UDC 666.96; 691.54

Kh.Sobol, Z.Blikharskyy*, V.Terlyha
Lviv Polytechnic National University,
Department of highway
*Department of building structures and bridges

OPTIMIZATION OF OIL-WELL MIX COMPOSITION WITH ZEOLITIC TUFF ADDITIVE FOR BOREHOLE CEMENTATION

Selection of oil-well mortar composition by the method of orthogonal central-compositional planning is implemented. Optimum content of the additives, such as cellulose ester and basalt fiber in the mix composition was determined.

Key words: dry oil-well mix, mathematical planning, zeolitic tuff, dehydration, bending tensile strength of mortar

Здійснено вибір складу тампонажного будівельного розчину за методом ортогонального центрально-композиційного планування. Визначено в складі суміші оптимальний вміст добавок, таких як складник целюлози і базальтове волокно.

Ключові слова: сухі будівельні тампонажні суміші, математичне планування, цеолітовий туф, зневоднення, міцність на згин розчину

Problem statement. Oil-well cementation technology has been developed on the basis of long-term practical experience and improved by the latest achievements of science and technology. At present it includes the system of elaborated performance requirements for implementing the cementitious works, as well as typical schemes of the cementation process organization. In each particular case cementitious technology requires elaboration depending on the construction and the state of the borehole, the length of cemented interval, ore-geological conditions, maintenance support and the experience in fulfilling the cementation works in each particular region, which, in turn, demand accurate composition selection of oil-well mortar [1,2].

Stratum detachment in existing technology of bore hole shoring is the completing and the most important stage the quality of which is responsible for successful bore hole building. Stratum detachment means the complex of the processes and operations which are implemented for pumping the oil-well mix into the casing string-borehole annulus (i.e. the space behind the casing) to create there reliable isolation in the form of solid-core material which is created in time as a result of oil-well mortar hardening. As the cement mortar is used most widely in the capacity of the oil-well material, the works concerning the bore hole casing are indicated as “cementation” [3].

Analysis of the latest research works and publications. The latest concerns related to bore hole casing evidence the necessity to pay more attention to sedimentation resistance of the system. Modern plugging materials must have zero dehydration characteristic and low water loss (up to 150 cm^3 at 30 min. for materials relieving). Implementing of these conditions provides minimum filtrate influence on the stratum producing capacity, picking up the plugging mortar on the necessary height in the casing annulus and formation of strength and leakless cement hoop for the whole time of the borehole operating [4, 5].

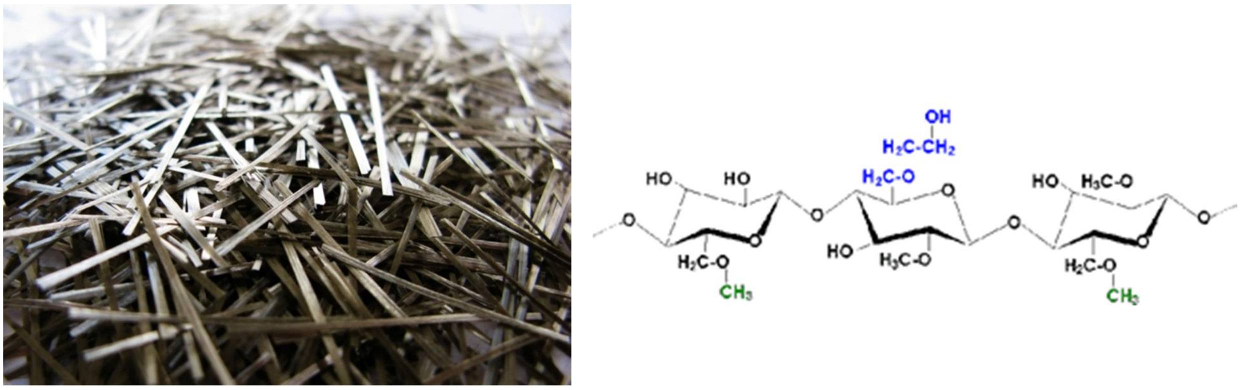
Cement stone behind the casing must be characterized by high strength and leakless, have good adhesion with the casing surface and with the walls of well bore. High demands to the cement stone are stipulated by its function diversity, that is dense filling of the space between the casing and wellbore walls, isolation and detachment of capacity oil-and-gas horizons and penetrating stratums, preventing of oil or gas spreading in annulus space under the formation pressure, casing fixation in the mountain massive, casing protection from stratal water corrosion influence and some relief from outer pressure. It should be mentioned that the role and significance of the cement stone are constant for the whole period of the borehole operation, therefore, the very high requirements concerning the resistance to negative factors influence are imposed to it [6].

