GEOSYNTHETIC CEMENT – BASED LINER (GCBL) FOR MECHANICAL AND CORROSION PROTECTION OF PIPELINES

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ABSTRACT: Behaviours of cement-based mineral filler and geosynthetic cement-based liner (GCBL) for protecting purposes, mainly of pipelines and related products are introduced. Properties measured include mechanical characteristics, chemical resistance and passivation ability of cement-based filler bound in GCBL. The geotechnical approach to the evaluation of hardened cement blend mixture (CBM) serving as the filler in a GCBL and the first experience with GCBL in field (2003) are reported as well. Portland cement CEM I 42.5 R is the main component in CBM; finely ground Ca^{2+}/Mg^{2+} - rich carbonate rock or $Ca^{2+}/Mg^{2+}/Al^{3+}$ aluminosilicate/carbonate rock are added chemical additives (CMA). Portland cement is mixed with CMA in the percentage ratio of 75 wt % to 25 wt %. CBM with thickness of 9 mm ± 10 % is put between two geotextiles, bound by needle punching, pre-hydrated by sprinkling and soaking of calculated volume of water (equal to water to cement ratio of 0.6), placed on the site e.g. around pipeline and then left to acquire final mechanical properties, chemical resistance and steel protection ability. Primary ability to protect steel by the cement mixture composition (CBM) is supported by techniques of cathodic protection serving as the secondary but equivalent measure for protection of steel against corrosion. Principles of CBM and GCBL manufacture, testing methods, mechanical, chemical, electrochemical and geotechnical properties and important data from the first application of GCBL on the Ondava River are also reported in the paper.

1 INTRODUCTION

In the late 80' s and early 90' s geosynthetic clay liners (GCL) have appeared and soon have become a standard practice in the construction of landfills. A GCL consists of the layer of bentonite, which is held between or on carrier layers of geotextiles or a geomembrane (Saathoff, Keller, 1996). Until recently, exclusively sodium bentonite (natural or activated) has been used as a sealing component. Bentonite filler has high specific surface area, high cation-exchange capacity, good plasticity properties, high swelling and water adsorption capacity, low permeability and low coefficient of diffusion (Alexiew, 2002). One has to keep in mind that swollen sodium bentonite is the least permeable of all naturally occurring soil-like minerals. In the second half of the nineties GCL with bentonite-zeolite mineral filler has appeared in Slovakia. Zeolite in the blended filler plays an important role by improving heavy metal sorption capacity, occlusion of water vapours and detrimental gases, neutralization ability and entrapment of crude oil products (Janotka et al., 2000 and 2002).

In 2002 the towns and many civil engineering structures were damaged or destroyed by the floods occurred in Europe. The outputs of the 8th European Information Conference held in Műnchen, February 18 - 19, 2003 mentioned that geotextile products are suitable for use to reduce damage of property due to the floods (Böttcher, 2003). These are divided into four groups: textile mats, textile tubes, textile containers and filled-in textile liners. The last group is represented by GCL with bentonite filler. New GCL systems are those filled by sand or slag. Sand liners of 9000 g . m^{-2} filler content are stable and resistant to water stream up to 1 m . s^{-1} (Böttcher, 2003).

In this paper information is included in which the standard needle punched GCL is replaced by a geosynthetic cement-based liner (GCBL) used mainly for pipeline applications. Mineral filler bound between two geotextiles in GCBL is a cement system instead of that of bentonite or bentonite - zeolite mixture fixed between geotextiles in GCL. However, it is worthy to note that a mixture of Portland cement with a cement modifier is used in GCBL creating thus a cement blend mixture. Cement is a system composed of clinker minerals and gypsum that react with water at different rates giving hydration products of different composition and crystallinity. Type and volume of the formed hydration products influence porosity, strength and other engineering properties of hardened final product (Taylor, 1998). The use of only Portland cement (PC) generates some undesirable problems with shrinkage/expansion behaviour, chemical resistance and durability of cement composites. To this end, much attention in recent years is devoted to the development of new generation cements with the aim to improve physical-mechanical properties, chemical and environmental resistance, non-permeability and durability of final products (Aitcin, 2000, Dhir et al, 2000). The key difference between PC and blended cement systems is their chemical and mineralogical composition. As a result, the microstructure of hardened blended cements can be markedly improved. Such special cements can be more advantageous in certain application conditions than PC mixtures (Perraki et al., 2003, Lea, 1998), also if cathodic protection is used.

