Identification of Most Influencing Blast Design Parameters on Mean Fragmentation Size and Muckpile by Principal Component Analysis

N. Sri Chandrahas, B.S. Choudhary, M.S.Venkataramayya

Abstract: ***Mean fragmentation size, muck pile are the most emphasis factors in terms of economic and safe production in mining. It is needful to maintain certain limits to reach optimum level of blast results. The motive of study is to categorize the most influencing blast design parametric values on average sized fragmentation and muck pile. The commitment of the research was dealt on time through field data collection that related to blast design parametric values such as drill hole depth, its diameter, no of holes, no of rows, burden, spacing, average charge per hole, explosive, firing pattern, length width ratio, powder factor, mean fragmentation size, throw from three limestone mines positioned at different vicinity in Rajasthan. The collected data has analyzed statistically using principal component analysis (PCA) in IBM SPSS and XLSTAT software's. Most influencing significant and non-significant parameters on mean fragmentation size and muck pile were drawn from regression analysis by considering P, F and R square values in IBM SPSS, For more robust results further analysis has done with XLSTST by considering influenced parameters from correlation circle according to their respective coordinates.***

Keywords: Blast Design Parameters, IBM SPSS, XLSTAT, PCA.

I. INTRODUCTION

Blast design parameters play a vital role in terms of mean fragmentation size and muck pile shape. The design parameters are drill hole depth, drill hole diameter, no of holes, no of rows, burden, spacing, average charge per hole, explosive, firing pattern, length width ratio, powder factor, mean fragmentation size, throw. It is very needful to find the which parameters influencing the mean fragmentation size and throw drastically both significant and non significant manner.The goal will be materialize by a statistical method called Principal Components Analysis in both IBM-SPSS and XLSTAT software's. Technically this method delivers a relatively small set of synthetic variables called principal components that account for most of the variance in the original dataset and hence this data-processing and dimension-reduction technique, has gained significance in numerous applications in engineering, biology, economy and social science. The end result of the principal components designates which components, and which variables should be retained as individual variables(2).

The blast design parameters (12)

- **Burden:** denotes the minimum distance between face and blast hole.
- **Spacing:** Denotes the distance between two consecutive blast holes taken at any instance. Spacing = (1.2 to 1.5) burden
- **Stemming:** It is used in blast holes. Stemming is a process that affects blown out shot of the hole and also affects fly rocks and is employed after the explosive is loaded. Stemming/burden > 0.6 (for controlling fly rock**)**
- **Bore hole depth:** Bore hole depth is a function of spacing and diameter of the hole. When the holes shorter they produce blasting at greater violence and vibration level with highly increased frequency.
- **Types of explosives:T**ype of explosives used is based on the ground vibrations.
- **Explosive quantity:** The level of vibration produced depends on the quantity of the charge incurred during explosion of rocks because a single row instantaneous blast is same as the level of vibration produced by a single or multi row blast with delay if the charge quantity per delay of the blast with delay equals to the total charge of the single row blast. Thus it is the charge per delay that controls the level of blasting not the total charge.

Mean Fragmentation Size: The word "fragmentation" being used frequently and means anything from "the limits/size of breaking" to "the percentage of breaking size passes, above or below, a certain size which is economically significant in the prescribed size range of a definite volume that is already defined in the context of broken rock. The sizes are classified in to oversize, Fines and Mid-range (6). If the boulder size exceeds the prescribed size for which secondary breaking is necessary before further handling in underground mines then it is considered as oversized and this can be as petite as 300mm,while in opencast mines depending on the requirement and application it is seldom considered to be greater than 100mm. If the particle size below which product can either not be sold, or which becomes difficult to handle due to flow, or other properties will be fall under fines, it is common for a minimum sized particle of 6mm for coal or dolomite, but when considered for gold ores this may be as small as l mm.

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N. Sri Chandrahas, Part-time research scholar, IIT(ISM) Dhanbad Asst Professor, Department of Mining Engineering, Malla Reddy Engineering College, Hyderabad,India

B.S.Choudhary, Asst Professor, Department of Mining Engineering, IIT(ISM) Dhanbad,Jharkhand, India

M.S.Venkataramayya, Professor, Department of Mining Engineering, Malla Reddy Engineering College, Hyderabad,Telangana, India

Finally the size belonging to the mid-ranges, those which have significant but not of terminal importance bear the ability to achieve premium pricing in the market.(4&10)

The Kuz-Ram model Equation which combines Kuznetsov and Rosin-Rammler equations has been employed widely by research scholars to predict blast induced fragmentation since its introduction (Cunningham 1983). It exclusively establishes the fragment size distribution based on a given set of rock parameters and after many trial and error type step substitutions Kuz-Ram model found the index number n(3&5)

Muck pile: The parametric variables include throw, drop & lateral spreading where throw designates the distance along the horizontal axis at the center of gravity of the blasted muck, while drop lies along the vertical lowering side.(6&7).