Objective of the research: mathematical optimization of the dry oil-well mix for cementation of the bore holes with low and normal temperature.

Research techniques and materials. Oil-well mixes obtained on the basis of Portland cement CEM I-500-H of JSC "Ivano-Frankivskcement". Zeolitic tuff of Sokirnycky deposit from Zakarpatska oblast was used as mineral component [6].

Methylhydroxyethyl cellulose, which is the product of substitution of hydrogen atoms from hydroxyl groups for alkyl or acid remains, was used to decrease the processes of sedimentation. The properties of methylhydroxyethyl cellulose depend on substitution rate, radical nature and the polymerization degree that also influences the initial strength of the mixes on the cement basis.

To increase the cement stone strength, basalt fiber was used. Production of the latter is based on obtaining of basalt melt in melting furnace and its free weaving through special devices produced from platinum or high-temperature metals. The end product of this are the short fiber pieces aimed at dispersion reinforcement of cementitious mixes. Fiber diameter is from 20 micron to 500 micron, length from 1 micron too 150 micron. In the research the fiber diameter of which was 60 micron and the length was 5 mm. The properties of the plugging material were investigated according to existing standards and procedures.



a (x20) *b*

Fig. 1. Photograph of basalt fiber (a) and formula of Methylhydroxyethylcellulose (b)

Results of investigations. Earlier implementing experiments showed that introduction of zeolitic tuffs results in decreasing of plugging mix strength in initial terms of hardening, but from the 28-th day the strength begins to increase gradually [7]. It could be explained by the interaction of active SiO_2 and Al_2O_3 with $Ca(OH)_2$ which releases during alit hydration (Table 1). That is why it is reasonable to introduce such zeolite in quantity of 30 %, which will provide the necessary initial strength of the mix and results in increasing of cement stone strength in long-term periods of hardening.

Table 1

Influence of zeolitic tuffs on the strength of oil-well mortar in different hardening periods

Composition	Content of components, mass. %		Bending tensile strength of mortar, MPa	
	Portland cement CEM I	Zeolitic tuff	2 days	28 days
1	90	10	1,71	2,21
2	80	20	1,34	1,90
3	70	30	1,15	1,71
4	60	40	0,69	1,62
5	50	50	0,65	1,50

To increase the cement mix sedimentation resistance and strength of oil-well mortar, the additives of cellulose esters and basalt fibers were introduced into the system. To determine the optimal quantity of modified chemical additives, mathematical planning of the experiment was elaborated. At that one of the methods of statistical data processing was used, i.e. the method of orthogonal central-compositional planning (OCCP). Characteristics of planning of the experiment is shown in Table 2

Table 2

Characteristics planning of the experiment

Characteristics	Planning options	
	Basalt fiber mass. % (X_1)	Cellulose esters mass. % (X_2),
Main level "0"	0.06	0.08
Variance interval	0.03	0.04
Low level "–1"	0.03	0.04
Upper level "+1"	0.09	0.12

When realizing the planning of the experiment, the following parameters were chosen: Y_1 – water-solid ratio; Y_2 – dehydration, ml; Y_3 – bending tensile strength of mortar at hardening temperature 22˚C, MPa; Y_4 – compressive strength of mortar at hardening temperature 22˚C, MPa.

Calculation of regression coefficients was realized according to special programme on EXSEL. Matrix approach to regression analysis and the regression coefficients finding was used.