In the introduced GCBL, a special composition of the blended filler contains cement as the main mineral component and 25 wt % of additive providing a chemically resistant cement blend for natural and engineering substrates, primary (due to cement blend mixture composition) and secondary (due to applied cathodic protection where sufficient cation mobility is required) antirust protection of metallic pipelines and related products. Primary and secondary antirust protections are equivalent measures. Hardened cement blend has primarily to passivate steel against corrosion. It is clear that the GCBL may be contemporarily used as the means for cathodic protection of gas and crude oil pipelines and related products against underground corrosion, acting as additional secondary protection. The liner consists of a layer thickness of 9 mm ± 10 % of hardened cement blend mixture. It can be used also underwater; as well as can operate under pressure; and also is suitable for renovating works of pipelines and related products.

The present paper is concerned with the effect of hydrated cement-based filler in GCBL on its mechanical and corrosion characteristics, geosynthetic parameters of hardened GCBL and the description of procedures that lead to the reliable protection of pipelines and related products in subsoil and underwater applications. The first experience from field (underwater renovation works on pipeline at Ondava River) in 2003 is reported as well. Cathodic protection of pipeline was realized. Cathodic protection is out of the material testing and geosynthetic orientation of this paper; and therefore has minor significance to mention here in a more detail.

2 MATERIALS

Portland cement CEM I 42.5 R (PC) and chemical additive (CMA) were used in tests. Chemical additive was regarded as a cement modifier changing in a certain mode important civil engineering properties of virgin Portland cement (reference material tested). Portland cement was mixed with CMA in the weight ratio of 75 % to 25 %. The additive was Ca^{2+} and Mg^{2+} - rich carbonate rock. The addition of cation-rich calciumaluminate/carbonate minerals is also available, utilizing also clay minerals as raw materials. Bentonite is excluded from this choice due to its extreme water consuming, swelling and undesirable effect on cement hydration. Acceleration of cement hydration with CMA by suitable admixtures is possible as well. Basic characteristics of the cement and additive are listed in Table1.

Table 1. Basic characteristics of the cement and additive employed

PC constituent	(%)	CMA constituent	(%)
Insoluble residue	1.60	CaO	52.40
SiO_2	20.64	MgO	44.59
Al_2O_3	5.88	SiO_2	1.40
Fe_2O_3	3.13	Fe_2O_3	0.21
CaO	61.49	Specific surface	430 $m^2.kg^{-1}$
MgO	1.34	Cement properties	
SO_3	2.30	Specific surface	340 $m^2.kg^{-1}$
K_2O	1.54	Initial set	3 h 15 min
Na_2O	1.04	Final set	4 h 20 min
Ignition loss	1.04	Strength: flexural / compressive	
		3 – day	4.4 / 23.5 MPa
		28 – day	7.9 / 41.7 MPa