II. OBJECTIVE

The predominant intent of the research was to explore the most influencing blast design parameters on mean fragmentation size and muck pile by the principal component analysis in both IBM SPSS and XLSTAT so that it is easy to maintain blast design parameters up to the mark to get optimum and safe production.

III. RESEARCH METHODOLOGY

As a mandate to fulfil the research objective several data's were collected from three different cement companies in rajasthan, Shree Cements, Wonder cements and Indian cements. The M/s Shree Cement Ltd owned Nimbeti Limestone Mines is highly mechanized and has about 15 million tonnes rock handling capacity per annum when compared with the other limestone mines & projects of consuming 2500MT of explosives per/annum.The blasting was done by down line initiation with noise less trunk line detonator at top and blast holes of 165 mm diameter are drilled by using rotary drill and the holes are charged with bulk ANFO explosives. Bhatkotri Lime Stone Mines of M/s Wonder Cement Limited. Bhatkotari limestone deposit forms a part of the Nimbahera belt and belongs to Semri series of Lower Vindhyan age and the total thickness of the Nimbahera limestone is estimated to be 144 meter, of which the bottom is deep reddish purple in colour, while the upper 133.5 meter is grey in colour and the production of Quarry was over 12000-14000 tone/ day and the blasting practice in the mine was to use ANFO in conjunction with cartridge slurry explosive. The Partipura limestone Mine (PLM) -a captive limestone mine of Trinetra Cement Limited (TCL) a Subsidiary company of The India Cements Limited (ICL). PLM is fully mechanized opencast Limestone mine and the blasting practice in the mine was ANFO in conjunction with cartridge slurry explosive.

Fifty blast results has collected with respect to various blast design parameters from above said cement companies and here independent variables are mean fragmentation size and throw and rest all will fall under dependent variables and the cases are categorized in to two, In one case independent variable as mean fragmentation size and dependent variables are rest all factors and in second case independent variable as throw and dependent are remaining all parameters and the analysis has done with respective to three different mines in two cases. For statistical analysis a method of principal component analysis has executed in both IBM SPSS and XLSTAT software's for sake of robust results. The methodology specifically identifies even the mild variances and the least correlations in the data. Attaining a factor resolution through principal components investigation is a step to step iterative process that usually requires frequent repetition of the SPSS factor analysis procedure numerous times to reach the utmost satisfactory solution

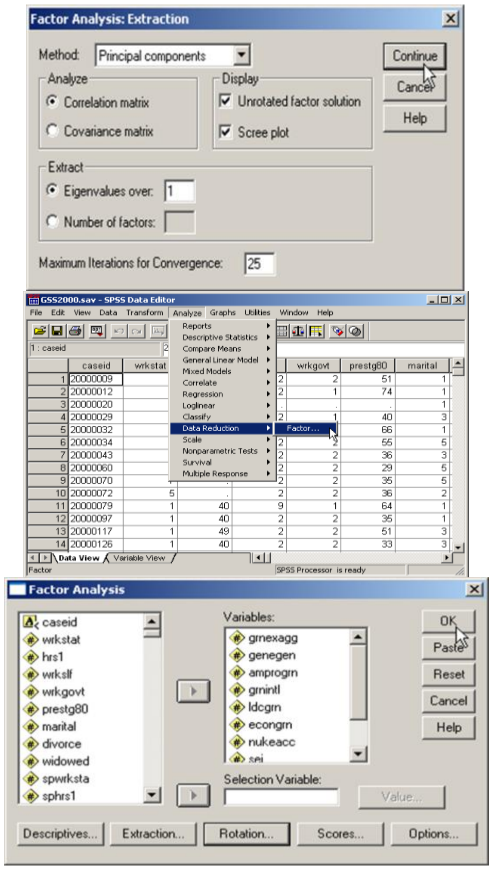

Figure1. Operation of principal component

IV. LAB WORK

MEAN FRAGMENTAION SIZE RESULTS OBTAINED FROM SHREE CEMENTS (Case 1)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.835446
R Square	0.697971
Adjusted R Square	0.69042
Standard Error	0.039678
Observations	42

