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**VISUALIZATION OF CALCULATION OF RAW MIXES FOR
PREPARATION OF CEMENT**

(part 1)

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The method of calculating the composition of the raw mix for making Portland cement traditionally run by Kinda – Okorokova [1]. Since the development of methodologies, to date, based on a mass of specialized programs to help automate the calculations, but the method of calculation has not undergone significant changes and improvements. It also performs calculations of raw mixes for preparation of various specialized cement, for example sulfation aluminate cement .

Since its inception, this methodology has been significant progress in the development of automated calculation. In use included personal computers, replacing bulky cathode-calculating machines. At the same time, the majority of specialized programmes designed for the calculation of raw mixes for preparation of Portland cement, are narrowly defined special meaning, and apply only to a certain technological process plant. Typically, these programs are licensed and their cost is quite high.

The author of this article aimed to improve the methodology for calculating, simplifying it and making it suitable for computations on the desktop using available computing systems with wide dissemination, such as Microsoft Office Excel Math CAD and STATISTICA. In addition, using data processing systems, to visualize the computational process that will allow at the stage of the intermediate calculation evaluate the suitability of the raw materials for the manufacture of cement, to identify ways to improve the raw mix and get the preliminary results, which will form the basis for more accurate calculations. This methodological approach, the author uses to train the students in the construction of the profile. Data, methodo-

logical recommendations can also be useful to engineers and technical workers and construction profile.

Graphic analysis of the possibility of manufacturing of Portland cement based on two raw mix

You want to determine whether the manufacture of Portland cement with

$$KN = \frac{CaO - 1,65Al_2O_3 - 0,35Fe_2O_3}{2,8SiO_2} = 0,9, \text{ silica modulus } n = \frac{SiO_2}{Al_2O_3 + Fe_2O_3} = 2,3 \text{ и}$$

alumina modulus $p = \frac{Al_2O_3}{Fe_2O_3} = 1,7$ limestone and clay, chemical composition shown in the table. 1.

Table. 1

Chemical composition of raw materials of cement clinker

Raw material	content of raw material, components, mas. %						$\Delta m_{\text{прк.}}$
	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	
Limestone	52,89	1,38	1,55	0,35	0,46	0,19	43,18
Clay	2,69	73,68	15,02	3,69	1,8	0,31	2,81

The calculation does not use traditional formula in which the conclusions adopted at the 1 mass part of the first component is **X** part of the second component and **y** parts of the third component (in the case of triple mixture). To simplify calculations is that the sum of the mass of all the components of the raw mix, regardless of their quantity, equal to 1. Denoting the limestone of the raw mix for component I, and clay for G, for two-component mixtures have

$$I + G = 1. \tag{1}$$

Saturation factor calculation and modules for graphical analysis of two-component of the raw mix is done using MathCAD system. Listing of calculation and visualization of payment data in the MathCAD is given in figure the Math. 1.

