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Corrosion Resistance of Rubber Concretes

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Abstract: Chemical resistance of the new polymer concrete with polybutadiene binder (*RubCon*) was investigated. Some important problems of corrosion environment attack based on experiments were discussed. Mechanism of relationship between organic and inorganic aggressive medium and *RubCon* was analyzed. Influence of elevated temperature and corrosive environment exposition was revealed. Forecast of *RubCon* chemical resistant coefficient was done. Application of special activating agents e.g. altax and sulfur $_+$ tiuram- D, TiO_2, $BaSO_4$ has a beneficial effect on chemical resistance of *RubCon*. Chemical resistance of *RubCon* is many times higher than ordinary Portland cement concrete and surpasses of chemical resistance of polyester, polyepoxy and vinyl ester polymer concrete.

Keywords: Polymer concrete, polybutadiene binder, chemical resistance, additives.

INTRODUCTION

Developments in civil engineering and industrial growth have created a continual demand for building materials with new and improved performance attributes. Polymer concretes (PC) appear to offer possibilities for meeting these new requirements. By polymer concrete is meant a polymer composite with a polymer matrix and sand and rocks, like those used in Portland cement concrete, as inclusions. Service conditions often dictate specific material requirements that may be met by PC when several composite properties are considered simultaneously.

Advancements in PC materials have slowed over the past 25 years as compared to the rate of advancements in the 1970s and 1980s. The knowledge base in concrete polymer materials has matured as many products have been made commercially available. There are now many polymer-based construction materials that have been shown to perform very well for their intended purposes: concrete spall repair, crack repair, concrete overlays, and precast concrete components. The cost of polymer-based systems is high relative to conventional portland cement concrete materials, and it is necessary to demonstrate the improved durability, reduced thickness/size, ability to be placed in difficult environmental conditions, and/or the fact that other non-polymer materials will not work. There are many situations for which concrete-polymer materials prove to be the most appropriate materials for the intended application.

Understanding of the nature of PC is necessary for the design of the most cost-effective PC composites and to produce materials with desired properties.

Polymer concrete is usually used in severe conditions in industrial and public buildings as well as in transportation and hydraulic structures. The main uses are repairing strengthening, and corrosion protection of concrete structures. The main advantages of polymer concrete over ordinary concrete are improved mechanical strength, low permeability, and improved chemical resistance. The main limitation is their relatively high material cost. This is why it is important to find the optimum technical/economic compromise. To solve this problem, it is necessary to formulate a reliable predictive mathematical model of polymer concrete material properties.

One of the new kinds of the structural polymer building materials created recently is rubber concrete based on polybutadiene binder (is short for *RubCon*). The idea of using liquid rubber as the binder for polymer concrete was the first time put forward by Prof. O. Figovsky [1]. *RubCon* is noted for its effective operational characteristics: the highest chemical resistance and some physical-mechanical properties, adaptability to manufacture, small shrinkage etc. [2].

Application of *RubCon* in practice of construction allows solving a problem of corrosion, negative influence of temperature, degradation of a material at raised UV - exposure, radiation and other adverse natural and technogenic factors, to increase the between-repairs period, reliability and durability of buildings and structures, especially at the action of aggressive environments. It is necessary to note, that *RubCon* is cheaper in comparison with other corrosion resistant polymer composites.

The complex of physical-mechanical, heat-physical and technological properties of *RubCon*, its behavior in conditions of influence of a broad aggressive environment spectrum, problems of durability and reliability are studied, pilot test of *RubCon* as new structural building material at the enterprises of various industries is made [2,4-9].

MATERIAL

New Type of Polymer Concrete Based on Liquid Rubber

The development of manufacture of diene oligomers belonging to a liquid rubber class with viscous liquids consistence allowed to create a new class of conglomerate

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polymer composite materials- rubber concrete (*RubCon*). Rubber concrete is the advanced constructional material created for last years. It is polymer concrete with a unique set of physical-mechanical, chemical and technological properties which allow to obtain highly effective building structures and products on its basis [2].

RubCon contains no cement as a binder; its matrix is polybutadiene — a polymer from the liquid rubber family so that *RubCon* has elastic properties and it is extremely resistant to aggressive chemicals, highly repellant to water and has the highest compression strength.

RubCon does not exhibit the common failure mechanisms of conventional concrete, such as cracking and flaking, freeze and thaw, and it resists vibrations, making it an ideal pad material for pumps and compressors. Furthermore, it coats reinforcing bars making the bars impenetrable to water, hence arresting corrosion. The strength and durability of concrete depends upon the variation of particles and the binder used with its fabrication.

RubCon is applied in the same manner as conventional concrete, formulated first from a component mixture into a liquid and then cured for 12 - 48 hours for hardening. The initial binder components are formulated off-site into a mixture. The component mixture consists of a single component package for hot curing (150º to 180º C) with a shelf life of three months (in a closed container), and a two-component package for cold (20º to 25º C) and semi-hot (70º to 100º) curing with a shelf-life of six months.

