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BUFFER PLUGGING SYSTEMS – ADVANCED DIRECTION FOR NATURAL ZEOLITE APPLICATION

Influence of flushing fluid on the quality of casing cementation of Romenska deposit group in Dniprovska-Donetska depression has been concidered. Comparative studies of technological characteristics of buffer plugging systems with micro silica additives DBM-1 and natural zeolits DBM-2 and influence of the mix on cements to microstructure formation were carried out. Operational experience and findings obtained by industrial application of buffer plugging systems of different composition during the process of bore holes building at Anastasivska deposit PAT “Ukrnafta” have been presented.

Key words: buffer plugging systems, borehole, flushing fluid.

Розглянуто вплив промивної рідини на якість цементації родовища Роменська в Дніпровсько-Донецькій долині. Наведено порівняльні дослідження технологічних характеристик тампонажних систем з мікрокремнезему – добавки DBM-1 і природного цеоліту DBM-2 і вплив суміші на цемент та формування мікроструктури. Висвітлено досвід роботи і результати, отримані промисловим застосуванням буферних систем різного складу в процесі буріння свердловин на Анастасівському родовищі ПАТ “Укрнафта”.

Ключові слова: тампонажні системи, свердловина, промивка рідиною.

Problem statement. In practice of oil and gas boreholes building, the term “buffer pluggin gsystems” means the materials which are used in the borehole to separate the plugging mortar from flushing and squeezing fluid. During the borehole cementation, buffer systems are performing the next functions:

– separation of flushing fluid and plugging material top revent their mixing in pipe sand annular space;

– washing-out of the flushing fluid from annular space of the borehole and its displacement from cavities and enlarged sections;

– destruction, in case of need, of filter cake with carrying out its partto the surface;

– creation conditions for reliable contact of the plugging stone with the borehole wall sand the casing;

– decreasing the sizes of liquid mix ingrate as intended to reduce the plugging mortar expend it ure with use of optimum volumes of flushing fluid.

Use of buffer liquid is an obligatory element of package of measures intended to provide the high quality sweep out of flushing fluidf romannular space and destruction of filter cake from the borehole walls. The problem of high effective buffer systems application is especially urgent for Romenska deposit group in Dniprovska-Donetska depression (DDZ), including Perekopivska, Anastasivska, Korzhivska and Artukhinska where it is noted the alternation of closely spaced deposits with different pressure – water-saturated (B-18) with anomality coefficient 1.05 and oil-and-gas saturated (B-19) with anomality coefficient 0.57. At the same time, the flushin gfluid at the moment of casing cementation contains from 13% to 20% of oil which waterproofing the borehole walls and casing surface worsening sufficiently the conditions of well casing.

Analysis of the latest research works and publications. Process water, plugging mortar kneading liquid, salt a queous solutions, aqueous solutions of surfactants and different water-soluble polymer sand other shave been the most active lyused as buffer liquids at DDZ deposits during boreholes cementation.

These liquids have some drawbacks, the main of which is that kneading area may include from 33 to 75% of volume of the the injected plugging mortar. The cements tone formatted in such conditions cannot ensure the necessary operating level of reliability of the borehole fastening as the engineering installation[1]. Determined by geophysical investigations (method “Burennije”, Russia) coefficient *K* of cementation quality of operating colomns is the example:

$$K = \frac{100\sum_{i=1}^{n} \mathbf{l}_1 + 200\sum_{i=1}^{n} \mathbf{l}_2 + 300\sum_{i=1}^{n} \mathbf{l}_3 + 400\sum_{i=1}^{n} \mathbf{l}_4}{L_ц}$$

where $L_ц$ – length of cementated section, m;

$\mathbf{l}_1, \mathbf{l}_2, \mathbf{l}_3, \mathbf{l}_4$ – length of cementated sections relatively with no contact, bad contact, partial contact and sealing contact, m. At: *K*> 300 – good quality; *K* = 200 – 300 – satisfactory quality; *K*< 200 – unsatisfactory quality.