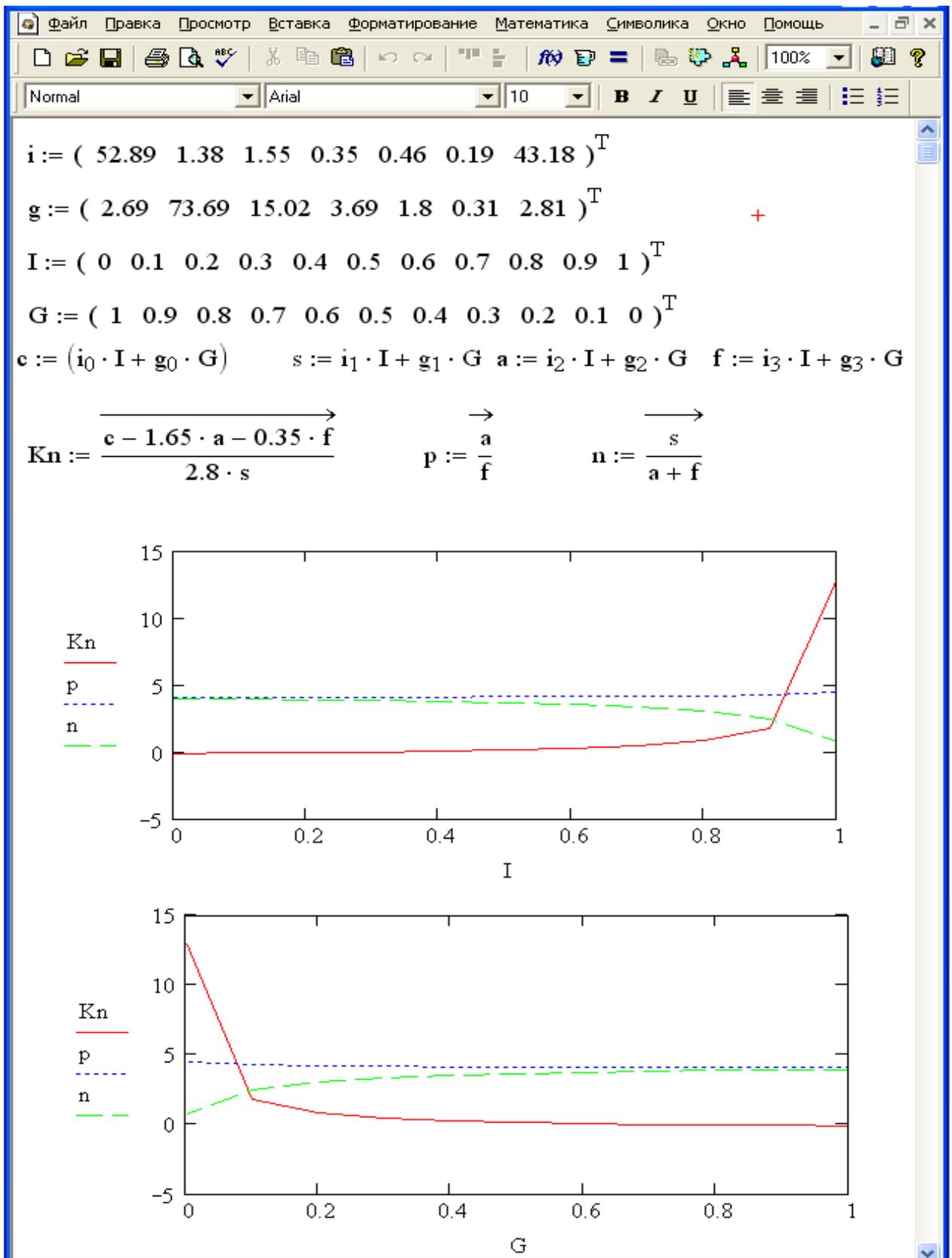


Figure. 1 Listing the saturation coefficient calculation modules and 2-component of the raw mix for preparation of Portland cement

According to the results of calculation and visualization of calculated data shows that the rate of saturation reaches 0.9 with limestone mixtures around 0.82 and clay 0.18 respectively. The content of the limestone and clay in raw mix silicate module $n = 3,01$, and mud module $p = 4,17$ that exceeds the value specified in the condition. For simultaneous reduction of silica and glinozemistogo modules you can use the supplement, rich in Fe_2O_3 . This additive can be piritovye it. Because of the two-component mixtures of Portland Cook, accurate calculation of components.

Graphic analysis of the possibility of manufacturing of Portland cement based triple raw mix

Determine whether the manufacture of Portland cement with $KN = 0,9$, silicate $n = 2,3$ module and glinozemistym module $r = 1,7$ of limestone, clay and piritovyh ogarkov, chemical composition shown in the table. 2.

Table 1

Chemical composition of raw materials of cement clinker

Raw material	content of raw material, components, mas. %						$\Delta m_{\text{прк.}}$
	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	
Limestone	52,89	1,38	1,55	0,35	0,46	0,19	43,18
Clay	2,69	73,68	15,02	3,69	1,8	0,31	2,81
Pyrite drosses	2,88	13,74	1,53	76,95	0,32	3,78	0,8

In this case, to calculate and visualize the saturation coefficient and modules, you must use two computing systems - **MathCAD** and **STATISTICA**, because MathCAD system does not support building ternary graphs. First you must identify the **STATISTICA** plan variation components of raw mix in ternary system under all possible combinations. For the calculation of combinations of components in the raw mix is simplex-method planning with three factors, with the ability to describe the results by the polynomials to the third degree. To the **STATISTICA** to outline a plan of the experiment should be in the start menu select "**Tools**"- "**Statistics production statistics and Six Sigma-experimental design (DOE)**", and

in this module you select *Mixture Designs & triangular surfaces*, as shown in Fig. 2 by pressing OK.

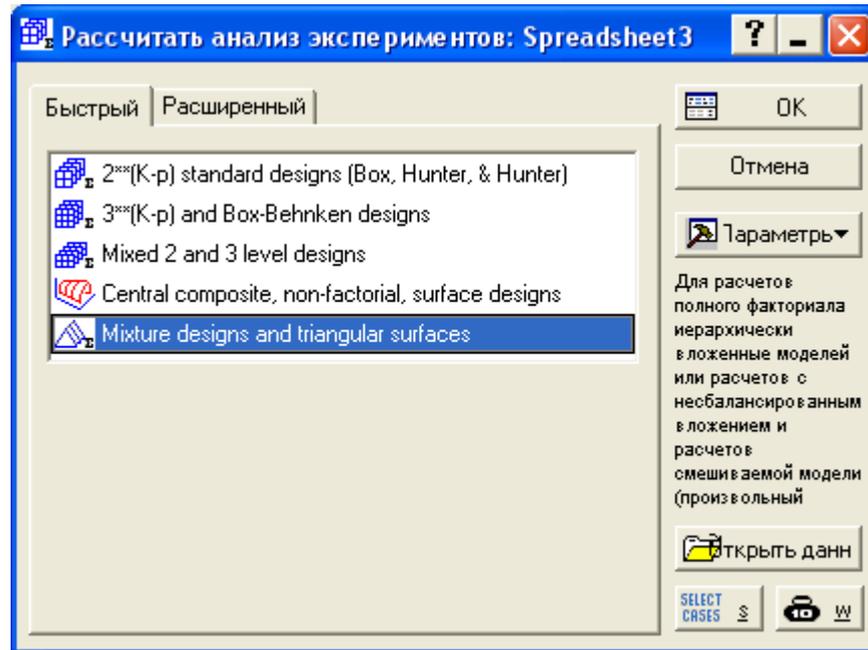


Fig. 2 Block selection tool analysis

After choosing an analysis tool will block calculation experiment provided in Fig. 3.