For the preparation of *RubCon* mix fine (quartz and stream sends, fly ash) and coarse (different kinds of chipping and gravel) aggregate were used (Fig. **1**).

The components of the mix can be easily formulated on-site in a nontoxic and completely safe manner. It will be noted that *RubCon* binder is easily applied and will adhere to metal or glass reinforcements. After two days, *RubCon* binder may be walked upon and after seven days, it is ready for work loads. With the use of special adhesives it can be applied over existing concrete flooring.

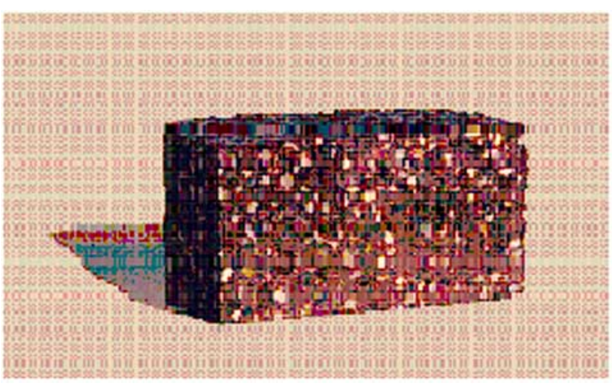

Fig. (1). View of cross section area of a *RubCon* sample.

RubCon's mechanical properties follow (Table **1**).

Corrosive attack of aggressive medium on composite polymeric materials is manifested as change of its structure and properties without disruption of integrity or with destruction of the materials. The corrosion environment penetrates between macromolecules through micro pores and fine capillaries and irreversibly changes a chemical structure of composite and reinforcing bars or fibers as well. Such changes of *RubCon* structure are characterized by formation of new active groups in molecular chains (carboxyl, hydroxyl, amine, and ketone) and presence of double links resulting in a lowering of physical-mechanical properties of the material. Water and water solutions of electrolytes adversely affects on composite materials, causing their destruction, cracking etc. [3].

As a rule the most widespread liquid excited environments are water solutions of acids, alkalis and salts. Chemical resistance of *RubCon* was specified from change of weight and compressive strength of the samples after its exposure in liquid aggressive environments during certain period of time. The choice of aggressive environment compositions was based on their prevalence in industrial production.

EXPERIMENTS AND DISCUSSION

Coefficient of Chemical Resistance of *RubCon*

A basic guideline in a choice of corrosion environments during the test of *RubCon* specimens was their wide spreading into industrial production. Such environments were: water, 30% and 70% solutions of sulfuric acid, 5% solutions of phosphoric and acetic acids, 3% solution of nitric acid, 3% and 30% solutions of hydrochloric acid, 10% solutions of lactic and lemon acids, caustic soda and caustic potash, diesel fuel, acetone, 25 % water solution of ammonia, 30% solution of copper vitriol, and saturated solution of sodium chloride. Chemical resistance of *RubCon* was estimated on test specimens in the size 4x4x16 cm [4, 5].

The following values were determined in the course of experiments before and after attack by water and corrosive media during one year of exposure at room temperature:

- Δm - change of test specimen mass,
- R_c -compressive strength,
- E--modulus elasticity,
- K_{cr}- coefficient of chemical resistance,
- K_E -coefficient of change of modulus elasticity,
- x -depth of penetration of corrosive liquid (was obtained by microscope-assisted measuring of the visible front of diffusion liquid movement).

It is obvious that the durability of a structural material depends on its resistance in corrosion environment. Indexes of this resistance are:

Coefficient of chemical resistance

$$K_{cr} = R_{c1}/R_{c0}, \tag{1}$$

Coefficient of change of modulus elasticity

$$K_E = E_1/E_0. \tag{2}$$

Change of test specimen mass

$$\Delta m = (m_1 - m_0)*100/m_0 \tag{3}$$

Here R_{c0}, E_0, m_0, R_{c1}, E_1, m_1 - compressive strength, modulus elasticity and mass of specimen correspondingly before and after corrosive media attack during one year of exposure.

Table 1. Basic Physical-Chemical and Mechanical Properties of *RubCon*

Indices	Units	Concrete on Portland Cement	*RubCon*
Density	kg/m^3	2400	2100-2300
ength at	MPa		
- compression		20-40	80-95
- bending		35	25-30
- tension		25	12-15
Modules of elasticity	$MPa10^4$	2-2.7	2.0-2.7
Poison's ratio		0.15-0.24	0.26-0.28
Thermal conductivity coefficient	W/m/°C	0.3-0.5	0.3-0.5
Wear resistance	$(kg/m^2)10^{-3}$		2-3
Specific toughness	$(J/m^2)10^3$	0.5	3.5-4.5
Heat stability	^{U}C	-	80-100
Water absorption	%	1	0.05-0.06
Coefficient of chemical resistance at 20°C (based on 360 days of exposure)			
- 20% H_2SO_4			0.97-0.98
- 10% Lactic acid			0.95-0.96
- 20% Caustic potash		no stable	0.97-0.98
- 35% H_3PO_4			0.96-0.98
- Water		no stable	0.99-0.995
- Salt water		0.6 1	1.00-1.05
Resistance to abrasion,	$(k/m^2)10^{-3}$	0.5	2-3.5
Labor input at manufacturing m^3	relatively	1	1
Cost of one m^3	relatively		0.6

Results of the experiments are given in Table **2** [4].

