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New Method for the Hydro-insulating of Construction Concrete by the Use of a Multifunctional Textile Geo-composite

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Abstract
A new method is presented to provide damp-proof insulation in horizontal outer constructions such as balconies, terraces and loggias, both in new buildings and existing structures requiring renovation. A newly prepared textile geo-composite is proposed for this purpose. Presented are results of experimental examination of the geo-composite prepared, made on a laboratory-and semi-technical scale to identify its physical properties in relation to the curing of concrete during maturation, and to the damp-proof function in exploitation expected.

Key words: *multifunctional textile geo-composite, hydro-insulation, concrete curing, damp-proof care, drainage nonwoven.*

Introduction

Modern textile technologies bring the opportunity of tailoring the physical-chemical properties of technical textiles and to build fibrous structures for a wide range of applications. Civil engineering is one of the possible domains where geo-textiles can be extensively used to satisfy such expected functions as protection, separation, drainage, filtration and reinforcement [16].

Presented is a new textile structure designed to confer damp-insulation upon common outer horizontal architecture elements exposed to weather conditions, like balconies, terraces, and loggias. The authors have applied for a patent for the method [6].

According to construction technology now in common practice, hydro-insulation can be conferred upon concrete after 28-days of standard maturation [10]. Some curing treatment is done in that time to provide a proper run of the maturing related to the hydration of cement, with the result that the concrete will have the class of strength desired.

After pouring, the curing treatment serves primarily to maintain a proper, constant humidity (80% at least) in the concrete and to protect it against ambient factors. After the standard time, hydro-insulation measures include the preparation of the base by means of its saturation with agents which are to reinforce the concrete and stabilise its imbibition as well as to improve the adhesion of the sealing substances which make the water barrier or insulating membranes like tar board or film (PVC, EPDM, PE).

After these technological steps, an overlay makes the final architecture operation. The same actions are followed in the maintenance of existing structures and in the repair of cracks, defects and the like. Hence the traditional hydro-insulating procedure implies the use of various chemicals harmful to humans both in new architecture constructions and in the renovation of existing ones; moreover, the procedure is labour–intensive.

In view of the hydro-insulating methods applied so far and their inconvenience, a new method was prepared that harnesses textile materials to build composite structures with tailored physical properties

The composite’s structure and new hydro-insulation method

The concept of the new hydro-insulation method arose from knowledge of the concrete curing, during which the moisture content is carefully controlled. Based on the phenomenon of moisture diffusion from one to another medium driven by the concentration gradient, it was concluded that a drainage nonwoven could be used for controlling the moisture. Assumedly nonwoven with a quasi-porous structure would perform this function in contact with the moist concrete immediately after pouring. The excessive made-up water would readily be transported outside. On the other hand, the hydro-insulation of concrete calls for a barrier protection. Bringing these two functions together was essential in the elaboration of a functional textile composite which would be capable of providing unattended curing of the concrete in the maturation period as well as the drying up and hydro-insulating of the construction during exploitation.

The textile composite comprises three thermo-bonded layers:
- upper layer – a nonwoven to provide protection against mechanical damage in the barrier layer when manually spreading the composite on the concrete surface,
- central layer – a thermoplastic film, which provides the barrier function and consolidates the upper protective layer and lower drainage layer in the thermal process,
- lower layer – a nonwoven to provide the effective drainage function based on the diffusion management of the make-up water contained in the concrete slurry to a point at which the

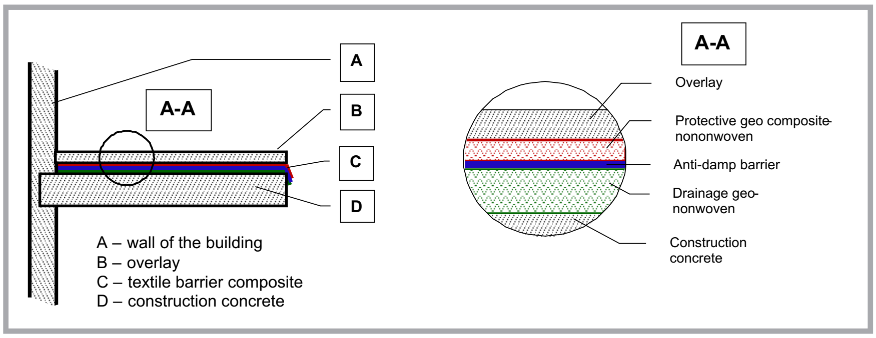

Figure 1. *Example of the position of the hydro - insulating composite in a concrete structure.*