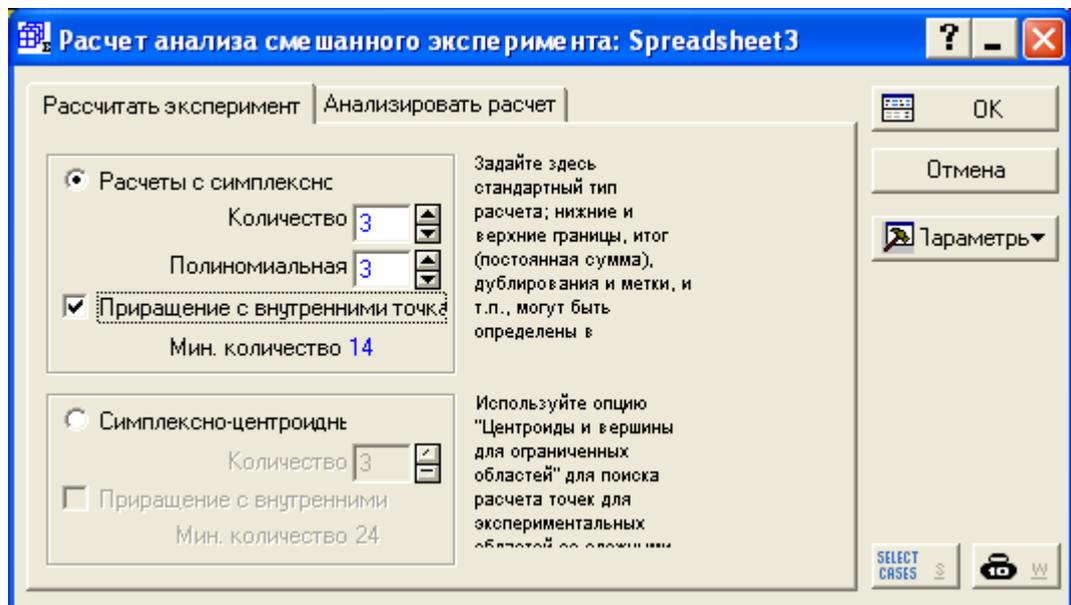


Fig. 3 Block calculation experiment

In this block, you must select the polynomial regression model of the 3-th degrees and put a tick, then increment internal points. After clicking on OK will appear for the table, the columns experiment A, B and C of the table. 3. outline of the experiment, when calculating the triple mixture is shown in the graph in Fig. 4.

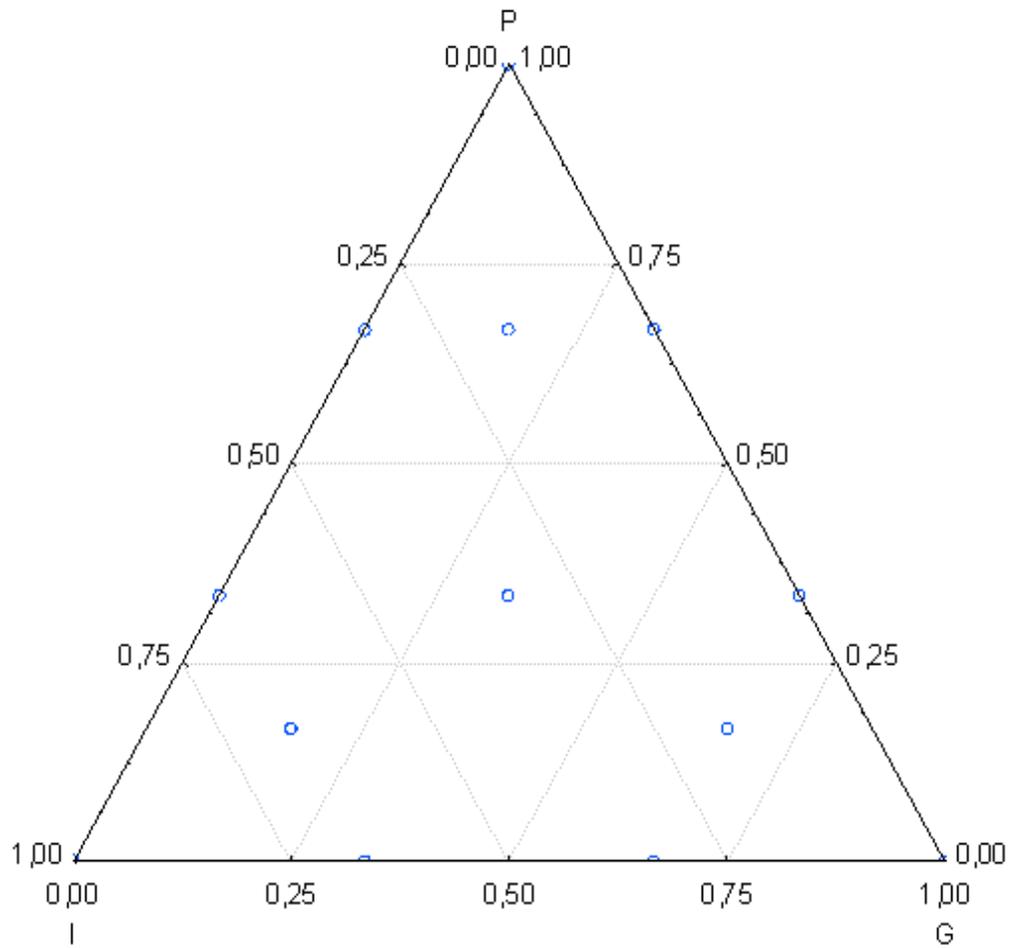


Fig. 3-component mixture analysis plan

Saturation factor calculation and modules for graphical analysis of triple the raw mix is performed by using Microsoft Office Excel. Table of the plan for the visualization and calculation results are listed in table 3.