As shown in Table **2**, coefficient of chemical resistance of *RubCon* is equal 1.0 for water, 0.81÷0.95 for all mineral acids (exception is K_{cr} = 0.69 for 36% solution of hydrochloric acid), 0.82÷0.95 for organic acids, 0.82÷0.91 for alkalis, 0.88 for solvents and petroleum products, 0.84÷0.86 for solution of salts. The analysis of experimental data has shown that *RubCon* offers the universal chemical resistance many times higher than ordinary Portland cement concrete and surpasses of chemical resistance of polyester, polyepoxy and vinyl ester polymer concrete. It is worth noting that penetration depths of 3% nitric and 36% solution of hydrochloric acids into *RubCon* samples body were 3,4 and 5.1mm correspondingly; penetration ability of these acids is higher as compared with other corrosive environments.

Dynamics of compressive strength change of *RubCon* samples during corrosion medium exposition is shown in Fig. (**2**) [6]. It is shown that *RubCon* has high chemical resistance not only under normal operating conditions, but also at long impact of compression loading (creep) in aggressive environment.

The Mechanism of Corrosive Environment Influence on Concrete with Polybutadiene Matrix

Physical-chemical impact of a corrosive environment on a polymer composite material is manifested in change of its structure, sometimes resulting to destruction. Fig. (**2**) show that the most intensive decrease of *RubCon* strength occurs during the first 6 months of the corrosion environments exposition. Penetration of corrosive environment between macromolecules of a material through its micro pores and fine capillaries produces reduction of a surface energy on the "body-environment" boundaries. It leads to formation and development of cracks in a composite, lowering of its strength, elevation of polymeric chains flexibility and plasticization of a material.

Destruction of polybutadiene occurs under the action of nitric acid is caused by oxidation of a polymer macromolecule. In other words cross-section links of a spatial composite network formed by vulcanization process are broken. A well-known oxidization ability of sulfuric acid is responsible for decrease of double links in rubber molecular structure resulting in a lowers of the *RubCon* strength indexes. Corrosive attack of hydrochloric acid is

Table 2. Physical-Mechanical and Chemical Properties of *RubCon* After Attack of Corrosive Environments

Corrosive Media	Indexes			
	Δm, %	K_{cr}	K_E	*x, мм*
Water	0.05	1.00	1,00	-
30% solutions of sulfuric acid	0.28	0.95	0.87	1.33
70% solutions of sulfuric acid	0.33	0.92	0.90	1.12
5 % solutions of phosphoric acid	0.14	0.94	0.81	0.93
3 % solution of nitric acid	0.63	0.80	0.70	3.40
5 % solutions of hydrochloric acid	0.13	0.81	0.81	0.81
36% solutions of hydrochloric acid	1.14	0.69	0.53	5.10
5 % solutions of acetic acids	0.22	0.82	0.78	1.32
10% solutions of lactic acids	0.28	0.95	0.93	1.57
10% solutions of lemon acids	0.16	0.87	0.86	0.92
25% water solution of ammonia	0.31	0.82	0.70	1.85
10% solutions of caustic soda	0.22	0.87	0.77	1.15
10% solutions of caustic potash	0.17	0.91	0.85	0.92
Diesel fuel,	0.28	0.88	0.86	2.25
Acetone	0.25	0.88	0.88	1.77
30% solution of copper vitriol,	0.22	0.84	0.81	1.32
Saturated solution of sodium chloride	0.16	0.96	0.95	0.92

linked to oxidation and isomerization processes and therefore durability of composite depends on speed of these processes course.

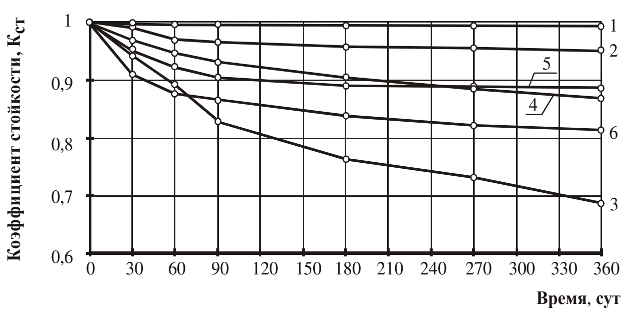

Fig. (2). Relationship between the *RubCon* coefficient of chemical resistance and time of corrosion medium exposition: 1- water, 2- 30% solutions of sulfuric acid, 3- 36% solutions of hydrochloric acid, 4- 10% solutions of caustic soda, 5- diesel fuel, 6- 5% solutions of acetic acids.

