179 N			transverse (weft) =126 N		longitudinal (warp) = 448 N			transverse (weft) = 315 N				
time (days)	16	15	16	16	10	11	10	11	19	46	20	18	22
initial elong.	1.0	1.5	1.0	0.8	0.7	1.5	1.3	1.1	1.0	1.0	0.9	1.0	1.2
secondary el.	0.1	0.2	0.5	0.0	0.0	1.8	2.2	2.0	1.7	2.3	2.1	2.2	2.2
total elong.	1.1	1.7	1.5	0.8	0.7	3.3	3.5	3.1	2.7	3.3	3.0	3.2	3.4

Table 3. Initial and secondary elongation of fabrics A and B subjected to long term loading equal to 80% of initial load and breaking (tensile load) - size of samples - 10*1 [cm]

	FABRIC A																		
	80% of loading and breaking																		
	longitudinal (warp) = 1578 N									transverse (weft) = 850 N									
time (min)	70	24	55	33	65	83	48	75	29	330	62	46	28	19	28	22	18	25	29
initial elong.	1.7	1.3	1.5	1.6	1.2	1.0	1.4	1.3	1.4	0.5	1.7	1.1	1.6	1.6	1.5	1.6	1.6	1.3	1.7
secondary el.	1.6	1.0	2.0	1.9	2.7	3.5	2.1	2.3	1.4	4.5	1.3	0.9	1.3	1.3	1.3	1.3	1.4	1.6	1.1
total elong.	3.3	2.3	3.5	3.5	3.9	4.5	3.5	3.6	2.8	5.0	3.0	2.0	2.9	2.9	2.8	2.9	3.0	2.9	2.8

	FABRIC B																			
	80% of loading and breaking																			
	longitudinal (warp) = 716 N										transverse (weft) = 504 N									
time (sec)	30	110	23	30	60	75	62	42	390	50	20	10	720	3600	480	3360	4440	2700	4080	5700
initial elong.	2.5	2.2	-	-	2.3	2.5	1.9	1.6	2.0	1.6	2.0	2.5	2.5	1.1	1.2	1.2	1.3	1.4	1.2	1.1
secondary el.	-	0.6	-	-	0.3	1.0	1.1	-	1.0	0.6	-	-	0.7	1.4	1.5	0.8	1.2	1.2	1.6	1.5
total elong.	-	2.8	-	-	2.6	3.5	3.0	-	3.0	2.2	-	-	3.2	2.5	2.7	2.0	2.5	2.6	2.8	2.6

subjected to testing, arbitrarily termed as types A, B, C, D and E, were made of various waste raw materials; thus :
geotextile A - of PES; geotextile B - of PES - natural fibre waste blend; geotextile C - of PP and PA filament as the weft on a jute warp; geotextile D - of PP and PA blend; geotextile E - made of fibre glass.

From data presented on Fig. 3, it can be seen that the postsoda sediment environment causes significant degradation of material A and B - as indicated by the decrease of tensile strength after exposure. Also material E is degraded, and from a very brittmaterial in primary state, it becomes more ductile (elongation grows) after exposing it to the sediment.

The strongly alkaline, calcium environment of postsoda sediments causes significant degradation of polyester materials, which means that geotextiles containing polyester PES have to be discarded.
Positive changes occur in materials C and D, the strength and elongation of which increase after exposure to the sediment. The postsoda sediment environment, containing large amounts of calcium carbonate, does not cause any degradation of geotextiles made of PP, PA and jute fibres.

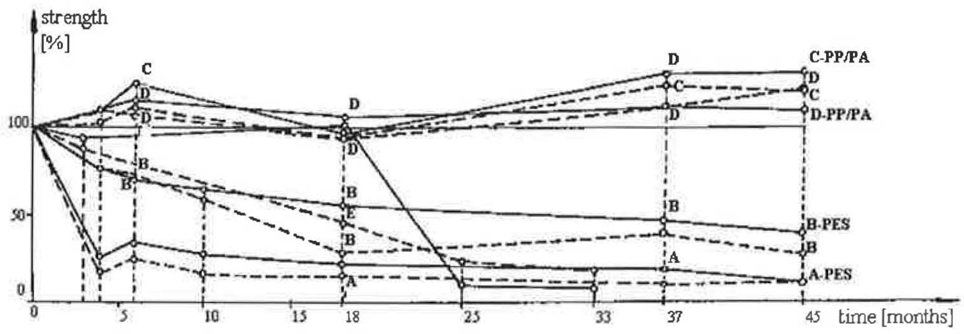

Fig. 3. Textile strength as a function of geotextile degradation in sediment - when extended longitudinally

CONCLUSIONS

Changes of strength parameters of geotextiles in marine environment proceed very slowly in needled cloth and fabrics made of PES, PP and in composites made of PES, PP and PA. This proves that marine environment does not cause a degradation of these materials. Visible degradation in this environment was observed in case of fabrics made of PA. In marine environment, it is better to use composites with combinations of fibres and PA instead of uniformly PA fibres.

Exposure to marine environment does not cause changes in elongation of geotextiles, except needled cloth in which slight shrinkage may occur.

No changes of strength parameters were observed in samples exposed to low temperature (-12°C), which proves that medium low temperatures, observed in natural conditions on the Polish coast, do not cause degradation of the materials.

Changes of strength of geotextiles due to UV radiation are large and diversified depending on the kind of material from which the fibres are made, on fibre thickness, and on the thickness of the manufactured material. Progress of degradation of materials exposed to UV radiation is larger in fabrics than in needled cloth. Use of UV stabilisers reduces degradation of the materials.
Changes of strength of geotextiles made of PP and PA, after 45 months of exposure to an alkaline environment are insignificant. In case of geotextiles made of PES the changes were quite large, which proves that polyester fibres exposed to a strongly alkaline environment, typical for industrial waste dumps, are quickly degraded. Geotextiles made of PES should not be used in strongly alkaline environments.

REFERENCES

1. Dembicki, E. and Niespodzińska, L. 1986. Selection of geotextiles for draining sediments in industrial decanters. Vienna, Austria. Third Int. Conf. on Geotextiles
2. Niespodzińska, L. and Gawlik, W. 1983-1988 Investigations of geotextiles for Soda waste tank drainage at Janikowo, Vol. 1-6. Maritime Institute Edition, Gdańsk
3. Niespodzińska, L. 1987-1991. Filtration materials as independent structures in coastal engineering. Vol. 1-5. Maritime Institute Edition, Gdańsk.
4. Niespodzińska, L. 1990. Geotextile shells in coastal protection at Kołobrzeg. Maritime Institute Edition, Gdańsk.
5. Niespodzińska, L. 1993. Laboratory investigations of geotextiles and their implementation - Proc. of the First Int. Conf. „Geo-filters". Karlsruhe, Germany 1992. AA Balkema, Rotterdam, Brookfield, 1993.
6. Niespodzińska, L. 1995. Application of geotextiles to hydraulic structures in region of Vistula Bay - Inżynieria Morska i Geotechnika No 6