Plan for visualization and calculation results

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	0,33	0,33	0,34		CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	Δm_{npk}	19,32	29,44	5,99	27,50	-0,00	0,22	0,88
2	0,66	0,17	0,17	I	52,89	1,38	1,55	0,35	0,46	0,19	43,18	35,85	15,77	3,84	13,94	0,56	0,28	0,89
3	0,00	0,34	0,66	G	2,69	73,68	15,02	3,69	1,80	0,31	2,81	2,82	34,12	6,12	52,04	-0,27	0,12	0,59
4	0,00	0,66	0,34	P	2,88	13,74	1,53	76,95	0,32	3,78	0,80	2,75	53,30	10,43	28,60	-0,16	0,36	1,37
5	0,66	0,34	0,00									35,82	25,96	6,13	1,49	0,35	4,13	3,41
6	1,00	0,00	0,00									52,89	1,38	1,55	0,35	12,99	4,43	0,73
7	0,66	0,00	0,34									35,89	5,58	1,54	26,39	1,54	0,06	0,20
8	0,34	0,00	0,66									19,88	9,54	1,54	50,91	-0,02	0,03	0,18
9	0,17	0,17	0,66									11,35	21,83	3,83	51,47	-0,21	0,07	0,39
10	0,00	1,00	0,00									2,69	73,68	15,02	3,69	-0,11	4,07	3,94
11	0,34	0,66	0,00									19,76	49,10	10,44	2,55	0,01	4,09	3,78
12	0,00	0,00	1,00									2,88	13,74	1,53	76,95	-0,69	0,02	0,18
13	0,17	0,66	0,17									11,26	51,20	10,44	15,58	-0,08	0,67	1,97
14	0,34	0,33	0,33									19,82	29,32	5,99	26,73	0,01	0,22	0,90

In the calculations in spreadsheets, Microsoft Office Excel must be borne in mind that when calculating the amount of oxides in the raw mix, you must use absolute references to cells containing oxides, convert relative links to absolute, by pressing the F4 after selecting a cell. This formula calculates the sum of oxides in the raw mix is as follows:

for CaO

$$=A1*\$E\$2+B1*\$E\$3+C1*\$E\$4; \quad (2)$$

for SiO₂

$$=A1*\$F\$2+B1*\$F\$3+C1*\$F\$4; \quad (3)$$

for Al₂O₃

$$=A1*\$G\$2+B1*\$G\$3+C1*\$G\$4; \quad (4)$$

for Fe₂O₃

$$=A1*\$H\$2+B1*\$H\$3+C1*\$H\$4. \quad (5)$$

The saturation coefficient calculation formula and modules are as follows:

for KN

$$=(L1-1,65*N1-0,35*O1)/(2,8*M1); \quad (6)$$

for p

$$=N1/O1; \quad (7)$$

for n

$$=M1/(N1+O1). \quad (8)$$

The estimated coefficient and saturation are substituted into the STATISTICA modules and builds ternary graphs for the values. Table analysis of modules, depending on the number of components in the raw mix in STATISTICA is provided in table 4. In Fig. 5, 6, 7 are ternary graphs isolines of equal values for KN, p and n.

Table 4

Table analysis module values depending on the composition of the raw mix

№	I	G	P	KN	n	p
1	0,33	0,33	0,34	-0,00	0,88	0,22
2	0,66	0,17	0,17	0,56	0,89	0,28
3	0,00	0,34	0,66	-0,27	0,59	0,12
4	0,00	0,66	0,34	-0,16	1,37	0,36
5	0,66	0,34	0,00	0,35	3,41	4,13
6	1,00	0,00	0,00	12,99	0,73	4,43
7	0,66	0,00	0,34	1,54	0,20	0,06
8	0,34	0,00	0,66	-0,02	0,18	0,03
9	0,17	0,17	0,66	-0,21	0,39	0,07
10	0,00	1,00	0,00	-0,11	3,94	4,07
11	0,34	0,66	0,00	0,01	3,78	4,09
12	0,00	0,00	1,00	-0,69	0,18	0,02
13	0,17	0,66	0,17	-0,08	1,97	0,67
14	0,34	0,33	0,33	0,01	0,90	0,22