Corrosive attack of organic carboxylic acids on polybutadiene binder is exhibited by oxidization and depolymerization processes, resulting the formation of carboxyl groups COOH. Carboxylic acids are generally weaker than inorganic because speed of these processes is below and therefore decrease of physical-mechanical properties of *RubCon* occurs more slowly. The most intensive lowering of *RubCon* strength properties (compressive strength and modulus of elasticity) at influence of carboxylic acids attack were noted in the first 90 days. Penetration depths of corrosive medium into body of test specimens after one year exposition are 1, 3, 1.6, and 0.9 mm for acetic, lactic an lemon acids correspondingly (Table **2**).

With reference to Table **2** it can be seen that among carboxylic an acids acetic acid is the most aggressive medium relative to *RubCon* because it is the strongest oxidizer. Lactic and lemon acids are less aggressive.

Temperature Influence on Chemical Resistance of *RubCon*

In **e**arlier investigation of *RubCon,* we have studied its behavior at the elevated and negative temperatures in conditions of the no aggressive environment operation [7]. Continuation of these researches became the examination of *RubCon* resistance in liquid corrosive environments at elevated temperatures, which visually demonstrated a destruction of the material. Joint influence of temperature and corrosive medium was determined by the test of *RubCon* specimens in the size 4x4x16 cm. Experiments were performed in 10% -solution of caustic soda and 30% solution of sulfuric acid environments at temperatures +40ºC and +60ºC. Results of the experiments are illustrated in Table **3**.

It can be seen that the elevated temperature reduces the chemical resistance of *RubCon* samples and leads to their destruction due to the acceleration of chemical reactions between the corrosion environment and the material.

Forecast of Chemical Resistance Coefficient

The forecast of *RubCon* chemical resistant coefficient for τ =10 years operation in corrosive environments has been carried out by the formulas:

$$\boldsymbol{lg\ K_{cr} = a + b\ lg\ \tau} \quad (4)$$

where

$$\mathbf{a} = \boldsymbol{lg\ K' - b\ lg\ \tau'};$$

$b = [\Sigma^{n}_{i=1} (\lg K' - \lg K_i) (\lg \tau' - \lg \tau_i) / \Sigma^{n}_{i=1} (\lg \tau' - \lg \tau_i)];$

$\lg K' = \Sigma^{n}_{i=1} \lg K_i / n;$

$\lg \tau' = \Sigma^{n}_{i=1} \lg \tau_i / n$

Here K_i, τ_i -coefficients of chemical resistance and intervening testing terms (30,60,90,180 and 270 days) correspondingly. Results of calculations are shown in the Table **4**.

Table 3. Impact of Elevated Temperatures on Chemical Resistance of *RubCon*

Corrosive Media	T°C	Indexes	
		Δm, %	K_{cr}
Water	+20	0.04	0.99
	+40	0.06	0.99
	+60	0.07	0.98
30% solution of sulfuric acid	+20	0.16	0.97
	+40	0.20	0.95
	+60	0.23	0.93
10% solutions of caustic soda	+20	0.14	0.92
	+40	0.16	0.90
	+60	0.19	0.87

Table 4. Predicted Chemical Resistance of *RubCon* After 10 Years Operation in Corrosive Environments

Corrosive Media	Predicted Values of K_{cr}
30% solutions of sulfuric acid	0.914
70% solutions of sulfuric acid	0.865
5 % solutions of phosphoric acid	0.892
3 % solution of nitric acid	0.682
5 % solutions of hydrochloric acid	0.706
36% solutions of hydrochloric acid	0.521
5 % solutions of acetic acids	0.728
10% solutions of lactic acids	0.923
10% solutions of lemon acids	0.799
25% water solution of ammonia	0.724
10% solutions of caustic soda	0.800
10% solutions of caustic potash	0.937
Diesel fuel,	0.800
Acetone	0.820
30% solution of copper vitriol,	0.737
Saturated solution of sodium chloride	0.927

It is evident that *RubCon* is corrosive stable structural material because its chemical resistance coefficient during 10 years operating in aggressive environments exceeds 0.5. Obtained data allow to appoint the thickness of the concrete cover of a reinforced *RubCon* structure.

Enhancement of Chemical Resistance of *RubCon*

As follow from Table **2** the *RubCon* coefficient of chemical resistance in 36% solution of a hydrochloric acid environment is minimal. We launched the series of experiments in order to raise the *RubCon* chemical resistance by introducting of special active additives into vulcanization process. These additives make possible to increase density of spatial crosslinks of polymeric molecules and by doing so, to improve physical- mechanical properties and resistibility of *RubCon* to the corrosive medium exposition..

Such additives were tiuram-D and altax. Optimum quantity of the additives in the *RubCon* composition was obtained by two-factor experiment. In this case, dosage of the additives was varied parameter and with its compressive strength of *RubCon* test specimens was efficiency function. In Fig. (**3**) is showed the efficiency function surface for *RubCon* samples in 36% solution of a hydrochloric acid depending on quantity of additives: sulfur + tiuram-D (x_1) and altax (x_2).