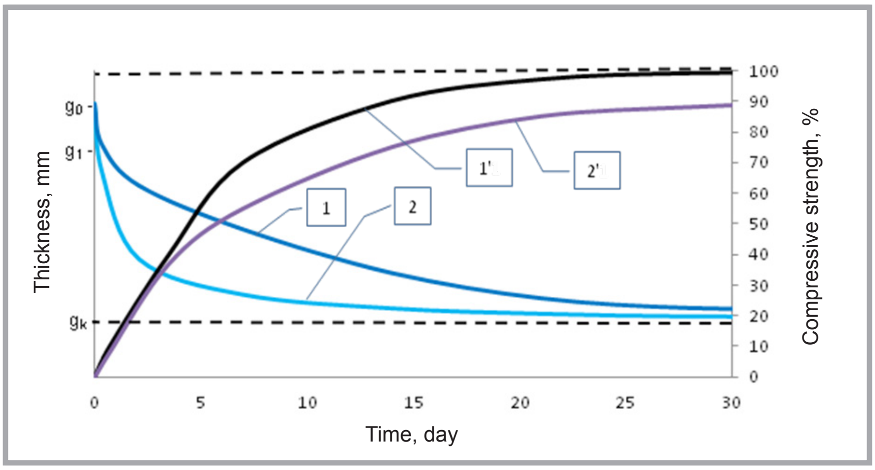

Figure 2. *Time-dependence of the drainage nonwoven settlement and increase in concrete strength. (source: own measurements); 1- an ideal, 2- a typical drainage nonwoven, 1' and 2' represent the strength of the concrete.*

concrete attains an adequate class in the standard time [1 - 4].

A typical needle-punched nonwoven with a surface mass of no less than 200 g/m^2 is a suitable material for the protective layer. Polymeric film of PE, PP, PCV as well as tar board can be used as perfect damp protection [12, 13].

Drainage geo-nonwovens or geo-fabrics and knitwear with a proper plait and density and 2-D or 3-D structure can be used as materials for the drainage layer provided that proper hydraulic conditions are assured in the course of maturing and drying up of the concrete.

The new technology of concrete damp-proofing consists in the spreading of the composite on the concrete surface once it sufficiently hardens to allow the operation. Next the individual composite bands must be properly connected to assure tightness. The casting of an overlay for the finishing work makes the last operation. The composite takes over entirely the functions of curing in the maturation period as well as damp-proofing during exploitation.

No publications could be found in technical literature reporting a solution for the hydro-insulation problem with the use of similar textile structures.

Figure 1 shows the structure of the composite and its position on a horizontal outer concrete construction.

To confirm the concept of the two function-curing and damp-proofing combined in one material, a geocomposite was prepared on a model experimental line designed for the combining of fibrous layer structures [8]. Commercial drainage nonwovens made by domestic producers were used in the experiments [14, 15].

Examination of the composite drainage capacity

On top of a typical concrete construction with hydro-insulation applied, a 5 cm thick overlay or another finishing material (e.g. ceramic tiles) is usually laid. The composite used as hydro-insulation will remain under a load of 900 N/m^2 (for concrete with a density of 1800 kg/m^3). In time, the load will cause a step-wise decrease in the composite thickness (settlement), thus deteriorating the drainage ability. Therefore fibres used in the preparation of the drainage nonwoven ought to be permanently highly elastic and a specific structure must be given to the nonwoven. The requirements are needed to secure a prolonged settlement time, beneficial to the maturing and drying up of the concrete.

Figure 2 presents the function of the drainage nonwoven in the course of maturing and drying up of the concrete.