So for the first (lower) sections of the operating colomns in the borehole No.162 (cementation interval 2900 – 4660 m) and № 165 (cementation interval 2900 – 4947.9 m) of Anastasivska deposit even in conditions of nominal borehole, coefficient *K* is respectively 226.4 and 273.1. At that amount of the sections with “no contact” makes respectively 46.08 % and 33.67 %.

There fore buffer system on the basis of the plugging mortar kneading liquid especially at hightened content of oil in the borehole solution can not provide the effective casing cementation.

In Ukraine among some other structural buffer liquids there had been aprobated with different success the system MUDPUSH II from the company Schlumberger" (certificate № 38-Perekopivska) and the buffer mixture from RPE "Specmaterialy" (certificate № 34- Lopushnyanska). Disadvantage softhese buffer liquids concern unsufficient stability, high cost and difficulties with their preparing field conditions, especially at the temperatures below 0 ^{o}C.

As analternative to above mentioned materials, authors of the presented publication have developed the dry stabilized buffer mixes (DBM-1 and DBM-2) compositionally designed according to contemporary worldtend sofborehole building taking into account peculiarities of oil-and-gas deposit boreholes buildinginUkraine and being in accordance with the requirements related with the principle of “technological tandem”, i.e. providing maximum compatibility with the typical flushing liquids and plugging materials. DBM-1 contains up to 50 % of ground sandand СБС-2 contains up to 50% of zeolite.

Objective: Study of the experience of use of zeolite additive in plugging buffer systems intended for cementation of the Romenska group DDZ deposit boreholes.

Research methods and materials. In the research there were used plugging buffer systems СБС-1, СБС-2 [2], the buffer mixture MUDPUSH II from "Schlumberger", expanding plugging mixEPM-150 LF [2], and composite plugging systems PM-100 LF [2].

Researches of technological properties of plugging cement and composite plugging systems were implemented inaccordance with the requirements [2], SOU 11.2-0013590:2012 «Borehole for oil and gas. Order of receiving, keeping of cement, selection of formulation and preparing of the plugging solution”, SOU 11.2-00135390-001:2009 «Parameter control of borehole flushing liquids”.

Micro structure of preparated patterns and photographs of cleaved facets of cement plugging stone in different terms of hardening, and micro zond spectral analysis were made on scanning electronic microscope PEMMA-102-02 and NOVA NanoSem 230.

Casing cementation quality was studied by the method of geophysical acoustic cement-bond logging (ACL) by production run equipment AKB-1 and with radial acoustic cement bond log sonde RBT (Sondex).

Findings of the investigations. Basic formulations of plugging buffer systems both СБС-1, СБС-2 and MUDPUSH II have practically the same structural and rheological properties, zero waterloss and low filtration characteristic satsatisfy pumpability (spreadability not less than 200 mm) (table 1).

Table 1

Comparativetechnological characteristics of plugging buffer systems

Indicators	Type of plugging buffer system		
	СБС-1	СБС-2	MUDPUSH II
Density, kg/m^3	1640	1580	1640
Spreadability, mm	200	210	195
Water loss, ml	0	0	0
Filtration inicator, cm^3 at 30 min.	8	6	8
Plastic viscosity, mPa·s	65	68	28
Dynemic shear stress, dPa	302	301	259.2
Washing capasity, %	49	65	15
Costfor 1 m^3, Hrvn	2410	2450	9100

Table 2

Compatibility test results for СБС-1,2 and typical flushing liquids

Type of borehole solution	Suspension sreadability by cone (T =22ºC), mm	Ratio of flushing liquid to stabilized buffer mixture	Sreadability (DBM-1/DBM-2), mm	
			T =22ºC	T =50ºC
СБС		–	200 / 205	210 / 210
Polymer -potassium ρ = 1160 kg/m^3, T = 50 c B = 4 cm^3 at 30 min. СНЗ$_{1/10}$ = 35/65 DPa	250	1:9	230 / 220	235 / 230
		1:1	235 / 220	240 / 230
		9:1	245 / 230	250 / 235
Lignosulphonate ρ = 1160 kg/m^3, T = 45 s B = 6 cm^3 at 30 min. СНЗ$_{1/10}$ = 30/65 DPa	250	1:9	230 / 235	240 / 240
		1:1	235 / 240	250/ 245
		9:1	240 /235	250 / 245