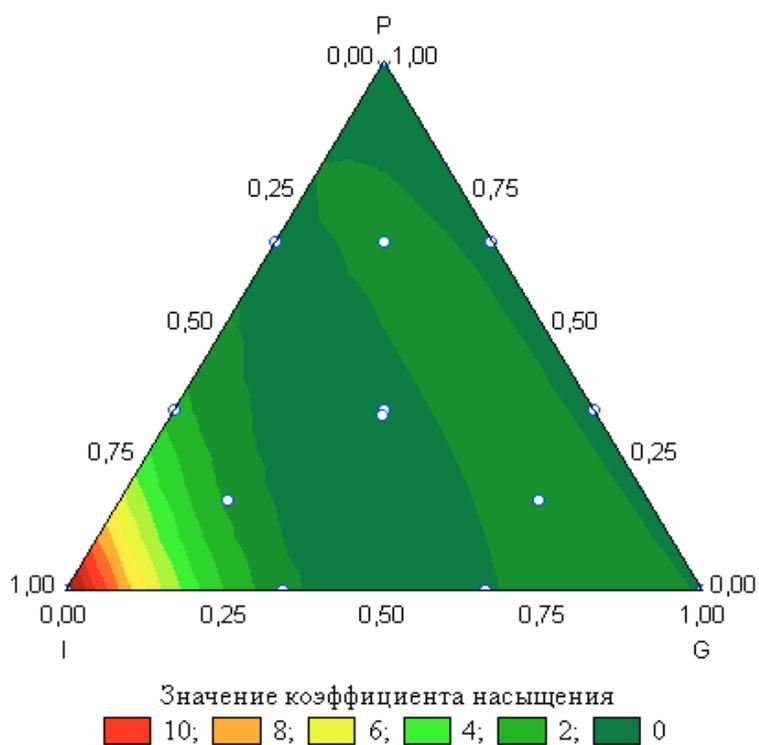


Fig. 5 Isolines of equal values KN

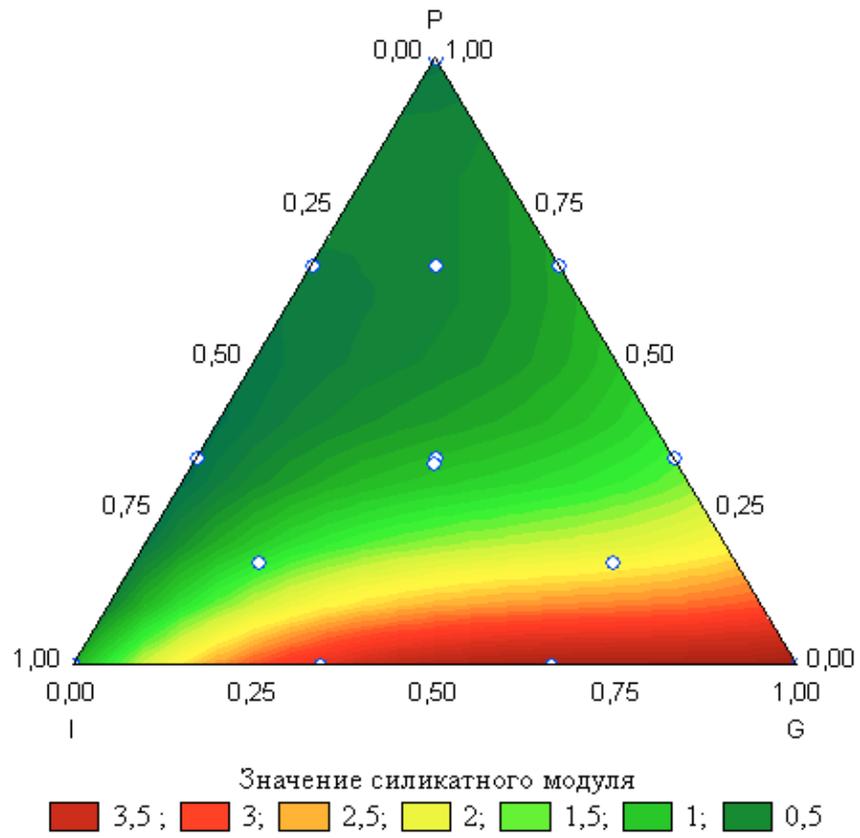


Fig. 6 Isolines of equal values of n

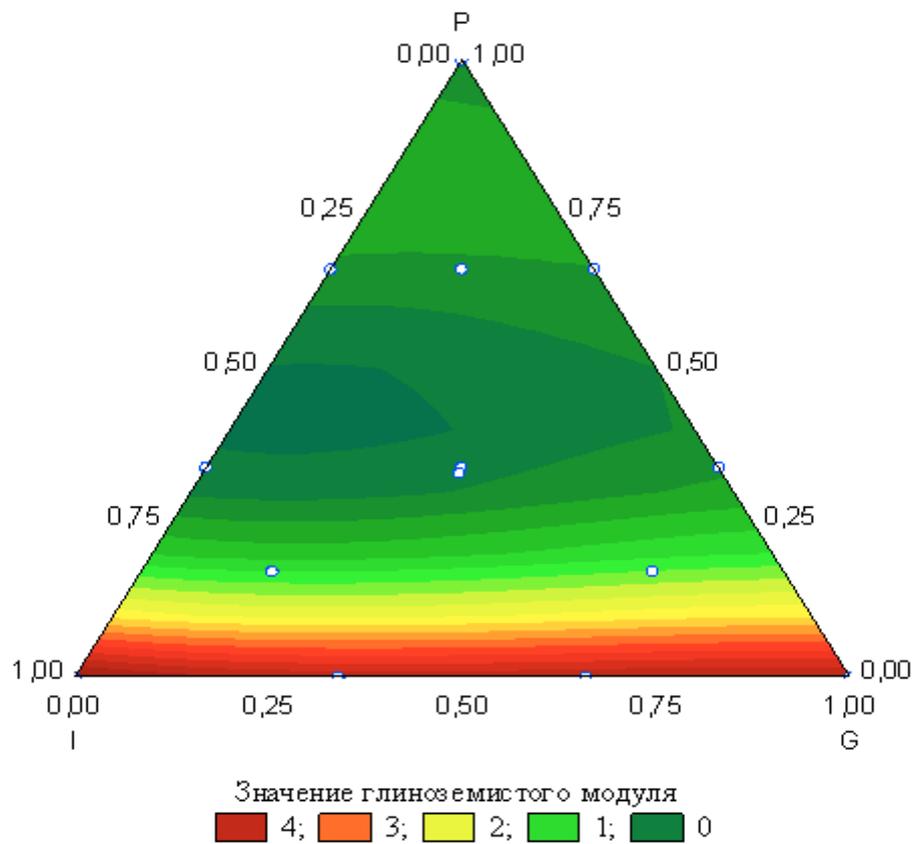


Fig. 7 Isolines of equal values of p

Visual analysis of saturation rate schedules and ternary graphs specified in the calculation module shows that isolines for $KN = 0,9$, $n = 2,3$, $p = 1,7$ intersect around the coordinates $I = 0,66$, $G = 0,166$ and $P = 0,166$, hence the raw mixture can be used to produce cement clinker with specified in the task parameters. STATISTICA allows the system to assess the estimated coefficient of saturation and data point modules (or in other words the raw mix), you need to block analysis of raw mix in the STATISTICA scheme *“Statistics-Production statistics and Six Sigma-Experimental design (DOE)-Mixture Designs & triangular surfaces-Select block calculation – “Analyze”-“Variables”* and a table select as dependent variables KN , n and p , as well as independent I , G and P , as shown in Figure 8.