3 TESTING PROCEDURES

3.1 *Preparation of specimens and curing*

Portland cement mixtures (PCM) as reference specimens and cement blend (75 wt % PC / 25 wt % CMA) mixtures (CBM) were used for 40 x 40 x 160 mm test specimens with water to cement ratio (w/c) of 0.6. The optimal w/c ratio of 0.6 was adjusted by previous tests using 0.4 to 0.9 w/c ratios. For comparison, cylindrical specimens with diameter of 100 mm and height of 150 mm with a dense net of perforated points on the whole surface of the moulds were used to simulate conditions of water penetration into the mixtures similar to that in GCBL. Dry PMC and CBM were poured into the moulds and then immersed into water (20°C) and left to hydrate. As reference test specimens, the same cylinders have served but made with full walls of the moulds. These mixtures as well as those for prismatic specimens were prepared in a cement mixer according to European Standard EN 196-1 Methods of testing cement; Determination of strength having the w/c ratio of 0.6. Here, our procedure differentiates from that prescribed in the EN Standard, where w/c ratio of 0.5 is required. A volume of water soaked up by dry PMC and CBM in perforated cylinders was difficulty measured but it was around w/c ratio of 0.6. In the next step laboratory-made GCBL specimens of size 100 x 150 mm filled with PMC and CBM were made. After slow and regular drenching the GCBL specimen from only one side (that of covering geotextile) by a volume of water calculated on the content of a dry cement-based filler equal to the w/c ratio of 0.6, the specimens were put into sand bed saturated with water to hydrate. The specimens were stored for 90 and 180 days.

3.2 *Techniques*

Cement blend: Strength characteristics of the specimens were estimated according to EN 196-1 Standard using the w/c ratio of 0.6. Ultrasonic pulse velocities were measured on ultrasonic apparatus UNIPAN type 543. The dynamic modules of elasticity (DME) values were calculated by the formula:

$$E_{bu} = \rho_{VD} \,.\, \gamma^2_L \,.\, 10^{-6} \qquad (1)$$

where E_{bu} – DME (MPa), ρ_{VD} – volume density ($kg.m^{-3}$) and, γ_L – impulse speed of longitudinal ultrasonic waves ($m.s^{-1}$). The length changes of prisms and cylinders were measured by a portable mechanical strain gauge apparatus (in a glass tube to minimize extraneous effects). The gauge length was 100 mm, with a measuring accuracy of 0.001 mm. Changes in the length of specimens (expansion/ shrinkage) were expressed in per mille (‰). The pH values of cement blend extracts were determined by a pH meter OP 113 (Radelkis, Hungary). Potentiodynamic curves of steel bars with diameter of 6 mm were obtained using a Potentiostat OH 405 (Radelkis) at a polarization rate of 30 mV. min^{-1}. Steel bars were immersed into cement blend extracts to determine the corrosion state of steel. Evaluation of the results of potentiodynamic method enables to assign three electrochemical states of steel: passive, unstable and active (when steel is corroded) (Krajči, 1999).

To study the cement hydration, formation of reaction products and important civil engineering properties of cement blends kept in water and exposed to aggressive media, the tests on chemical resistance have also started that are supported by XRD, DTA and pore structure studies until now. For the tests 0.6 % solution of magnesium chloride ($MgCl_2$) and 0.3 % solution of ammonium sulphate [(NH_4) SO_4] were chosen. This was done as the result of consulting the problem with hydro geologists to determine "an average value" of underground water aggressiveness. It concerns either natural condition; either sufficiently aggressive laboratory solutions to indicate the resistance of cement blend in relatively short testing time of 2 and 3 years. Having in mind this simplification, concentrations of individual ions are: Mg^{2+} = 1 532 $mg.l^{-1}$, Cl^- = 4 468 $mg.l^{-1}$, NH_4^+ = 818 $mg.l^{-1}$ and SO_4^{2-} = 2 182 $mg.l^{-1}$. According to EN 206-1 Concrete, Part 1, Specification, performance, production and conformity Mg^{2+} ion concentration represents "middle" XA2 degree of aggressiveness; that of Cl^- ions has no estimated criteria but $MgCl_2$ solution is equal to that of 0.7 % CaCl solution; that of NH_4^+ ions is slightly over XA3 "high" aggressiveness and finally that of SO_4^{2-} ions corresponds to "middle" XA2 degree. The combined chemical attack characterizes the influence of $MgCl_2$ solution on cement blend: chloride and ion-exchange between Mg^{2+} and Ca^{2+} ions resulting in non-binding Mg-based reaction products instead of Ca-based hydration products. For $(NH_4)_2SO_4$ solution the combined sulphate and ion-exchange attacks are typical. In contrast to $MgCl_2$, Ca^{2+} ions in hydration products are replaced by non-binding NH_4^+ ions.