Compatibility test results of "borehole solution – buffer system" (Table 2) and "plugging solution - buffere system" (Table 3) in different ratios evidence the complete tolerance of DBM-1 and DBM-2 with typical borehole liquid sand plugging systems which have been used during boreholes building of Romenska deposit group from DDZ. In significant increase inspreadability from 9,5 to 18 % and jelling time variation from – 4,2% до + 20,1% were noted, which is acceptable for the casing cementation conditions and have allowed to recommend the designed buffer systems for industrial testing.

Table 3

Compatibility test results for plugging systems

№	Pluggingsolution(composition,, density)	Pluggingsolutionto stabilized bufferesystem ratio	Thermo baricconditions		Jellingtime of the mixture(Pluggingsolution+ buffersystem, СБС-1/ СБС-2), h.-min.
			temperature, ºC	pressure, MPa	
1	ТС-100 – 100 % НТФК – 0.03 % * W/C – 0.5 ρ = 1810 kg/m^3	–	50	30	4-00 / 4-00
		1:9	50	30	4-40 / 4-30
		1:1	50	30	4-20 / 4-35
		9:1	50	30	3-50 / 4-00
2	РТС-150ПВ – 100% Пластифікатор – 0,2 % НТФК – 0.08% *W/C– 0.48 P=1810 kg/m^3	–	90	82	5-15 / 5-15
		1:9	90	82	6-15 / 6-20
		1:1	90	82	6-00 / 5-50
		9:1	90	82	5-40 / 5-45

* W/C – water – cement ratio

Comparative industrial testing of the designed systems during cementation of low sections of operating colomns was implemented in the boreholes No. 170 andNo. 160 at Anastasivka deposit. Formation selection for the first (PM-100 LF, DBM) and the second (EPM-100 LF) portions of pluging materials were performed in accordance with thermobaric and technico-technological peculiarities of cementation (Fig. 1 and 2 respectively), that is static temperature 118°C, dynamic temperature – 100°C, pressure 65 MPa, operation durability 6-00 hours, operational shutdown at 70°C and pressure 32 MPa – 1 hour 15 min.