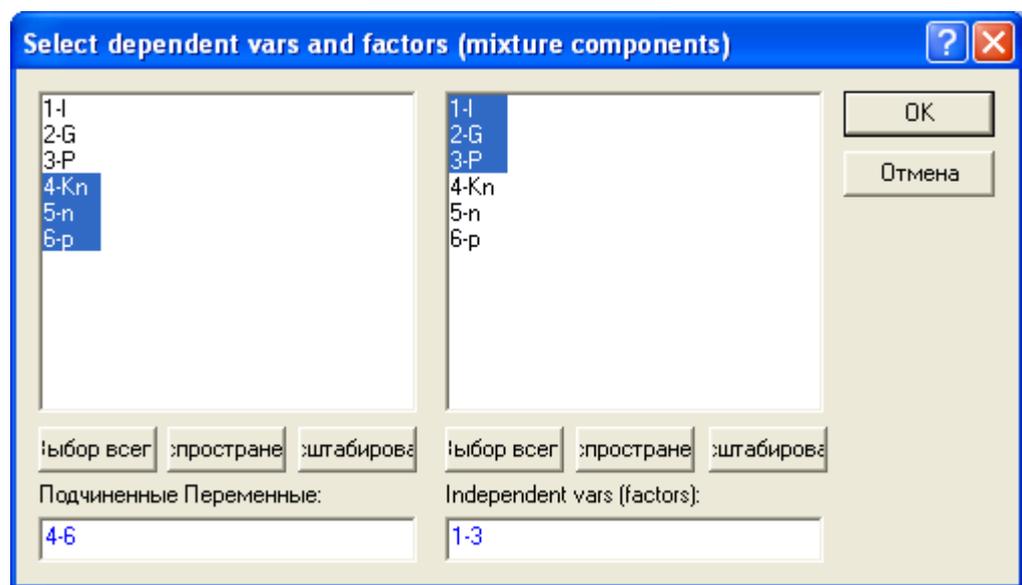


Fig.8 Table assignment of variables

After clicking OK activates the block analysis shown in Fig. 9, in which you first need to select a variable for the analysis and check for the total cubic model.