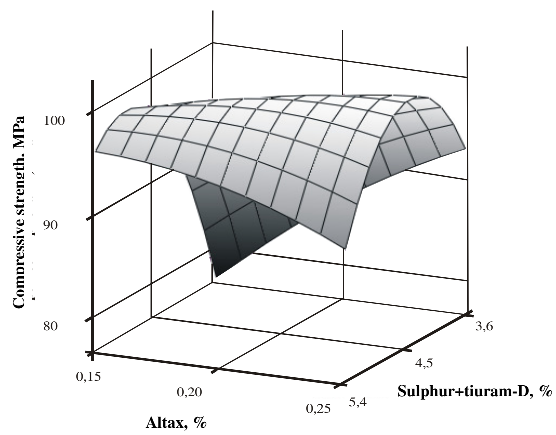

Fig. (3). Compressive strength of *RubCon* samples relationship between quantities of altax and sulfur + tiuram-D after exposition in 36% solution of a hydrochloric acid.

Regression formula of relationship between *RubCon* compressive strength R and quantities of additives (x_1- sulfur + tiuram-D and x_2- altax) is:

$$R = -369.5 + 162.7 x_1 + 774.5 x_2 - 15.5 x_1^2 - 553.2 x_2^2 - 106.0 x_1 x_2 \quad (5)$$

Compressive strength of the *RubCon* samples after 90 days exposition in 36% solution of HCl peaks at x_1 = 4.45% and x_2 = 0.28%. As this took place, coefficient of chemical resistance was increased from 0.83 to 0.94; after one year exposition in the same corrosive environment from 0.69 to 0.88.

Introduction of other additives into the *RubCon* mix also make possible to raise its compressive strength. Our experiments have shown that addition of 2.3% TiO_2 or 3.6% $BaSO_4$ allows to increase compressive strength of the *RubCon* samples after 90 days exposition in 36% solution of HCl up to 11÷12% (Table **5**).

As illustrated in Fig. (**4**), growth of compressed strength R of *RubCon* operated in no aggressive environments (line 1) is connected with increase of the TiO_2 doze since oxide of metals are activating agents of vulcanization process. After 90 days exposition into 36% solution of HCl and quantity of

Table 5. Effect of Oxides and Salts of Multivalent Metals on Resistance of *RubCon* in 36% Solution of HCL

Test No	Addition	Contains in the Mixture, %	Indexes		
			Strength, MPa`		K
			Initial	After 90 Days	
1	TiO_2	1,5	103,6	93,2	0,9
		2,0	103,8	95,5	0,92
		2,5	104,4	97,1	0,93
		3,0	104.6	93,1	0,89
2	$BaSO_4$	2,0	101,9	89,7	0.88
		3,0	102,1	91,9	0,9
		4,0	101,8	93,7	0,92
		5,0	97,8	90,0	0,92
3	Control		103,0	83	0,83

TiO_2 more 2.3% chemical resistance coefficient K_{cr} and compressive strength R are decreased (lines 2, 3). We attribute this phenomenon to intensive formation of soluble compounds resulting in the production of micro cracks.

Following equation was obtained from regression analysis:

$$R = -6.3\,x^2 + 28.4\,x + 64.5 \qquad (6)$$

Hence it follows that optimal dose of TiO_2 is equal 2.3%.

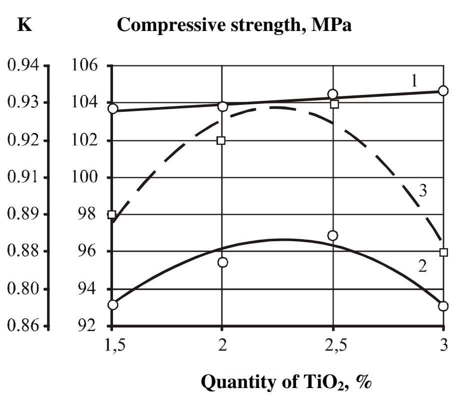

Fig. (4). Impact of TiO_2 quantity on *RubCon* compressive strength operated in no aggressive environments (line 1), resistance coefficient (line 2) and compressive strength (line 3) after 90 days exposition into 36% solution of HCl.

In contrast to TiO_2 additive the introduction of $BaSO_4$ reduces the compressive strength R of *RubCon* operated in no aggressive environments (Fig. **5**, line 1) because $BaSO_4$ plays a role of fine grained filler. With increasing dose of this additive the discreteness of the rubber matrix grows resulting in reduction of *RubCon* strength. After 90 days exposition into 36% solution of HCl and quantity of $BaSO_4$ more 3% chemical resistance coefficient K_{cr} of *RubCon* samples is increased (lines 3) whereas its compressive strength falls (line 2).

Regression model of these experiments is depicted by equation:

$$R = -1.5\,x^2 + 10.6\,x + 74.1 \qquad (7)$$

Hence it follows that optimal dose of $BaSO_4$ is equal 3.6 %.