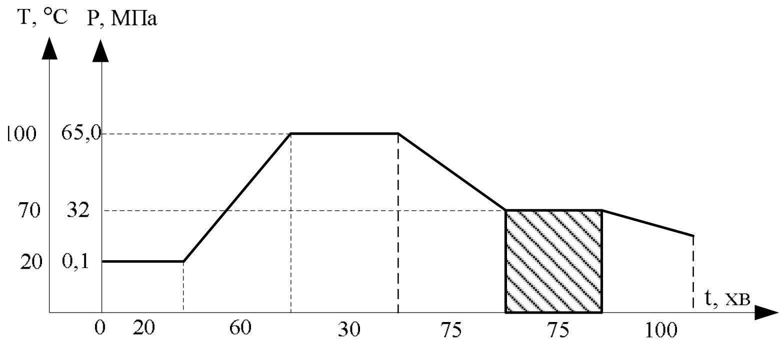

Fig. 1 –Pogrammeof PM-100 LF, DBM - 1,2 testing

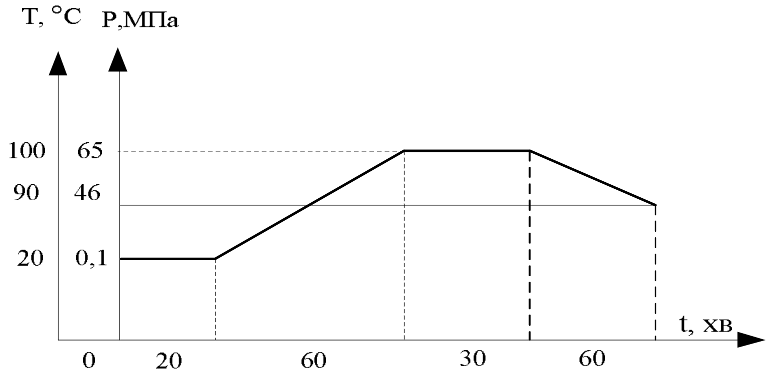

Fig. 2 – Pogrammeof EPM-100 LF

Table 4

Technological properties of plugging systems

Type of material	Suspen-sion density, kg/m^3	Suspen-sion sprea-dability, mm	Testing Conditions		Terms of setting hours-min.		Jelling time, h.-min.	Water loss, ml	Water dehydration after thermostating, cm^3/30 min	Bending tensile strength, MPa	Stone linear expan-sion, %
			tempe-rature , °C	pressure, MPa	Initial set	Final set					
ТС-100 ПВ	1820	250	100/70	65	11-40	12-00	6-00	0	32	3.7	–
РТС-150 ПВ	1840	220	118/ 100	65	3-30	4-00	2-50	0	22	5.3	4.5
СБС-1	1640	210	100	65	–	–	–	0	18	–	–
СБС-2	1560	220	100	65	–	–	–	0	16	–	–

Structural and technological properties of plugging and buffer suspensions and physical and mechanical properties of cement stone (Table 4) were designed in comformity with the borehole casing conditions. Technological processs of cementation was realized according to the special hydraulic programme Turbo Cem-1. During cementation of the borehole No. 160 Anastasivska, at the beginning the preparation works and pumping of the stabilized buffer mixture (8,6 m^3in volume) were performed. In the process of kneading of the first batch of plugging material on the basis of ТС-100ПВ, mortar with the density 1750 – 1840 kg/m^3 was obtained. After homogenization in averagind tank, 23 m^3 of pluging mortar (ТС-100ПВ) with density 1830 kg/m^3 (Q = 12 – 20 l/s, P_y = 4,0 – 3,0 MPa) was pumped into the borehole. Then there was prepared and pumped the second batch of the cement mortar on the basis of РТС-150ПВ with density 1850 kg/m^3 and volume 39 m^3. Pumping was carried out at pressure 4,0 – 0 MPa with productivity cement machine 5 – 25 l/s. After 5 min. operational shutdown, the second buffer (kneading water) of 0.2 $м^3$ in volune (Q = 5 – 10 l/s, P_y = 0 – 10 MPa) was pumped into the borehole for releasing the rubber ball. And then the plugging mortar 2 m^3 in volume (Q = 8 – 10 l/s, P_y = 0 MPa) for opening the liner tie-back packer. Pumping of the second batch of buffer liquid (kneadingwater) 1.9 m^3 in volume (Q = 20 – 26 l/s, P_y = 1,0 – 2,0 MPa) was performed. Pumping of pushing liquid 17.4 m^3 in volume – borehole solution with density 1200 kg/m^3 and productivity 20 – 30 l/s was implemented; the pressure during the pushing was 4,0 – 6,0 MPa. Pumping of the third batch of buffer liquid (kneadingwater) 2.3 m^3 in volume (Q = 20 – 15 l/s, P_y = 6, – 7,0 MPa) was performed. Pumping of 26 m^3 of pushing liquid with density 1200 kg/m^3 (Q = 20 – 4 l/s, P_y = 7 – 13 MPa) was done. During the Pumping of the last 2 m^3 of pushing liquid, productivity cement machine was reduced to 4 l/s to prevent hydroblow when receiving the signal “stop”. Total pushing volume made 49,8 m^3. The pressure at the signal “stop” receiving made 21,0 MPa. After this the works with packer «PAYZONE», which is situated in the interval 4513 – 4506.9 m (work surface), were done.The pressure was increased up to 29 MPa with holding for 2 min. The segregator windows were opene and the residue of the plugging mortar behind casing were washed (Q = 30 – 35 l/s, P_y = 12 – 13 MPa). Flushong liquid volume made –130 m^3. During the cement residue washing, distinct demarcation of borehole mortar – buffer liquid – plugging suspension was fixed. On the borehole well head the buffer solution which is characterized by increasing structure-rheological parameters with the particles of clay cake and sufficient content of slime (Fig. 3), and 4 m^3 of gelcement with density 1600 – 1760 kg/m^3 was hovered.