In the graph, the minimum concrete strength is established from the time of pouring at which the composite can be manually unfolded on the fresh concrete surface and the overlay poured. Plots 1

Table 1. *Technology parameters of the drainage geo-nonwovens.*

lp	Nonwoven / Parameter	I	II	III	IV	V	VI	VII
1	Producer	LENTEX	LAMA	LAMA	FILTEX	LENTEX	NOVITA	NOVITA
2	Marking of the nonwovens	154-250-150 330-00 PP	developed for this study		I/Sm6501 K-1/200	154-400-150 330-00 PP	GEON 200 PES	GEON 400 HTS
3	Type of nonwovens	PP	PES		PES	PES	PP	PES
4	Surface mass offered, g/m^2	250 ± 10%	300 ± 10%	250 ± 10%	200 ± 10%	400 ± 10%	200 ± 10%	400 ± 10%
5	Surface mass measured, g/m^2	254,57	326,17	265,93	220.00	415.06	183.21	406.17
6	Thickness offered, mm	2.60 ± 20%	4.00 ± 20%	4.00 ± 20%	6.50 ± 20%	3.30 ± 20%	2.10 ± 20%	3.20 ± 20%
7	Thickness measured, mm	2.93	4.02	4.00	6.37	3.41	2.70	3.37

and 2 relate to the drainage nonwoven: 1 - an ideal one, with settlement time prolonged to four weeks, and 2- a typical drainage nonwoven. Plots 1' and 2' represent the strength of the concrete, respectively [3, 4]. The nonwovens tested were acquired from domestic producers. They are resistant to chemical and biological corrosion and contain rather thick polyester or polypropylene fibres, favourable for their elastic properties. All are needle-punched nonwovens: nonwovens I, IV, V, VI & VII are of a classical flat structure, while II and III are of a special structure (***Table 1***).

For the purpose of testing, 10 samples sized 150 × 270 mm were cut out of each of the 7 various nonwovens. The quality parameters of the nonwovens quoted by the producers were verified by measuring the average surface mass and thickness in each of the materials. Digital laboratory scale made by Radwag (Radom, Poland), type AS110/C/2 with d = 0.1 mg were used in the estimation of the surface mass.

The thickness of the samples (see ***Table 2***) was measured by means of a laser meter - WT-G200 equipped with four types of pressing plates with defined dimensions. The masses of individual plates to provide pressure were according to Standard PN-EN ISO 9073-2 February 2002: Textiles. Testing methods for nonwovens, Part. 2. "Estimation of Thickness". The table of the device serves as the reference plate. The device is marked with the Declaration of Conformity CE and Certificate of Calibration U/08/W1-10820262 of 27.05.2008, issued by OUM, Katowice (District Office of Measurements).

For the purpose of the testing of drainage properties, a stand was built composed of a plate on which one-side-open boxes were arranged sized 150 × 270 mm (same as the samples). The stand was equipped with glass plates of the same size (with a negative tolerance of the longitudinal measure of the sample) and two 1.8 kg weights (each) for each of the boxes. The weight was reckoned as the equivalent of an overlay with a density of 1800 kg/m^3. Pre-treated test samples of the drainage nonwovens were placed in the singular boxes

The pre-treatment of the drainage nonwovens (acc. to own method) includes immersion in water for one hour, after which the moist material is put onto a sieve to allow the free gravity dripping of excessive water. With the dripping finished, the sample is weighted and put into a film packaging (same size as the sample). The packaging is open one side to permit humidity to evaporate during the testing time. The wrapped samples are put singly into the boxes of the test stand and covered with the glass plates (***Figure 3***), on top of which go two symmetrically positioned weights (1.8 kg each).