Geosynthetic cement – based liner: Samples of GCBL of size 150x100 mm were cut and prepared for laboratory tests at Research Institute of Textile Chemistry (VÚTCH – CHEMITEX) Žilina. Activation of dry cement blend (CEM I 42.5; particle size distribution: particles with diameter over 40 μm: 60 to 80 % and particles with d < 90 μm = 90 %; specific gravity 3 200 $\pm$ 10 kg.m^{-3}, humidity max. 10-12 % and weight of the layer of cement blend 4 500 g.m^{-2}) was performed by sprinkling using the prescribed volume of water.

Optimal amount of water is 2.7 litres per 1 m^2 of the cement blend layer bound between two geotextiles in the thickness of 9 mm $\pm$ 10 %, indicating water to cement ratio of 0.6. Times recommended for 1.) sprinkling and wrapping the moistened liners e.g. around pipeliners are 2-3 hours, 2.) developing early strength and ductility are between 12 and 24 hours, depending upon climate (temperature and humidity) conditions. The cement blend under hydration has to be left in a peace to set and harden at least between 3 and 12 hours. After 2-3 hour keeping in peace, the applications underwater are possible as well.

The laboratory samples were sprinkled and the tests on puncture resistance by measuring the force required for pushing a flat ended plunger through hardened cement blend [EN ISO 12236 Geotextiles and geotextile-related products. Static puncture test (CBR test)]; plunger pull-in resistance (STN 80 6111); tension test (STN 80 6130) were done. Next geosynthetic tests according to standards reported in Table 4 were performed as well.

4 RESULTS AND DISCUSSION

Dynamic modulus of elasticity (Figure 1), expansion (Figure 2) and compressive strength (Table 2) of cylindrical specimens prepared either by mixing according to EN 196-1 Standard or soaking of water into CBM through a dense net of perforated points are considerably influenced by the type of cement mixture and insignificantly by the way of mixing and storage of the specimens. The 90-day compressive strength of CBM is slightly increased compared to that of PCM. It is explained by hydration of surfaces of CMA particles with supersaturated cement solution in time; and also better penetration of water throughout CBM compared to PCM due to less content of cement and possibly less water sorption on CMA grains compared to PC particles. Expansion of CBM is lower and DME values are similar to those of PCM. Differences in the expansion and DME between cylindrical specimens prepared in full moulds and after remoulding immersed to water and those kept in performed moulds are negligible. This supports our previous concept to make possible the improvement of PCM by blending with a suitable cement modifier not only for cement hydration but also cathodic protection of steel. By cathodic protection the underground or underwater pipelines and related products are prevented from being corroded through electrochemical reactions. Specially, an electric field is applied between earth and the matter to be protected Cathodic protection serves for metal structures such as gas pipelines, water pipelines, communication cables, oil pipelines, shop side, plating, ballast tanks, sea and river buoys and bridge substructures. Tests on 150 x 100 mm cylinders confirmed negligible differences among those made by EN 196-1 Standard (placed in full moulds) and those soaked by water in the perforated moulds. Bearing this in mind next experiments were performed only on 40 x 40 x 160 mm specimens prepared by EN 196 – 1 Standard (w/c = 0.6) to verify PCM and CBM properties in water and aggressive

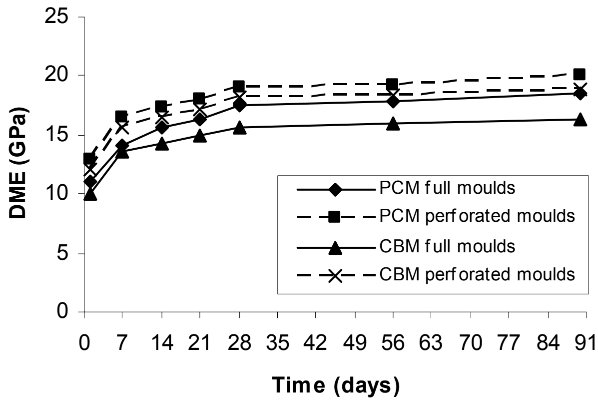

Figure 1: Comparison of dynamic modulus of elasticity of cylindrical specimens from full moulds and perforated moulds