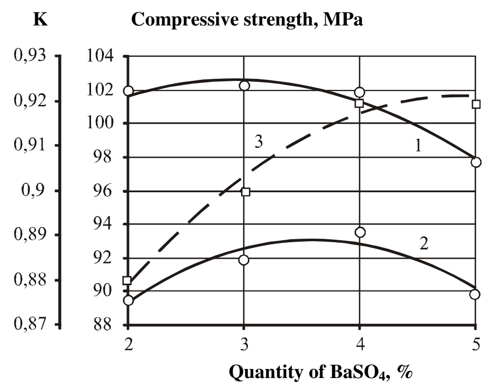

Fig. (5). Impact of $BaSO_4$ quantity on *RubCon* compressive strength operated in no aggressive environments (line 1), compressive strength (line 2) and resistance coefficient (line 3) after 90 day's exposition into 36% solution of HCl.

Chemical Resistance of Steel Fiber Reinforced *RubCon*

Corrosive environments were: water, 70% solutions of sulfuric acid, 5% solution of phosphoric acid, 36% solution of hydrochloric acid and 25% water solution of ammonia. Chemical resistance of fiber reinforced *RubCon* was estimated on testing specimens in the size 4x4x16 cm at exposure during 180 and 360 days at intermediate terms of 10, 30, 60, 90, 180 and 270 days.

Three samples of *RubCon* were made for each term of exposure. Before immersing in medium samples were measured and weighed. After reaction of corrosion reagents with *RubCon* the samples were taken out from exiccators, dried by filtering paper and put on compression test with speed 60 MPa/min.

Experimental curves of the mass transfer and chemical resistance of fiber reinforced *RubCon* samples are illustrated in Fig. (**6**).

The analysis of the obtained results shows, that fiber reinforced *RubCon* is a composite hydrophobic material with coefficient of water resistance K_{cr}= 0,995. Decreasing of compressive strength was not observed and water absorption was 0,05 % on weigh of samples. The small change of weight is due to surface hydrophobic of *RubCon* by which polybutadien binder intrinsical properties is not moistened with water. Furthermore, polybutadiene oligomer is non-polar liquid.

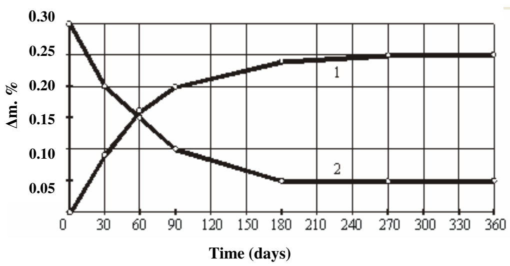

Fig. (6). 1- Water absorbing of fiber reinforced *RubCon*; 2- Coefficient of water resistance depending on exposure duration into water.

A reduction of the physical-mechanical properties of *RubCon* samples in the first day of an exposition is connected with penetration of water into *RubCon* body through micro pores and micro cracks. As this take place mobility of structural elements and pressure in tops of micro cracks increase resulting in a lowering of intermolecular binds and decrease of strength.

Carried out researches have shown that water has little or no effect on decrease of strength and change of a material structure; in other words, influence of eater on efficiency of *RubCon* structures is insignificant. Destructive action of acids is caused by their nature, concentration, pH of water solutions, the presence of oxidizing properties, temperature of environment and solubility of formed corrosion products at their interaction with polymer concretes and steel reinforcement.

Alkaline environments destroy the majority of composite building materials based on organic matrix. Water solution of ammonia was chosen as the aggressive media. Ion of ammonium NH_4^+ arises from dissolution of ammonia in water with the resulting formation of a hydroxide NH_4OH.

Results of the experiments are illustrated in Table **6** and Figs. (**7**, **8**).

One can see that after 180 days of exposure of *RubCon* into aggressive environments its compression strength decreased: in 36%-th solution of a hydrochloric acid on 22%, in 5%-th solution of a phosphoric acid – 8 %, in 70%-th solution of a sulfuric acid on 7 %, in 25%-th solution of NH_4OH on 16%.

Destruction of polymer binder is caused by the action of inorganic acids produce rupture of polymer macromolecules with the resulting increase of deformability and decrease of composite strength. Visual inspection of the samples after 180 days exposure into inorganic acids show, that steel fibers are not protruded, the surface of the samples immersed into 36 %-th solution of a hydrochloric acid had strongly changed painting.

The analysis of obtained results show that strength of the *RubCon* samples immersed in inorganic acids increases during the first 10 days (Table **6**). For this period, compression strength raised: in 36%-th solution of a hydrochloric acid on 7%, in 5%-th solution of a phosphoric acid – 9%, in 70%-th solution of a sulfuric acid on 8 %.

Increase of the *RubCon* samples strength in an initial stage of interaction with the liquid aggressive environments is due absorption of a liquid phase by structural micro defects that are responsible for superficial compacting. During the long action of aggressive environments-oxidizers: mineral acids (hydrochloric, phosphoric concentrated sulfuric), alkalis etc. the deep structural changes occur in composites worsening their operational properties. Destruction of the polymeric binder and rupture of adhesive bonds cause decrease of polymer strength.