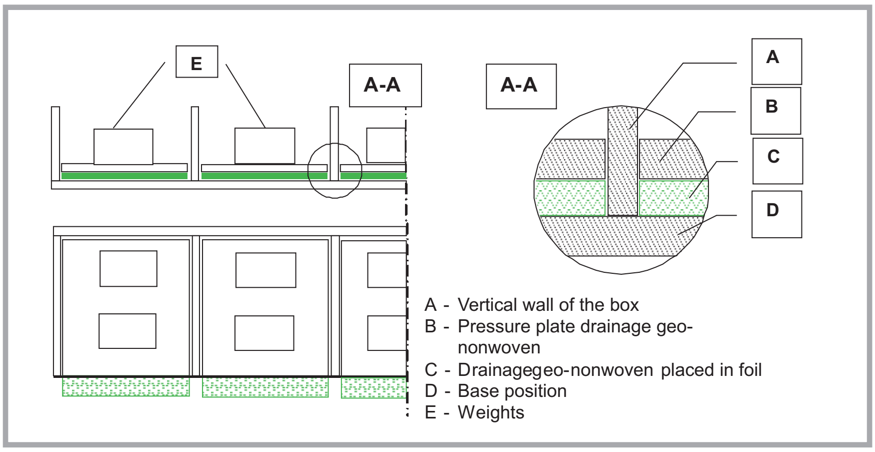

Figure 3. *Laboratory stand for the testing of composite drainage.*

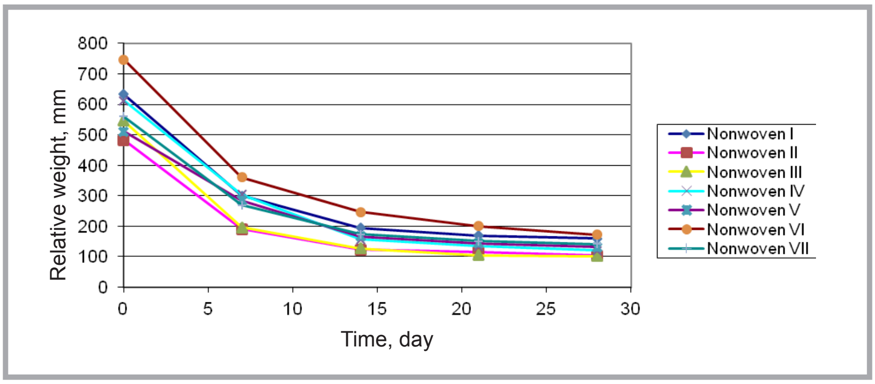

Figure 4. *Relative change in the samples' humidity as a function of time.*

Table 2. *Measurements of the samples' mass (150 × 270 mm) as a function of time.*

Time, day	Nonwoven mass, g						
	I	II	III	IV	V	VI	VII
0	64.88	63.54	58.05	55.23	62.10	52.12	58.72
7	30.70	25.18	20.54	27.08	27.60	25.20	27.32
14	20.00	16.27	13.47	14.28	20.50	18.25	21.81
21	17.40	15.34	11.22	12.07	19.10	14.00	19.11
28	16.30	13.80	10.88	9.88	18.30	12.02	17.68
Sample mass conditioned, g	11.31	13.21	10.77	8.91	16.81	7.42	16.45

The time-dependent humidity loss was determined by measuring the mass of the moist samples at defined time intervals, which is a measure of the drainage efficiency of the nonwovens. The method mimics the working conditions of the drainage nonwoven under a load and its capacity to drain humidity in the course of the 28-day maturing and drying up of the concrete in regular exploitation of the composite.

Figure 4 shows graphs of the time-dependent change in the samples' humidity content as a result of water evacuation by diffusion in relation to the sample mass.

After 28 days, there was varied humidity trapped in the quasi- pores of the nonwovens, which is reflected in the change in mass of the materials. Nonwovens II, III and IV retained after 28 days the smallest amount of water, meaning that they display much better drainage properties than the other ones, which

Table 3. Statistical parameters for samples of highest drainage efficiency.

Non-woven	Time, day	Sample mass, g					$\bar{x}$, g	δ, g	V_s, %
		1	2	3	4	5			
II	0	65.92	62.90	62.09	64.80	62.00	63.54	1.56	2.45
	7	25.02	24.63	26.00	24.12	26.14	25.18	0.78	3.10
	14	16.91	15.84	15.76	16.50	16.32	16.27	0.43	2.62
	21	15.37	14.95	15.10	15.96	15.33	15.34	0.35	2.25
	28	13.47	13.46	14.04	14.14	13.89	13.80	0.28	2.05
	Mass nonwoven in normal humidity	**12.96**	**12.89**	**13.75**	**13.95**	**12.86**	**13.28**	**0.47**	**3.54**
III	0	59.31	57.71	56.29	58.16	58.80	58.05	1.04	5.05
	7	21.12	19.91	19.96	20.70	21.02	20.54	0.52	3.83
	14	13.69	13.04	13.14	13.45	14.02	13.47	0.36	3.21
	21	11.36	10.85	10.93	11.53	11.41	11.22	0.27	2.51
	28	10.99	10.76	10.52	11.22	10.91	10.88	0.23	2.15
	Mass nonwoven in normal humidity	**10.95**	**10.70**	**10.45**	**11.02**	**10.75**	**10.77**	**0.20**	**1.86**
IV	0	56.04	57.21	56.76	53.03	53.10	55.23	1.81	3.27
	7	28.02	27.69	27.00	26.37	26.31	27.08	0.69	2.53
	14	13.66	14.54	15.06	14.10	14.02	14.28	0.48	3.37
	21	11.85	13.10	12.10	11.68	11.62	12.07	0.54	4.47
	28	9.45	10.47	10.03	9.84	9.59	9.88	0.36	3.63
	Mass nonwoven in normal humidity	**8.52**	**9.35**	**9.31**	**8.70**	**8.68**	**8.91**	**0.35**	**3.91**