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.145527	0.145527	92.43749	5.93E-12
Residual	40	0.062973	0.001574		
Total	41	0.2085			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.060555	0.020139	3.006815	0.004547	0.019852	0.101258	0.019852	0.101258
2pc	0.001736	0.000181	9.614442	5.93E-12	0.001371	0.002102	0.001371	0.002102

Figure2. Obtained regression exploration with PCA components in IBM SPSS

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	Component				
	1	2	3	4	5
Front row burden	.857	-.220	.062	.196	.028
Burden	.161	-.592	.508	.188	-.251
Spacing	.061	-.843	.333	-.041	-.003
Delay	.230	.656	.346	.012	.353
No of holes	-.181	.483	.694	-.009	.209
No of rows	-.589	.036	.125	.709	.138
Hole depth	.590	.111	.062	.561	.391
L/W ratio	.506	.361	.374	-.604	-.168
Se/Be ratio	-.687	-.323	.343	-.259	.280
MFS	.170	.339	.351	.328	-.604
Throw	.798	-.077	-.197	.076	-.031
Firing Pattern	.420	-.151	.348	-.161	.331

Extraction Methodology: Principal Constituent Analysis.5 components extracted.
T

Figure3.Extracted components from matrix

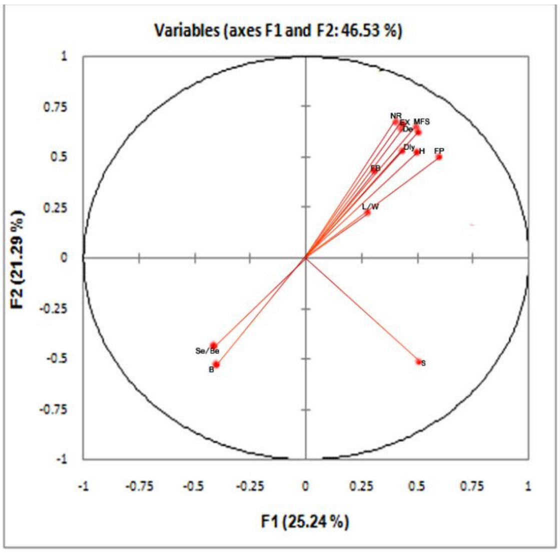

Figure4.Variable chart obtained from XLSTAT

MUCKPILE RESULTS OBTAINED FROM SHREE CEMENTS (Case 1)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.769997
R Square	0.592896
Adjusted R Square	0.582718
Standard Error	2.634584
Observations	42

ANOVA

	Df	SS	MS	F	Significance F
Regression	1	404.3496	404.3496	58.25495	2.51E-09
Residual	40	277.6414	6.941034		
Total	41	681.991			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-0.09217	1.175057	-0.07844	0.937868	-2.46705	2.282706	-2.46705	2.282706
1pc	0.374733	0.049097	7.632493	2.51E-09	0.275504	0.473962	0.275504	0.473962

Figure5. Obtained regression analysis with PCA components in IBM SPS

	Component				
	1	2	3	4	5
Front row burden	.829	.293	.222	.040	-.044
Burden	.123	.820	-.015	-.004	.211
Spacing	-.020	.877	.021	-.106	-.216
Delay	.177	-.368	.102	.734	.109
No of holes	-.259	-.051	-.016	.799	.288
No of rows	-.203	.021	-.886	.139	.195
Hole depth	.790	-.019	-.272	.360	-.074
L/W ratio	.095	-.066	.856	.360	.206
Se/Be ratio	-.752	.348	-.176	.211	-.279
MFS	.193	.023	.033	.074	.834
Throw	.760	.028	.295	-.125	-.077
Firing Pattern	.262	.300	.269	.404	-.247

Figure6.Extracted components from matrix

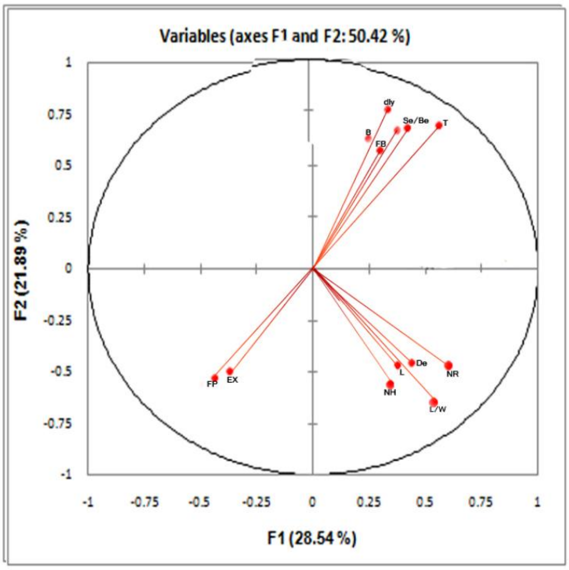

Figure7.Variable chart obtained from XLSTAT

MEAN FRAGMENTAION SIZE RESULTS OBTAINED FROM WONDER CEMENTS (Case 2)