Action of ***sulfuric acid*** on *RubCon* is accompanied by insignificant reduction of masses of the samples in the first exposition days; however in process of dissolution of steel fibers masses absorption process becomes obvious. At this place hydrogen sulphide and sulphurous anhydride are realized and do possible process sulfiding.

Firm thermoplastic mass identical on structure to initial rubber but with the smaller content of double bonds is developed under the influence of the concentrated sulfuric

Table 6. Physical-Mechanical Properties of *RubCon* Samples at Action of Inorganic Acids and Solutions of the Alkalis

Corrosive Media	Indexes	Time of Exposure Days					
		0	10	30	50	90	180
36 %-th solution of HCl	Δ *m*, %	0	-0,09	0,021	0,052	0,234	0,526
	K_{cr}	1	1,07	0,98	0,915	0,85	0,78
70 %-th solution of H_2SO_4	Δ *m*, %	0	-0,02	0,023	0,031	0,13	0,26
	K_{cr}	1	1,08	1,026	0,974	0,94	0,93
5 %- th solution of H_3PO_4	Δ *m*, %	0	-0,05	0,01	0,033	0,064	0,11
	K_{cr}	1	1,09	1	0,947	0,93	0,92
25 %-th solution of NH_4OH	Δ *m*, %	0	0,002	0,05	0,063	0,107	0,22
	K_{cr}	1	1,01	0,96	0,925	0,88	0,84

acid. Decrease of quantity of double bonds in a rubber molecule structure leads to decrease strength parameters of vulcanizates.

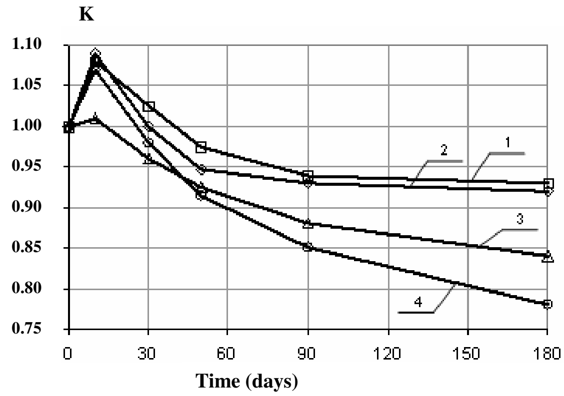

Fig. (7). The coefficient chemical resistance dependence of the exposure time; **1** - 70 %- solution of H_2SO_4; **2** - 5 %- solution of H_3PO_4;**3** - 25 %- solution of NH_4OH; **4** - 36 %-solution of HCl.

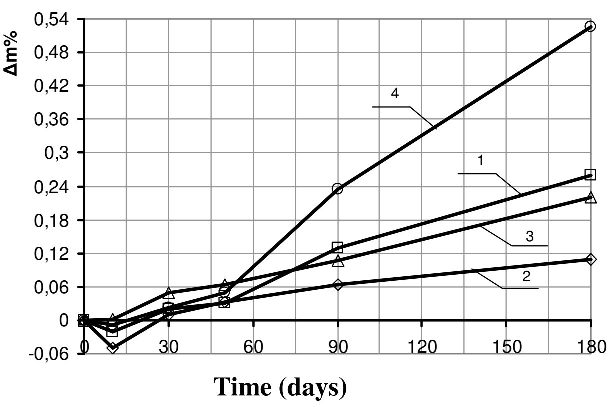

Fig. (8). Kinetics of mass-absorption of *RubCon* : **1** - 70 %-th solution of a sulfuric acid; **2** - 5 %-th solution of a phosphoric acid; **3** - 25 %-th water solution of ammonia; **4** - 36 %-th solution of a hydrochloric acid.

The ***hydrochloric acid***, dry and damp chlorine cause fast destruction of the most rubbers irrespective of type of filler. Chemical resistance of ebonites i.e. high filled composites on the rubber base (including *RubCon*) to the influence of a hydrochloric acid is rather high that permit their application for corrosion protection of building structures and articles. It is worth noting that at an early stage of interaction the acid with *RubCon* samples process of mass absorption damps. In this case, processes of oxidation and isomerization are observed; products of chlorination layer are produced on ebonite surface which inhibits the penetration of the material into the aggressive media. Therefore, service life of the composite depends on the speed of chlorination and oxidation processes and density of the powders formed on it surface.

Mass absorption process of *RubCon* samples immersed in ***phosphoric acid*** goes more slowly because low penetration ability of the acid.

Thus, decrease in physical-mechanical characteristics of *RubCon* under the action of inorganic acids is caused by various speeds of chemical reactions, such as corrosion, oxidation, sulfiding, chlorination etc. Processes of oxidation and depolymerization proceed with formation of the low-molecular compounds containing hydroxyl and carboxyl groups. Process of oxidation has the branched out character.