*Table 4. Results of the deformation tests for samples of selected geononwovens II, III and IV; * thickness after load.*

Time, day	Thickness of nonwoven					
	II		III		VI	
	value, mm	%	value, mm	%	value, mm	%
0	3.98	100.00	3.98	100.00	2.70	100.00
0.04*	3.85	96.76	3.86	97.01	2.61	96.85
7	3.79	95.25	3.81	95.68	2.55	94.62
14	3.78	94.87	3.78	95.01	2.53	93.80
21	3.77	94.65	3.78	94.91	2.52	93.58
28	3.77	94.62	3.77	94.85	2.52	93.58

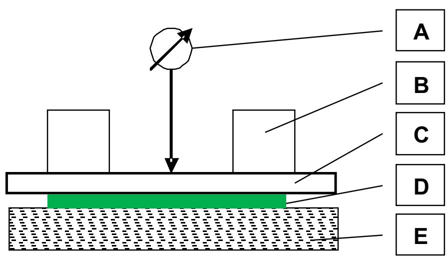

Figure 5. Stand for the testing of deformation in the selected samples of drainage nonwovens under a static load.

implies that with the three nonwovens, the concrete acquired the assumed class of strength.

The measurement method was assessed for the three best drainage nonwovens evaluated: II, III and IV. From each of the materials, five samples were taken, equal in size. The samples were tested according to the same procedure as described above. Mass loss measurements were repeated for the samples (as result of water evaporation) to determine the following statistical parameters:

- average value - $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$,
- standard deviation - $\delta = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n}}$
- variation coefficient - $V_S = \frac{\delta}{\bar{x}}$.

Results are presented in ***Table 3***.

The statistical analysis made leads to the conclusion that the examination method for nonwovens drainage properties proposed provides sufficient accuracy and repeatability of results, and presents itself as a good tool for the assessment of the suitability of drainage nonwovens for the construction of barrier composites.

Rheological examination of the drainage nonwovens subjected to a load

The load-deformation (settlement) of the composite drainage layer was examined in dependence on time over 28 days at the same static load as in the drainage testing. [11, 12] Samples of the three best drainage nonwovens - II, III and IV were spread on the scale's table and each was loaded with weights of 2 × 1.8 kg, as in the drainage examination. Measurements were made with the use of a meter made by Mahr GmbH (Esslingen, Germany), type 1075 (see ***Table 4*** and ***Figure 5***).

Figure 6 presents the characteristic of the time-dependent relative change in the thickness of samples statically loaded.

On the grounds of the results obtained, it may be concluded that the samples of geo-nonwovens II and III take a longer time to attain a stabilised thickness after having lost their elasticity in comparison to the material numbered IV. As regards the composite quality, a longer time is favourable. A fast decrease in nonwoven quasi-porosity deteriorates the drainage properties of the composite, causing a prolonged drying up of the construction concrete

Examination of composite barrier properties

The composite barrier characteristic was estimated according to standards concerning water-proof properties: PN-EN 13859-1:2010 "Elastic water-proof materials. Definitions and properties of ground materials" and PN-EN 13967:2012 Elastic water-proof materials: "Products of resins and caoutshouc for damp-proof insulation inclusive plastics”. The testing was accomplished by applying the pressure of a 30 cm high water column for 24 hours on the composite surface. A 100% barrier effect was the test result.