Fig. 3 – Photograph of the fragment of slime material pushed by buffer mixture DBM-2

Pushin gupslime is related to Vizejsky deposit and is presented by lots of dark-grey fragments of argilite. There were noted the splinters of bituminous substance, bit insert sofmica, large grain sofquartz, fragments of sandstone, green filite fragments, iron and red arglilte oxides, and micro reinforcing fibers.

During the process of cementation of the borehole No. 160 Anastasivska, two samples of plugging material were picked up. The first of them was formated from plugging suspension PM-100 LF, homogenized in averaging tank. The second sample was the gel cement with density 1740 kg/m^3, which was obtained on the daylight surface just after completing the “outwashing”of the mixture DBM from the borehole. The stone formation at the temperature 22 ^oC and pressure 0.1 MPa lasted 28 days.

Formated samples were investigated by the of x-ray diffraction method on the automatical difractometer STOE STADI P (production of «STOE & Cie GmbH", Germany) with the linear position-sensitive detectorPSD according the scheme of of modified geometry Gigner.The equipment has been tested for the compliying with the standards NIST SRM 640b (Si), NIST SRM 676 (Al_2O_3) and NIST SRM 660a (LaB_6). Testing conditions: Cu$K\alpha_1$-radiation; bent Ge-monochromator (III) of Ioganne type; $2q/w$-scanning, anglerange 2θ $2.000 \leq 2\theta \leq 110.945$ °2θ withpitch 0.015 °2θ; detectorpitch 0.480 °2θ, scanning time with the pitch 330 s, testing temperature T = 25.0±5 °C, U = 40 кВ, J = 37 mA. Experimental linear absorption coefficients were determined by logarithmic ration of the first ray intensity to the first ray intensity after passing through background and active objects. Processing of the eksperimental diffraction files, evaluation of theoretical diffraction patterns, indecsation of elementar cels parameters was made with the program package of STOE WinXPOW (version 3.03) [3] and PowderCell (version 2.4) [4].

Super imposed diffraction patterns of investigated objects (initial files are located by the angle$2q$ = 6.005°) are shown in fig. 4.