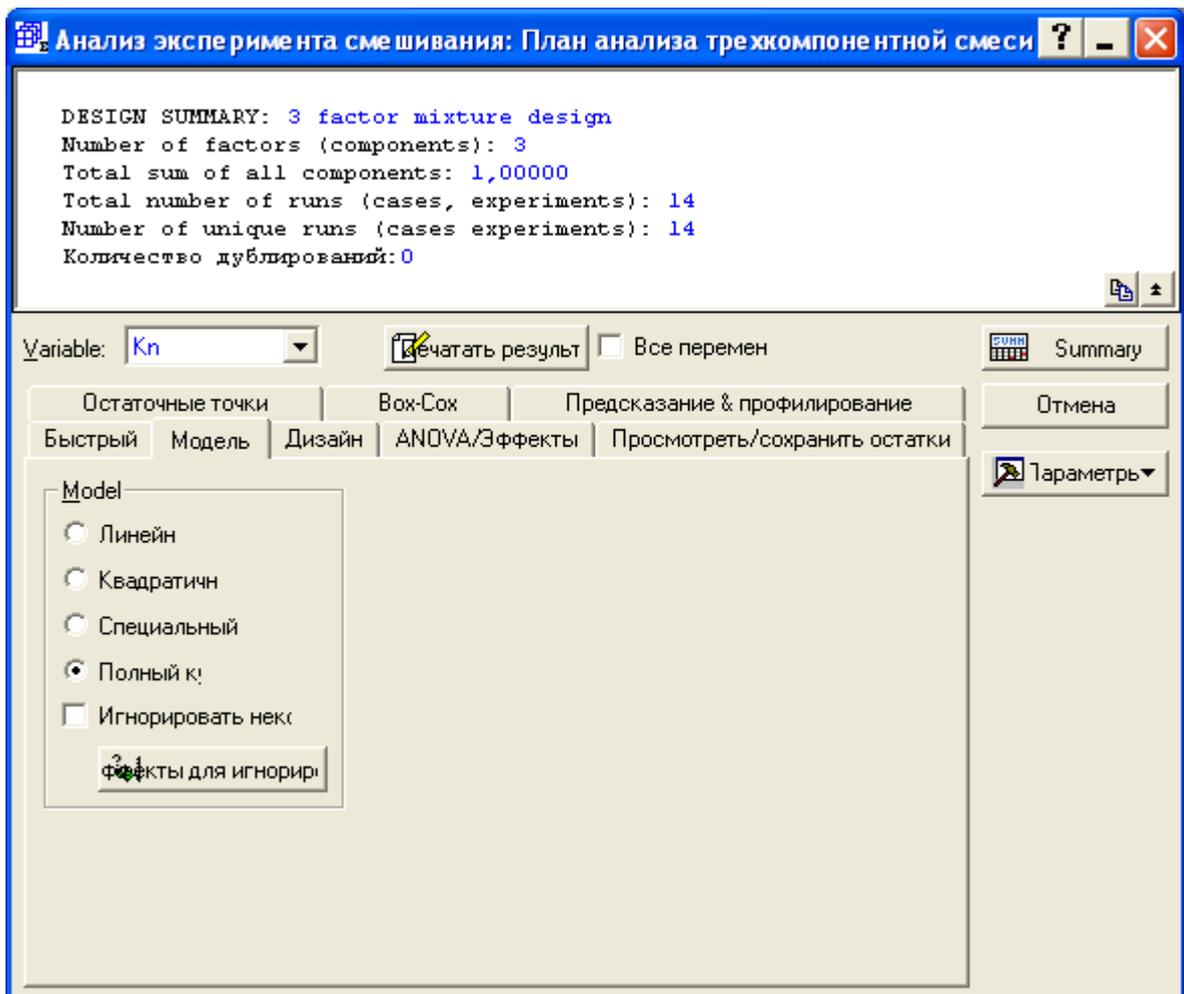


Fig. 9 Block Analysis

In the analysis, you should select block *"Prediction and profiling"* and enter the module *"Show the value of the variable"*. In the module set $I = 0,66$, $G = 0,166$ and $P = 0,166$, as shown in Fig. 10.

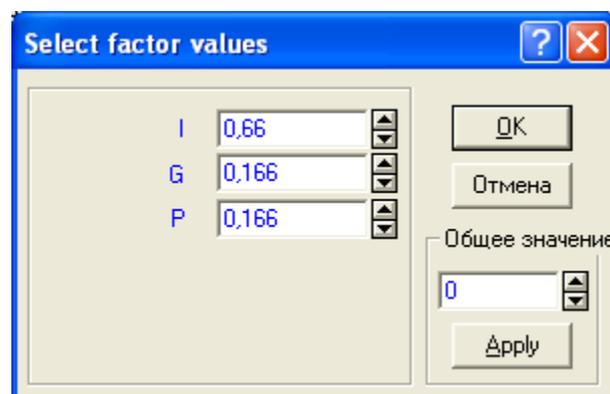


Fig. 10 Determination of bound variable

In the table. 5, is the forecast values KN.

Table 2

Table prediction values variable KN

Factor	The value of the regression equation coefficients	Error	Value of the coefficients of the regression equation with errors
(A)I	12,9488	0,665323	8,61512
(B)G	-0,1484	0,167339	-0,02483
(C)P	-0,7321	0,167339	-0,12251
AB	-28,0009	0,111334	-3,11746
AC	-24,0279	0,111334	-2,67513
BC	0,6695	0,028002	0,01875
ABC	38,6590	0,018631	0,72024
AB(A-B)	-26,0516	0,055443	-1,44437
AC(A-C)	-19,2776	0,055443	-1,06880
BC(B-C)	-1,0393	0,000000	0,00000
Forecast			0,90101
-95,% Measured confidence interval			0,24179
+95,% Measured confidence interval			1,56023
-95,% Predicted confidence interval			-0,29778
+95,% Predicted confidence interval			2,09979

Likewise defines the value of n, and p. Forecast for KN = 0,9, for n = 1,16 and for pr = 0,98. Focusing on ternary graphs you can pick up the timetables that meets the conditions of this task, but it is better to make an accurate calculation of the raw mix.

Accurate calculation of triple the raw mix for preparation of Portland cement

In the calculation of triple the raw mix, denoted limestone component raw mix for I, G, and clay for the sulfur waste as P, record condition amounts to triple the raw mix as

$$I+G+ P= 1. \quad (9)$$

Accurate calculation of triple mixture in Math CAD system, in which the content of oxides in the raw mix is set in the form of transposition matrix. Access to the elements of matrix in this system is the lowest indexing, indexing of elements of the matrix begins with 0. If you designate the corresponding oxides indexes, providing access to this element of the matrix, then the content of CaO in each of the raw mix is labeled i_0 , g_0 , p_0 , as well as Fe_2O_3 , i_3 , g_3 , p_3 . The content of each oxide into the raw mixture is equal to:

$$SiO_2=Ii_1+Gg_1+Pp_1; \quad (10)$$

$$SiO_2=Ii_1+Gg_1+Pp_1; \quad (11)$$

$$Al_2O_3=Ii_2+Gg_2+Pp_2; \quad (12)$$

$$Fe_2O_3=Ii_3+Gg_3+Pp_3. \quad (13)$$

If you substitute the above values of the oxides in the formula to calculate the saturation coefficient, we get

$$Ii_0+Gg_0+Pp_0 -1,65 Ii_2-1,65Gg_2-1,65Pp_2-0,35Ii_3-0,35Gg_3-0,35Pp_3-2,8KnIi_1-2,8KnGg_1-2,8KnPp_1=0 \quad (14)$$

If the label for A1, B1 and C1 expressions

$$A1=i_0-1,62i_2-0,35i_3-2,8Kni_1, \quad (15)$$

$$B1=g_0-1,62g_2-0,35g_3-2,8Kng_1, \quad (16)$$

$$C1=p_0-1,62p_2-0,35p_3-2,8Knp_1, \quad (17)$$

That, can write a formula

$$A1I+B1G+C1P=0. \quad (18)$$

Similarly, if you substitute the values of the oxides in the formula to determine the silica modulus, you can get a second equation in the system to find the

components of the raw mix. The third equation in the system is a condition that the sum of the components of the raw mix is equal to 1. Finally the system of equations to find the number of components with triple the raw mix will look

$$\begin{aligned}A1I+B1G+C1P&=0; \\ A2I+B2G+C2P&=0; \\ I+G+ P&= 1\end{aligned}\tag{19}$$

To solve such a system of linear equations system MathCAD has built-in function "**Find**" and "**Minerr**". To find the roots of systems of linear equations using these functions you must all components of the raw mix set to some initial value $I = 1$, $G = 1$ & $P = 1$. Assigning the initial values for the components of the raw mix won't affect the result, since such a system only. Then enter the keyword "**Given**" and sets the conditions, a system of 19. Note that when setting the conditions after the keyword "**Given**" is not the equal sign, and the logical operator "=", which means-must be equal to, and enter from the "**Boolean**" (logical) operators. After writing the conditions for solving systems of linear equations, you must enter the inline function "**Find**" and as a variable type symbols that denote the components of the raw mix. Listing exact calculation of triple the raw mix is shown in Fig. 11.