Examination of the textile composite in a semi-technical construction concrete

The examination of the composite in real concrete constructions relates to its professional preparation in industrial conditions. The following components were used to prepare a pilot charge of the composite:

1) for the protective layer - PES nonwoven with a surface mass of 150 g/m2
2) for the barrier layer - a thermoplastic film with a thickness of 0.075 mm
3) for the drainage layer - a PES structured nonwoven with a surface mass of 328 g/m2

The examination was made on three stands at the same time. Three concrete blocks sized 1200×600×150 mm were poured simultaneously. The blocks were wood-lined, and a water-proof insulation (film) and thermal insulation (styrofoam) were applied on the bottom and sidewise to prevent loss of water through the wooden lining and side-evaporation during the maturing and drying up of the concrete [7, 8]. Five sensor probes were installed in each of the boxes’ linings (***Figure** 7*). When the concrete casting finished, a hydro-insulation composite was spread over one of the blocks and a 5 cm overlay was poured on the composite, producing a load of 900 N/m2.

Curing and drying of the concrete was accomplished in three different ways:

- Use of barrier composite prepared (stand I),
- Classical moisture curing (stand II),
- No moisture curing (stand III).

During 28 days from the pouring, the moisture content was measured by means of the apparatus TDR/MUX/mpts EASY TEST made by the Institute of Agrophysics of the Polish Academy of Sciences, Lublin, Poland. The device comprises an eight-channel recorder for measuring the moisture content in porous materials, the matrix potential of water, electrical conductivity and temperature by the use of electro-conductive probes [5].

In ***Figure** 7* a scheme is shown of one of the stands with connections to the measure/recording equipment.