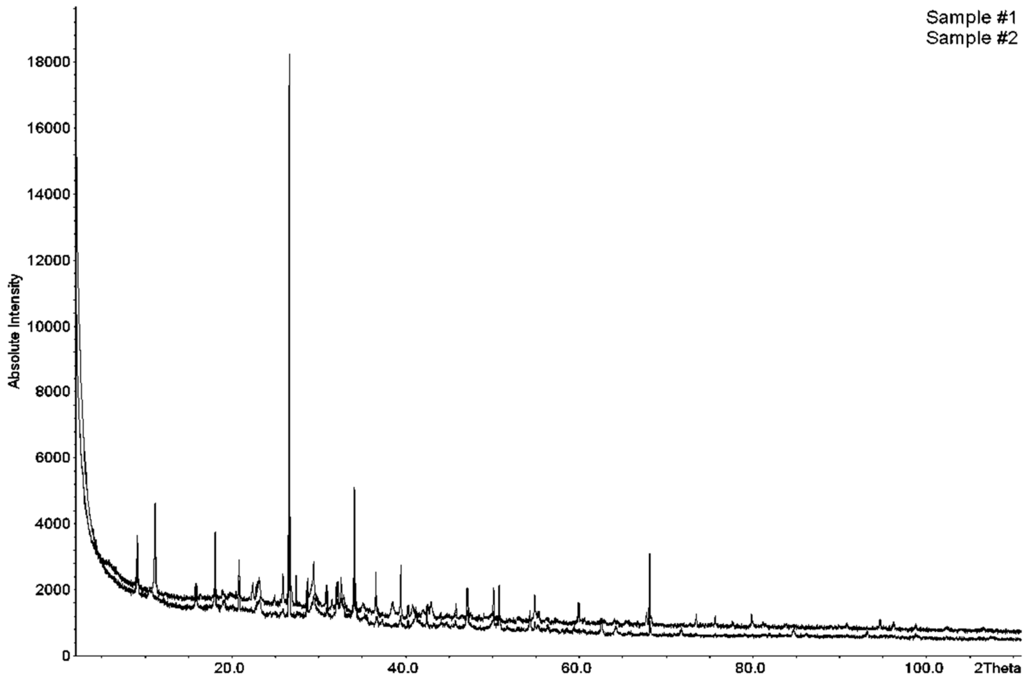

Fig. 4 – Super imposed diffraction patterns of investigated objects

As could be seen from Fig. 4, both diffraction patterns of the stone samples are almost identical. Sample No. 1 (Table 6) is characterized by calcium hydroxide $Ca(OH)_2$ (42.8 % (portlandite)), β-form of belite $Ca_2[SiO_4]$ (21.4 %), monoclinic form of alite $Ca_3[SiO_4]O$ (20.5 %), and solocom oxide SiO_2 (α-quartz – 15.3%). Sample No. 2 (Table 7) contains $Ca(OH)_2$; β- formofbelite $Ca_2[SiO_4]$ and α- quartz SiO_2 as well. By x-ray diffraction and diffraction thermalanalysis, phases in herent for zeolites could be identify in it as well.

Table 5

Sample No. 1 (the phase constitutionand crystallographic parameters)

Phase	Abundanceweight %*	Structure type, space group	Elementar cell parameters, Å		
			a	*b*	*c*
$Ca(OH)_2$ Portlandite	42.8	$Mn(OH)_2$ P-3m1	3.5899	–	4.9071
SiO_2 α-quartz	15.3	SiO_2 $P3_121$	4.9153	–	5.4045
$Ca_2[SiO_4]$ belite, β-form	21.4	$Ca_2[SiO_4]$ $P2_1/c$	5.5282	6.7769 β=117.606°	10.5380
$Ca_3[SiO_4]O$ Alite	20.5	$Ca_3[SiO_4]O$ $C1m1$	12.2362	7.0693 β=116.260°	9.2961

Table 6

Sample No. 2 (the phase constitutionand crystallographic parameters)

Phase	Abundanceweight %*	Structure type, space group	Elementar cell parameters, Å		
			a	*b*	*c*
$Ca(OH)_2$ Portlandite	7.9	$Mn(OH)_2$ *P*-3*m*1	3.5911	–	4.9074
SiO_2 α-quartz	53.7	SiO_2 $P3_121$	4.9126	–	5.4075
$Ca_2[SiO_4]$ belite, γ-form	38.4	$Mg_2[SiO_4]$ $P2_1/c$	11.2076	6.7487	5.0875

Table 7

Comparative results of cementation of borehols No. 160 and No. 170 Anastasivska deposit

Item	Indicators	Certificate No. 160 Anastasivska	CertificateNo.170 Anastasivska
Cementation conditions			
1	Cementation interval, m	2896 – 4646	2836 – 4670
2	Chisel diameter, mm	215.9	215.9
3	Casing diameter, mm	146.1	146.1
4	Cavernosity coefficient	1.39	1.34
Borehole mortar			
1	Type	Polymerpotassium	Lignosulphonate
2	Temperature, °C	20	21
3	Density, kg/m^3	1220	1220
4	Relative viscosity, c	96	88
5	Filtration indicator at 30 min, cm^3	4	6
6	Filtration cake thickness, mm	1	1.5
7	Cake friction coefficient	0.0787	0.039
8	CH3 at 1 min.aaaand at 10 min, dPa	10/53	44/76
9	Plastic viscosity, mPa·s	50	27
10	Shift dynamic loading зсуву,dPa	44	67
11	HydrogenSolution indicator (pH)	9.2	10
12	Calcium ions content Ca^{++}, mg/l	250	200
13	Magnesiumions content Mg^{++}, mg/l	61	0
14	Total mineralisation, %	9.34	7.31
15	KCl content, %	3.6	4.7
16	content of colloidal phase, %	2.1	1.5
17	content of carbonates co_3^{2-}, mg/l	540	480
18	content of hydrocarbon phase, % (vol.)	15.7	13.5
19	content of bicarbonate $нco_3^{-}$, mg/l	8113	5002
Plugging materials			
1	EPM-150 LF	3700 – 4646	3630 – 4670
2	PM-100 LF	2896 – 3700	2836 – 3630
Quality of cementation (onGDS data)			
1	Coefficient of cementation quality, *K*	375.2	296
2	*K* (EPM-150 LF)	375.3	307.8
3	*K* (PM-100 LF)	375.1	280.8