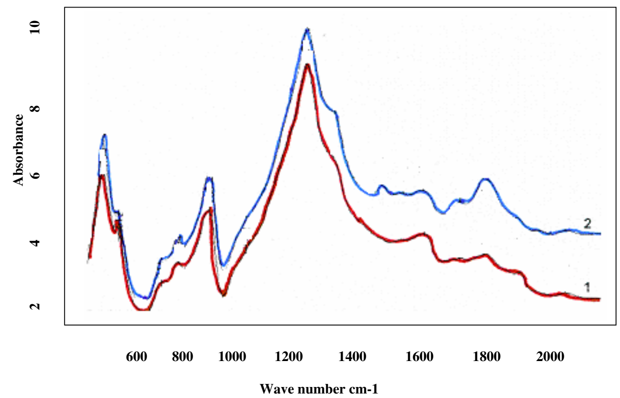

Fig. (9). Specters of *RubCon*: 1- before γ-exposition, 2- after γ-exposition.

Intensive destruction of the rubber based polymer under the effect of ***alkalis*** occurs, due to formation of an unstable complex which is breaking up with regeneration of initial substances and the following insignificant isomerization. It is believed that the nitrogen containing in 25 %-th water solution of ammonia will form nitrocompounds which at interaction with vulcanizate initiate process nitriding with the resulting destruction of a polymeric chain.

Effect of γ –Radiation on Corrosion Resistance of *RubCon*

Rapid growth of nuclear power has brought to a major problem of storage and burial of radioactive waste products. Now, over 250,000 tons of the exhausted nuclear fuel is accumulated in the world. In this connection, creation of the new radioactive resistance structural materials intended for protection, storage and, burial of radioactive waste products are rather actual. Application of *RubCon* for protection against radiation in space enclosing structures of radioactive waste products storehouses is discussed below.

Effect of γ-radiation on the *RubCon* structure was studied by infrared spectroscopy in area 4,000-400 cm^{-1}. Specters of the *RubCon* samples demonstrate the essential changes of the material structure after γ-radiation exposition (Fig. **9**) [8,9].

The joint action of the *chemically aggressive environments* and ionizing radiation was experimental studied. Absorbed dose of γ-radiation was 5 Gy; prevalence of the aggressive environment was its selection criterion, results of experimental investigation are demonstrated in Table **7**.

The analysis of experimental data has shown (Table **7**) that *RubCon*, displays universal chemical stability and keeps it after γ-radiation exposure. Coefficients of chemical resistance of *RubCon* were above 0,8 in all environments except for 36 % solution of hydrochloric acid where it was equal 0,69

Table 7. Effect of γ-Radiation on the Coefficient of Chemical Resistance of *RubCon*

Aggressive Environment (1 Year Exposition)	Coefficient of Chemical Resistance		
	Before γ-Radiation K_0	After γ-Radiation K_1	(K_0-K_1) 100%
70 % solution of a sulfuric acid	0.920	0.920	0
5 % solution of a phosphoric acid	0.935	0.900	-3.7
3% solution of nitric acid	0.810	0.800	-1.2
36% solution of a hydrochloric acid	0.690	0.690	0
5% solution of an acetic acid	0.816	0.780	-4.4
10% solution of a lactic acid	0.950	0.940	-1
10% solution of a citric acid	0.873	0.870	-0.3
25% water solution of ammonia	0.815	0.790	-3.1
10% solution of caustic sodium	0.871	0.820	-5.,9
10% solution of potassium hydroxide	0.910	0.900	-1.1
Saturated water solution of sodium chloride	0.957	0.950	-0.7
30% solution of copper sulfate;	0.835	0.816	-2/3
Acetone	0.881	0.830	-5.8
Diesel fuel	0.878	0.850	-3.2

The further researches have shown, that replacement of granite rubble by quartz sand has allowed raising coefficient of chemical resistance of *RubCon* up to 7% in 36% solution of hydrochloric acid.

CONCLUSION

- *RubCon* offers the universal chemical resistance many times higher than ordinary Portland cement concrete and surpasses of chemical resistance of polyester, polyepoxy and vinyl ester polymer concrete.
- The most intensive decrease of *RubCon* strength occurs during the first 6 months of the corrosion environments exposition.
- Destruction of polybutadiene under the action of inorganic acids is caused by oxidation of a macromolecule of polymer and depends on the speed of this process course. In other words cross-section links of a spatial composite network formed by vulcanization process are broken.
- Elevated temperature (up to 60˚C) insignificantly reduces the chemical resistance of *RubCon* samples and leads to their destruction due to acceleration of chemical reactions between the corrosion environment and a material.
- Chemical resistance coefficient of *RubCon* operating in aggressive environments during 10 years exceeds 0.5. Obtained data allow appointing the thickness of the concrete cover of a reinforced *RubCon* structure.
- Additives make possible to improve physical-mechanical properties of *RubCon* and its resistibility to the corrosive medium Optimum quantity of the sulfur + tiuram-D and altax additives in the *RubCon* composition is 4.45% and 0.28%, correspondingly. Optimum quantity of the TiO_2 or $BaSO_4$ additives in the *RubCon* composition is 2.3% and 3.6%, correspondingly.
- Fiber reinforced *RubCon* is chemical resistance material.
- *RubCon*, displays universal chemical stability and keeps it after γ-radiation exposure.

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