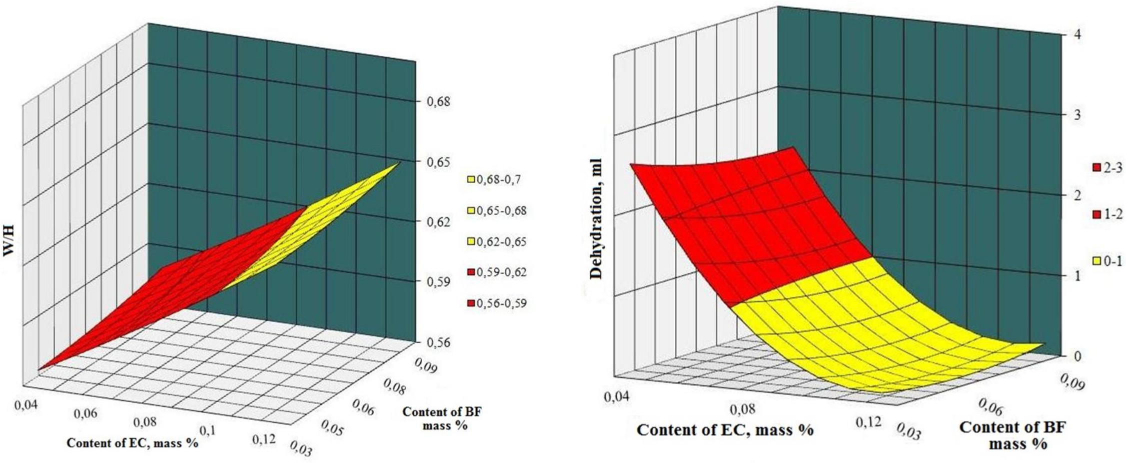
The results of regression coefficients calculation are shown in Table 3. On the basis of these coefficients the regression equations of the functions of the investigated properties of plugging cement were formed (Y_1, Y_2, Y_3, Y_4).

Table 3

Regression equation coefficients

Response function	Regression coefficients					
	$в_0$	$в_1$	$в_2$	$в_{12}$	$в_{11}$	$в_{22}$
Y_1	0.605	0.005	0.035	0	0.001	0.001
Y_2	0.5	-0.1	-1.166	0.1	0.1	0.7
Y_3	1.111	0.088	-0.198	0.025	0.038	0.008
Y_4	3.986	0.28	-0.493	-0.097	0.12	0.33

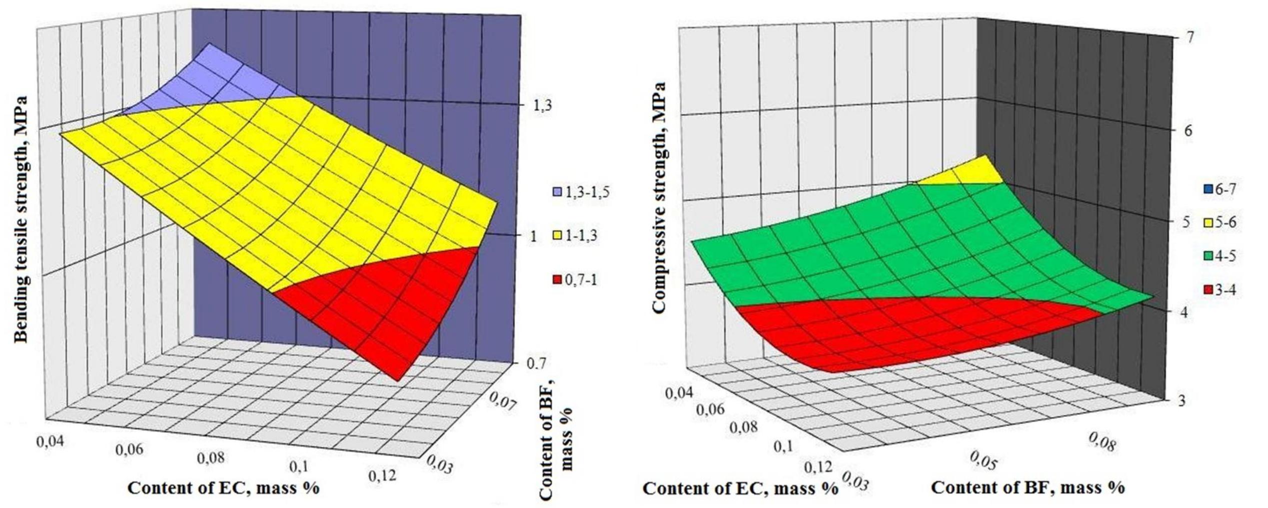
The lowest influence of the filtrate on the productive stratum is achieved by maximum stabilization of the plugging mix. Just for these purposes the additives of cellulose esters are used. By mathematical planning of the experiment it is established that optimal content of this additive is 0.1 %, what allows decreasing dehydration of the oil-well mix almost to zero (fig. 2, b). It should be mentioned that this additive influence substantially on the water-solid ratio (increasing of water content with the aim to save the given spreadability) which decrease negative influence on the structure and strength of the mix (fig.2, a).