Regression Statistics	
Multiple R	0.217423
R Square	0.772729
Adjusted R Square	0.001905
Standard Error	0.039068
Observations	23

ANOVA

	Df	SS	MS	F	Significance F
Regression	1	0.00159	0.00159	1.041988	0.04319
Residual	21	0.032053	0.001526		
Total	22	0.033643			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.148258	0.016982	8.730363	1.97E-08	0.112942	0.183574	0.112942	0.183574
4pc	0.000573	0.000562	1.020778	0.001744	1.020778	0.001744	-0.00059	0.001741

Figure8. Obtained regression analysis with PCA components in IBM SPSS

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	Component				
	1	2	3	4	5
Burden m	-.366	-.054	-.198	-.112	.661
Spacing m	-.422	.212	.742	.408	-.029
Depth of holes m	-.297	.272	.890	.036	-.013
No of holes	.886	.277	-.271	.075	.046
No rows	.551	-.763	.219	.063	-.058
Explosive ANFO kg	.817	.321	.333	-.109	.199
Throw	.333	-.337	-.131	.666	-.101
Total explosive kg	.808	.346	.398	-.039	.227
Firing pattern	.551	-.763	.219	.063	-.058
LW Ratio	.415	.844	-.234	.141	-.034
MKSK50	-.148	-.128	-.098	.568	.627

Extraction Precedure:. a. 5 components extracted

Figure9.Extracted constituents from matrix

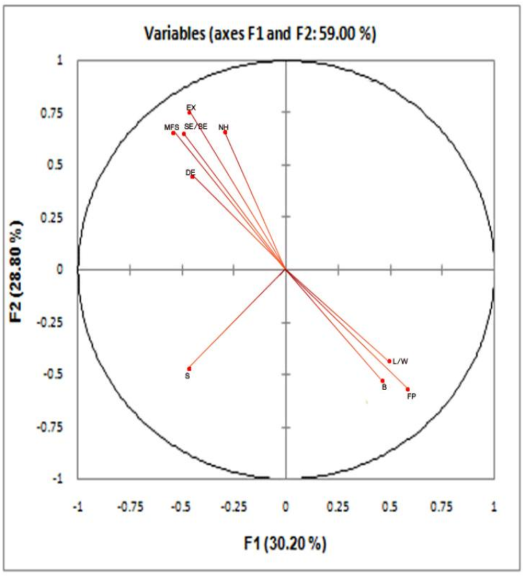

Figure10 Variable chart obtained from XLSTAT

MUCKPILE RESULTS OBTAINED FROM WONDER CEMENTS (Case 2)

Regression Statistics	
Multiple R	0.121872
R Square	0.848528
Adjusted R Square	-0.03206
Standard Error	4.851939
Observations	23

ANOVA

	Df	SS	MS	F	Significance F
Regression	1	7.453451	7.453451	0.316611	0.034796
Residual	21	494.3676	23.54132		
Total	22	501.8211			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	8.478197	2.108997	4.020015	0.000619	4.092299	12.8641	4.092299	12.8641
4pc	0.039248	0.069752	0.562682	0.047961	0.484113	0.047961	0.484113	0.184305

Figure11. Obtained regression analysis with PCA components in IBM SPSS

	Component				
	1	2	3	4	5
Burden m	-.366	-.054	-.198	-.112	.661
Spacing m	-.422	.212	.742	.408	-.029
Depth of holes m	-.297	.272	.890	.036	-.013
No of holes	.886	.277	-.271	.075	.046
No rows	.551	-.763	.219	.063	-.058
Explosive ANFO kg	.817	.321	.333	-.109	.199
Throw	.333	-.337	-.131	.666	-.101
Total explosive kg	.808	.346	.398	-.039	.227
Firing pattern	.551	-.763	.219	.063	-.058
LW Ratio	.415	.844	-.234	.141	-.034
MKSK50	-.148	-.128	-.098	.568	.627