Sufficient increase of α-quartz SiO_2 creates the opportunity of better bounding of the product of alitephase hydration into low base calcium hydrosilicates C-S-H (I). This is evidenced by distinct maximum at the angle 2*q* - 29.35° and interplanar spacing 3.040 Å.

As the presented studies has shown, the microstructure of the stone formated with PM-100 LF (Fig. 5, sample No. 2 (plugging mixture from the borehole) has no contaminants inherent for buffer solution and slime. On the microphotographs the reare presented close-packed hexagonal plates of calcium hydroxide, and hydrated fornations of methamict mineral with low porosity. Thin prolongated crystals of high sulfate form of calcium hydrosulphoaluminate $3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$ intergrow in the structure promoting colmatage of the pores and increase in strength and decrease of permeability of the material.

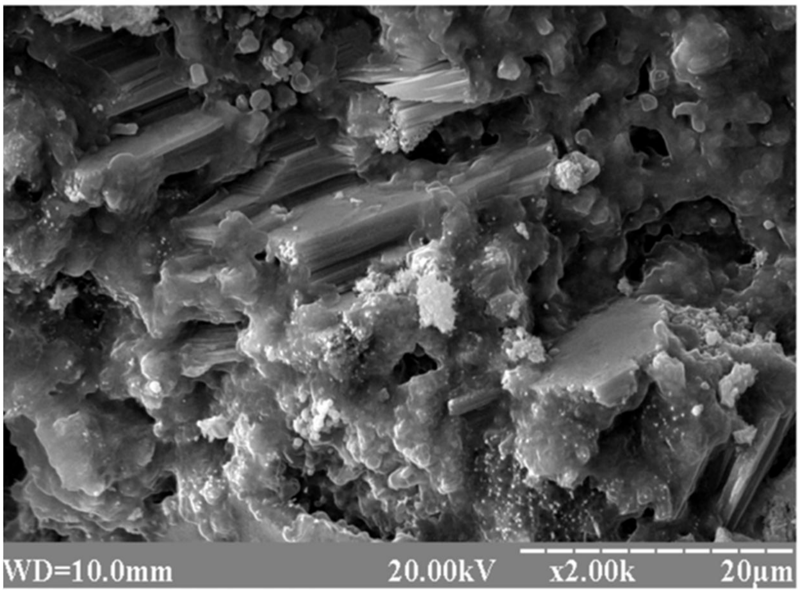

Fig. 5 – Microstructure of the cement stone PM-100 LF (example № 2)

Effectivness of zeolite-content plugging buffer system DBM-2 in comparison with DBM -1 is confirmed by geophysical investigation results of the operating colomn cementation by the method of acoustic cement-bond logging (ACL), Table 7.

So, despite the worse background of cementation conditions (increasing content of oil and bicarbonates, as well as higher cavernosity) in the borehole No. 160 Anastasivska, first of all due to application of buffer system DBM -2 with the zeolite additive of 50%, good quality of cementation K = 375.2 was provided which is by 26.76 % better than in the investigations whereDBM -1 (borehole No. 170 Anastasivska) was used and the cementation quality was satisfying K = 296.

Conclusions

Buffer liquidis – water of plugging cement kneading is notable to push effectively flushing liquid during casing cementation. Cements tone formatted in such conditions does not provide the necessary operating level of borehole casing reliability as an engeneering installation.

The implemented research has shown the expediency of application of the mineral additives of natural zeolite in the buffer plugging systems during the borehole building of Romenska group deposit DDZ.

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