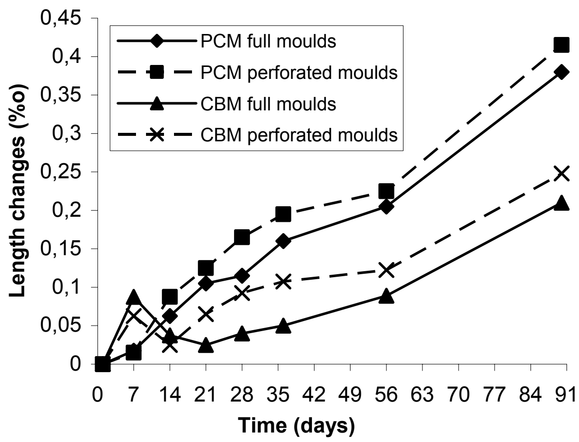

Figure 2: Expansion of cylindrical specimens with PCM and CBM from full and perforated moulds

Table 2 Compressive strength of cement mixtures kept 90 days in water

Mixture	Production and storage	days	Compressive strength (MPa)
PCM	full moulds perforated moulds	90	13.5 13.0
CBM	full moulds perforated moulds	90	17.5 13.3

media, and also to evaluate the ability of cement mixtures to protect steel against corrosion. The results are interpreted to indicate that CBM has the same passivation ability than PCM, besides it is intended with cathodic protection of steel as secondary but equivalent protection.

Both specimens (PCM and CBM) kept 180 days in water and aggressive solutions show evident differences in expansion values (Figure 3).

Expansion of PCM is higher than that of CBM. This is due to 100 % portion of Portland cement in PCM. However, one would remember that cement material has to possess length changes as low as possible. High expansion or shrinkage are undesirable features that may evoke cracks

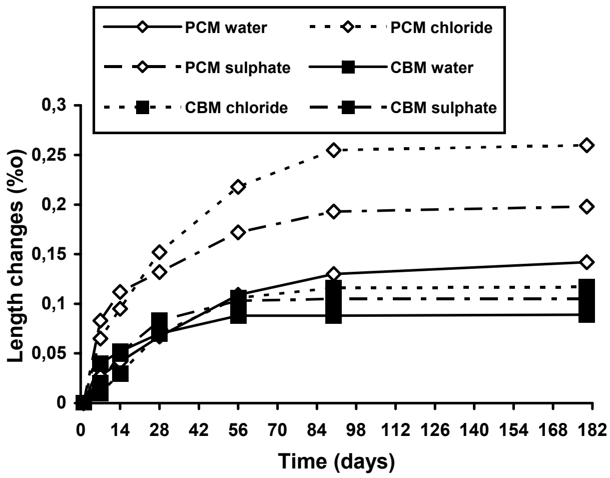

Figure 3: Expansion of PCM and CBM specimens in water, 0.6 % MgCl2 and 0.3 % (NH4)2SO4 solutions

and permeability increase. It is clear that CBM is more advantageous cement system than PCM from this point of view. Expansion of PCM and CBM is always higher in chloride and sulphate solution due to the formation of voluminous reaction products such as ettringite 3 $CaO.Al_2O_3$.3 $CaSO_4.32H_2O$ in sulphates and Friedel´s salt 3 $CaO.Al_2O_3.CaCl_2.6H_2O$ in chlorides. Chemical attack by ion-exchange between binding Ca^{2+} ions and Mg^{2+} or NH_4^+ ions having non-binding potential is not unambiguously distinguished by expansion behaviours. The DME values of all tested specimens are similar. It indicates still high resistance of PCM and CBM against aggressive media when compared with water curing (Figure 4). In contrast, compressive strength of PCM and CBM specimens differ pronouncedly; and symptoms of chemical attack by ion-exchange are demonstrated by this way. Here one would take into account the importance of the achieved strength values. Compressive strength of PCM kept in water is higher than that of CBM (Table 3). The reason lies in higher portion of hydrated cement in PCM compared to CBM.