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Файл  Правка  Просмотр  Вставка  Форматирование  Математика
Символика  Окно  Помощь

Normal  Arial  10  B  I

i := ( 52.89  1.38  1.55  0.35  0.46  0.19  43.18 )T
g := ( 2.69  73.68  15.02  3.69  1.8  0.31  2.81 )T
p := ( 2.88  13.74  1.53  76.95  0.32  3.78  0.8 )T
Kn := 0.9    n := 2.3
A1 := i0 - 1.65 · i2 - 0.35 · i3 - 2.8 · Kn · i1
B1 := g0 - 1.65 · g2 - 0.35 · g3 - 2.8 · Kn · g1
C1 := p0 - 1.65 · p2 - 0.35 · p3 - 2.8 · Kn · p1
A2 := i1 - n · i2 - n · i3
B2 := g1 - n · g2 - n · g3
C2 := p1 - n · p2 - n · p3
I := 1    G := 1    P := 1
Given
A1 · I + B1 · G + C1 · P = 0
A2 · I + B2 · G + C2 · P = 0
I + G + P = 1
R := find(I,G,P)

R =  $\begin{pmatrix} 0.807 \\ 0.175 \\ 0.018 \end{pmatrix}$     I := R0 · 100    I = 80.71
G := R1 · 100    G = 17.52
P := R2 · 100    P = 1.77

Press F1 for help.  АВТО  NUM P

```

Fig. 11 Listing of calculation of triple the raw mix

In accordance with precise calculation, three raw mixture for preparation of Portland cement with a such characteristics must contain 80,71% limestone, 17,52% clay and 1.77% pyrite drosses.

It should be noted that when calculating the component of the charge, usually set KN and one of the modules, and in the calculation of rectangular mixture KN-and both modules.

Accurate calculation of rectangular raw mix for preparation of Portland cement

Calculate the rectangular raw mix cement clinker with $KN = 0.9$, $n = 2.3$, $p = 1.6$, using as a fourth blast furnace granulated slag component commodity, chemical composition of which is shown in table 6.

Table 3

Chemical composition of raw materials of cement clinker

Raw material	content of raw material, components, mas. %						$\Delta m_{\text{прк.}}$
	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	
Limestone	52,89	1,38	1,55	0,35	0,46	0,19	43,18
Clay	2,69	73,68	15,02	3,69	1,8	0,31	2,81
Pyrite drosses	2,88	13,74	1,53	76,95	0,32	3,78	0,8
Furnace granulated slag	48,0	36,0	8,05	0,6	3	1,4	2,94

Listing the calculation of rectangular raw mix for preparation of Portland cement is shown in Fig. 12.

```

Файл  Правка  Просмотр  Вставка  Форматирование  Математика
Символика  Окно  Помощь
Normal Arial 10 B I
i := ( 52.89  1.38  1.55  0.35  0.46  0.19  43.18 )T
g := ( 2.69  73.68  15.02  3.69  1.8  0.31  2.81 )T
p := ( 2.88  13.74  1.53  76.95  0.32  3.78  0.8 )T
s := ( 48  36  8.05  06  3  1.4  2.95 )T
Kn := 0.9    n := 2.3    p1 := 1.6
A1 := i0 - 1.65 · i2 - 0.35 · i3 - 2.8 · Kn · i1
B1 := g0 - 1.65 · g2 - 0.35 · g3 - 2.8 · Kn · g1
C1 := p0 - 1.65 · p2 - 0.35 · p3 - 2.8 · Kn · p1
D1 := s0 - 1.65 · s2 - 0.35 · s3 - 2.8 · Kn · s1
A2 := i1 - n · i2 - n · i3    A3 := i2 - p1 · i3
B2 := g1 - n · g2 - n · g3    B3 := g2 - p1 · g3
C2 := p1 - n · p2 - n · p3    C3 := p2 - p1 · p3
D2 := s1 - n · s2 - n · s3    D3 := s2 - p1 · s3

I := 1    G := 1    P := 1    S := 1
Given
A1 · I + B1 · G + C1 · P + D1 · S = 0
A2 · I + B2 · G + C2 · P + D2 · S = 0
A3 · I + B3 · G + C3 · P + D3 · S = 0
I + G + P + S = 1
R := find(I,G,P,S)

R =  $\begin{pmatrix} 0.644 \\ 0.062 \\ 6.232 \times 10^{-3} \\ 0.288 \end{pmatrix}$ 
I := R0 · 100    I = 64.39
G := R1 · 100    G = 6.21
P := R2 · 100    P = 0.62
S := R3 · 100    S = 28.78
Press F1 for help.

```

Fig. 1 Listing the calculation of rectangular raw mix for preparation of Portland cement

In accordance with precise calculation, rectangular raw mixture for preparation of Portland cement with a such characteristics must contain 64,39% limestone, 6,21% clay, 0,62% pyrite drosses and 28,78% granulated slag.

Literature

1. Бутт Ю.М. Технология цемента и других вяжущих веществ. - М.: Стройиздат, 1964. – 352 с.: ил.