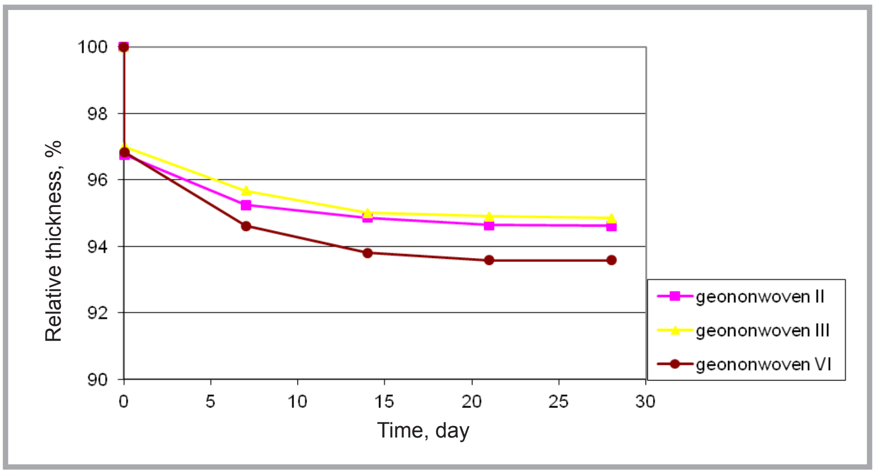

***Figure** 6. Impact of the static load upon the change in nonwoven thickness as a function of time.*

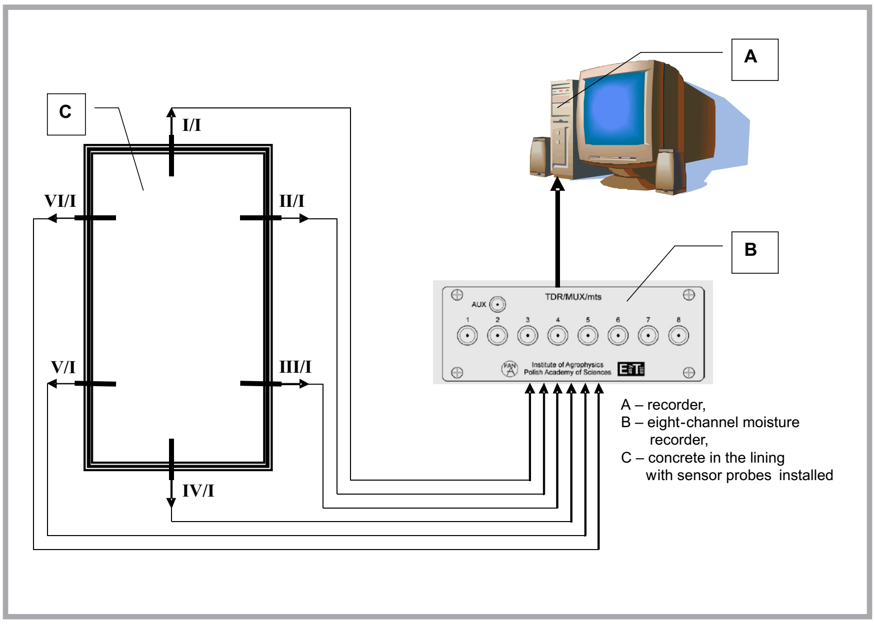

***Figure** 7. Stand for examination of moisture content in the course of concrete curing.*

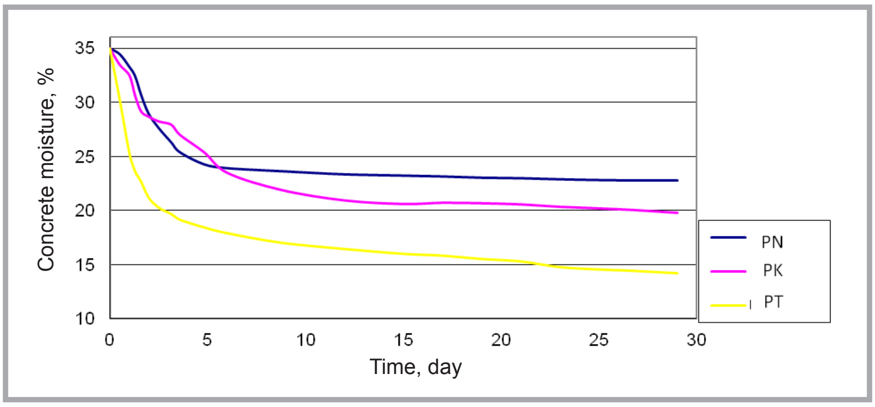

***Figure** 8. Registered change in moisture of the experimental concrete in three variants: (PK)-concrete with hydro-insulating composite, (PT) - concrete with classical curing, (PN) - concrete without curing. **Soirce**: Own measurement.*

***Figure** 8* presents examination results of the maturing and drying up of the construction concrete.

The change in humidity in the concrete with the composite (PK) proceeds in a proper way; however, the time after which the concrete acquires its regular humidity is longer than in those cured standard-wise (PT). The reason for this lies in the different curing adopted. The curing of concrete with the composite runs stably, depending merely upon the diffusion efficiency of the drainage layer. In standard-wise cured concrete, the moisture control *firstly* depends on human action, and *secondly* after one week it is done occasionally, which makes that after that time the drying is much faster on the entire surface. In the case of non-cured concrete its surface is porous and tends to scald, and, in contrast to the two other ones, it did not acquire the assumed strength

Conclusions

1. The new method offers the opportunity of applying of hydro-insulation on horizontal outer concrete constructions, unlike in the traditional method, after only a few hours from the pouring of the concrete. The function of moisture curing and drying up is integrated with the damp-proof function. In the classical method hydro-insulation can be laid only after at least 28 days, meaning a prolonged cycle of engineering work.
2. Unattended curing of the concrete, the simple application of the composite (which reveals anti-corrosion properties) without the use of tools or chemicals, and eco-friendliness add to the strong points of the method.
3. Testing results confirm that the new fibrous composite in the form of a multi-functional structure satisfies the assumed joint functions of hydro-insulation and curing.
4. It was found that the drainage layer of the composite must retain high elasticity, particularly in the first week when intensive hydration of the concrete proceeds. Hence the hydraulic features of the composite drainage layer play an important role.
5. Tests done both on a lab –and semi-technical scale and the results of experiments accomplished confirmed the usefulness of the new method prepared for the hydro-insulation of concrete with the use of a composite textile structure.
6. The hydro-insulation nonwoven composite prepared presents itself as a potential material for wide use in civil engineering.

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Received 31.07.2012 Reviewed 04.02.2014