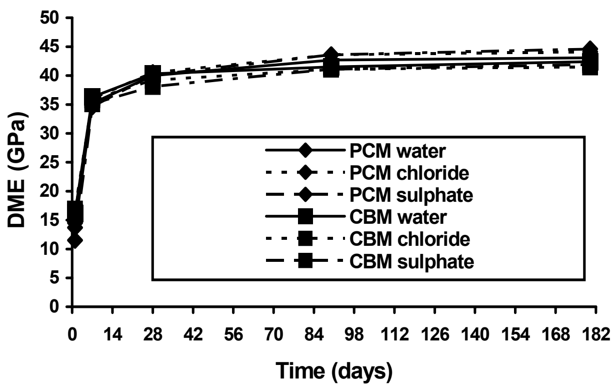

Figure 4: Dynamic modulus of elasticity of PCM and CBM specimens in water and aggressive media

It is noteworthy to mention that differences in strength of one specimen type but in various exposures compared to water curing are of extreme significance when evaluating the resistance to chemical attack. The lower changes in strength are observed, the higher resistance of cement-based material is found. The drop in 180-day compressive strength of PCM from 60.3 MPa (100 % relative strength)

Table 3 Compressive strength of PCM and CBM kept in water, chloride and sulphate solutions

Mixture	Medium	Time (days)	Compressive strength (MPa)
PCM	water (20 °C)	90	39.0
		180	60.3
	chloride $MgCl_2$	90	27.0
		180	35.6
	sulphate $(NH_4)_2SO_4$	90	42.6
		180	53.7
CBM	water (20 °C)	90	27.4
		180	35.9
	chloride $MgCl_2$	90	20.1
		180	25.2
	sulphate $(NH_4)_2SO_4$	90	29.2
		180	38.1

in water to 35.6 MPa (59 %) in chloride or 53.7 MPa (89 %) in sulphate indicates a pronounced detrimental attack by the mentioned ion-exchange than those observed in CBM specimens having 70 % relative compressive strength in chloride and 106 % relative compressive strength in sulphate solution. The latter value shows that CBM undergoes only to voluminous expansion in the $(NH_4)_2SO_4$ solution; and ion-exchange attack enhancing non-binding portion of the hydrate phase does not occur significantly or has only negligible character. The 180-day tests are relatively short for complete evaluation of the CBM resistance. The 2-3 year tests, as usually, are required to gain a reliable picture on the resistance of new material. However it is necessary to add that such tests can be regarded as partially accelerated tests because of relative high concentration of aggressive media. These preliminary results indicate the improved resistance of CBM to aggressive media and sufficient physical-mechanical properties as well. Long-term tests connected with XRD, DTA and pore structure studies bring final explanations and resistance evaluations. The pH values and corrosion characteristic of steel in PCM and CBM extracts show negligible differences among individual parameters to be followed (Figure 5). Slightly decreased pH value of CBM extract exhibits less alkaline character compared to that of PCM. Related potentiodynamic curves of steel bars are of the same course. Steel is fully passivated in cement systems. It is clear that the CBM protects steel reinforcement as well as the reference PCM.