a) *б)*

Fig. 2. Response surface of water-solid ratio and water loss of the oil-well mix

Creating of strength resilient carcass in annulus space is one of the basic requirements to reliable isolation of the boring casing from the zones with penetrating stratums. Investigation concerning the characteristics of the oil-well mix shows reasonability of adding of basalt fibers as reinforcing components of the system. As for example, introduction of them in quantity from 0.06 to 0.09 % allows to increase oil-well mix strength both at bending tensile strength, and at compression almost half as much again (fig. 3 a,b).



a) *б)*

Fig. 3 Response surface of bending tensile strength (a) and at compression (b) light-weight of the oil-well mix, hydrated 2 days at 22 ˚C

Adding of reinforcing fibers into the plugging systems smoothes the negative effect of strength decreasing that is provoked by cellulose esters usage, and dry and then wet mixing of given components in mix composition promote creating the system with the stable characteristics in time.

Summary

The main requirement of the mathematical planning methods application and data processing is decreasing of the number of experiments with obtaining at the same time the necessary results. By orthogonal central-compositional planning of the experiment, optimal content of the additives of basalt fiber and cellulose ester in the composition of oil-well mix included zeolite was determined. Combined introduction of these additives in quantities of 0.1 % cellulose ester and 0.09 % of basalt fiber provides formation of the system with good sedimentation resistance, which during the hardening process turns into the stone of specified strength.

1. Bulatov A. Y., Proselkov Ju. M., Shamanov S. A. Tekhnyka y tekhnologhyja burenyja neftjanыkh y ghazovыkh skvazhyn. // M.: OOO «Nedra-Byznescentr». – 2003. – 1007 s. 2. V. Terlyha, Kh. Sobol, B. Tershak Modified oil-well cements for casing boreholes with abnormally low stratum pressure // 18-th international conference on building materials “18.Ibausil”. – 12-15 September 2012. – Weimar. 3. Kockulych Ja.S., Kochkodaj Ja.M. Burinnja naftovykh i ghazovykh sverdlo¬vyn. – Kolomyja: Vik. – 1999. – 504 s. 4. Erik B. Nelson, Dominique Guillot Well cementing: Second Edition // Sclumberger Educational Services – 2006. – ISBN-10:0978853008. 5. Vojtenko V.S., Vitryk V.Gh., Jaremijchuk R.S., Jaremijchuk Ja.S. Tekhnologhija i tekhnika burinnja: uzaghaljnjujucha dovidkova knygha. – Ljviv: Centr Jevropy. 2012. – 708 s. 6. Franus W.: Zastosowanie zeolitow wytworzonych z popiolow lotnych do usuwania zanieczyszczen z wody I sciekow. Polska Akademia Nauk, Lublin 2012. 7. V. Terlyha, Kh. Sobol Tamping mortars with stabilizing and plasticizing admixtures // SSP – Journal of civil engineering. – Kosice, 2012. – Volume 7, Issue 1. – p. 87-94