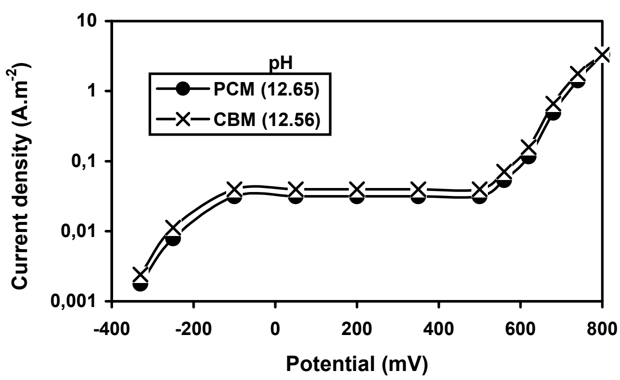

Figure 5: Potentiodynamic curves of steel in extracts of PCM and CBM kept 180 days in water

5 GEOTECHNICAL EVALUATION

GCBL with cement-based filler is a new material of sandwich structure having two geotextile layers between which a 9 mm ± 10 % layer of CBM is bound. GCBL is the product consisting of bottom carrying geotextile (100 % PP or synthetic fibre material) and upper covering geotextile (100 % PP or synthetic fibre material) bound by well-known needle punching. GCBL with dry cement-based powder is manufactured and delivered in lengths mainly of 10 m but also in maximum of 30 m; and widths between 0.3 and 3.5 m. Important geotechnical parameters of GCBL with hydrated CBM are reported in Table 4.

Table 4. Geotechnical parameters of GCBL and evaluation of quality of CBM hardened 180 days in water

Property tested	Value measured
Weight of surface layer (g.m^{-2}) STN 80 0845 (STN EN 965)*	4 500 + 10 %
Thickness of hardened CBM (mm) STN 80 0844 (STN EN 964-1)	9 ± 10 %
Tension strength (kN.m^{-1}) STN 80 6130	> 10
Plunger pull-in resistance (kN) STN 80 6111	1.3
Disturbing force CBR (kN) STN EN ISO 12236	> 2.0
Compressive strength (MPa) STN EN 196-1	> 15
Resistance to climate attack STN 73 1215	satisfactory
Resistance to chemical attack STN EN 206-1	satisfactory
Resistance to biological attack STN 72 4310	satisfactory
Resistance to steel corrosion STN 73 1341	satisfactory

* Slovak Technical Standards (STN) are in the process of approximation to European Standards (EN).

One would regard as the most important property of GCBL a firm mechanical cover around the element (e.g. pipeline) that has been wrapped. This material behaves as highly reinforced composite system. Production, application conditions and check tests (quality testing) are described in a detail in national documents: PN 010603 Geocomposite CEMTEX: Works Standard (2003), NP 01/03 Geocomposite CEMTEX: Directions for use (2003); and TPV – 01/03 Geocomposite CEMTEX: Technological rules for production, storage, placing and testing (2003). The CBM was applied for a patent in Slovakia (2003) already.

6 APPLICATION EXPERIENCE

It is well-known that pipelines are protected mainly against mechanical load by various technological procedures such as organic-based and cement-based coatings using factory manufacture before application. The 20 – 50 mm cement-based coating (usually from polymer-cement mortar) has outstanding mechanical properties. Sanding is not required even in rough rocky terrain. Moreover, cement-based coating serves as a sufficient load at the placing into rivers, swamps or sea. Cement-based coatings are usually not applied on large-dimension pipelines (over diameter of 1 000 mm) because of very heavy pipeline segments and on tanks (reservoirs, cisterns) of irregular shapes. The GCBL was developed on the requirement of workplaces dealing with mechanical and antirust protection of engineering mains placed mainly in soils. Its application is intended for transit and local pipelines and tanks. GCBL possesses a couple of protection functions that mutually supply and come through each other. These functions are: mechanical, chemical and electrochemical, protection, support of cathodic protection, partially also fire protection and resistance to environmental (atmospheric) corrosion. GCBLs are planned to covering insulated and non-insulated surfaces of steel pipelines and related products as well as plastic pipelines, tanks but also other civil engineering structures. At least, one of the protection functions is always utilized at the application. Besides mechanical, chemical and electrochemical protection, it is important to protect steel against corrosion by means of cathodic protection. Much more negative potential opposite to that of surrounding environment (soil electrolyte) is kept on the surface of protected steel by cathodic protection. Protective electrical current reaches steel surface after passing through hardened CBM layer, causing thus its slight dissolution. “Friendly” cations (Mg^{2+}, Ca^{2+}, Al^{3+}) are transported to steel surface creating firm coating similar to that of a dense ceramic layer with thickness of some nanometres. As the consequence of this, corrosion of steel is stopped, even of naked steel when insulation is missing or is defect. Wet hardened CBM has also sufficient conductivity for protective electrical current on the sites of steel surface without running contact with soil or water electrolyte. This enables to apply cathodic protection of steel pipelines in protectors, over water levels or when sand bed around pipeline has been washed out already. Mechanical protection of pipelines by cement–based coating is commonly applied in Slovakia.
GCBL has been used two times already; in both cases in very specific conditions. One application was performed in the storehouse of products where petroleum disturbed a top layer of asphalt insulation into the depth of inserted PVC sheet. Repair works were based on the substitution of deteriorated bitumen layer by GCBL. The second application was done (both in 2003) at the repair works of pipeline situated under water level of the Ondava River (region of Eastern Slovakia). Contemporarily with repair works using GCBL, cathodic protection was applied. GCBL was wrapped around pipeline and fixed by special ties placed step by step each 200 mm. After placing and fixing GCBL on the steel surface, pipeline was covered by an inverse “U” concrete blocks. Finally “U” blocks were buried by crushed aggregate. Figure 6 shows the work of divers with GCBL to be placed around the pipeline. Figure 7 illustrates a “half pipe-line” sample serving for control measurements of cathodic protection carried out under water. After half-year exposure in Ondava River, the measurements showed transport of cations occurred in CBM on the surface of steel creating a dense coating of high quality. This is confirmed by measured values of switch on potential (E_{ON} = - 1.453 V) and switch off potential (E_{OFF} = - 1.075 V), respectively. Switch off potential fallen down to – 1.006 V after 3-hour depolarization indicating passive state of steel. Cathodic protection was realized by cable anode ANODEFLEX 1 500 using close-coupled anode procedure. The “U” blocks were buried by crushed aggregate to form a firm threshold in the river, and the load preventing any possible deterioration of pipeline (Figure 8).

7 CONLUSIONS

The following conclusions are applicable to the tested cement-based mineral filler (CBM) and GCBL:

1) Civil engineering properties of CBM kept underwater are similar to those of PCM indicating shrinkage - reducing

Figure 6: Divers catching GCBL before wrapping around pipeline underwater

Figure 7: Steel " half pipe-line" sample for control measurements at cathodic protection

Figure 8: Aggregate determined for burying " U" blocks situated over pipeline

character and lower strength development of CBM.

2) The measured properties of CBM are not dependent upon manufacture procedures: preparation of laboratory samples in a mixer gives the mixtures of the same quality than those soaked by water.
3) Preliminary 180 – day resistance tests in $MgCl_2$ and $(NH_4)SO_4$ solution show improved durability of CBM opposite to PCM. Tests until 2-3 year exposures are required and will be performed.
4) GCBL with CBM indicates such material behaviour and geosynthetic parameters that enable reliable mechanical and antirust protection of pipelines and related products.
5) The first applications of GCBL even together with cathodic protection of steel pipeline show the perspective use of this geo-cement composite product in the future.

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STN 80 0844 Flat textiles. Determination of thickness.

STN 80 6130 Geotextiles. Determination of tensile strength and breaking elongation.

STN 80 6111 Non-woven fabrics. Resistance to pushing- through. Plunger pushing- through test.

STN EN ISO 12 236 Geotextiles and geotextile-related products- Static puncture test (CBM test).

STN EN 196-1 Method of testing cement. Determination of strength.

STN 73 1215 Concrete structures. Classification of aggressive environments.

STN EN 206-1 Concrete. Part 1: Specification, performance prediction and conformity.

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