Figure12 Extracted components from matrix

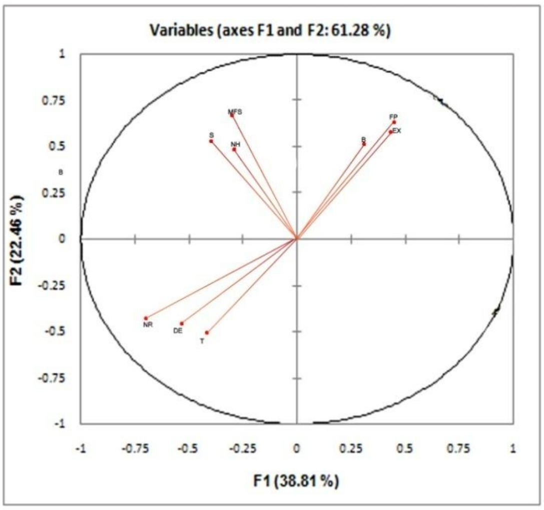

Figure13.Variable chart obtained from XLSTAT

MEAN FRAGMENTAION SIZE RESULTS OBTAINED FROM INDIAN CEMENTS (Case 3)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.465376
R Square	0.216575
Adjusted R Square	0.160616
Standard Error	0.100879
Observations	16

ANOVA

	Df	SS	MS	F	Significance F
Regression	1	0.039386	0.039386	3.870246	0.069288
Residual	14	0.142472	0.010177		
Total	15	0.181858			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.224268	0.033591	6.67648	1.05E-05	0.152223	0.296314	0.152223	0.296314
pc1	0.000809	0.000411	1.967294	0.069288	-7.3E-05	0.00169	-7.3E-05	0.00169

Figure14. Obtained regression analysis with PCA components in IBM SPSS

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Component Matrix[a]

	Component					
	1	2	3	4	5	6
Burden m	.405	.702	.034	.021	-.479	.287
Spacing m	.454	.804	.217	-.052	-.078	.202
Depth of holes m	.902	.056	-.120	.181	.287	.053
Front row burden m	.034	.645	-.373	.114	.502	.074
No of holes	-.621	.031	.695	.050	-.042	.214
No of rows	-.718	.403	.124	.443	.114	.152
Explosive quantity Kg	.228	.084	.902	.289	.026	-.014
Charge length m	.900	.109	.088	.252	.209	.100
Firing pattern	.238	-.610	-.355	.379	.049	.450
Total delay time ms	-.361	-.374	.225	.045	.678	.339
Throw m	.118	-.747	-.023	.120	-.466	.373
LW Ratio	.347	-.291	.303	-.772	.249	-.065
MKSK50	.746	-.328	.356	-.124	.027	.061

Extraction Method: Principal Component Analysis. a. 6 extracted

Figure15.Extracted components from matrix

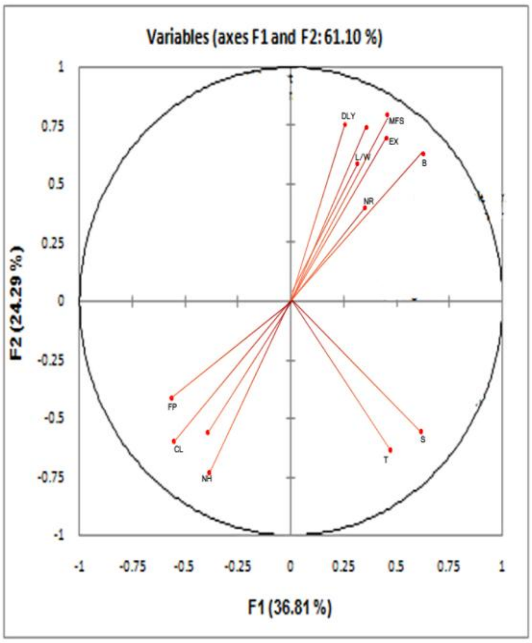
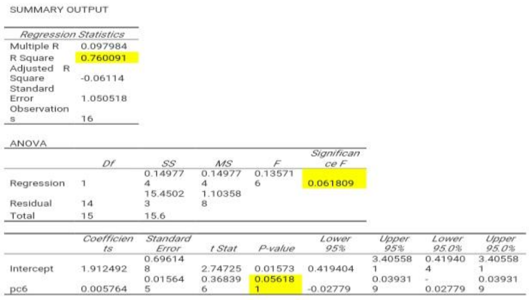


Figure16.Variable chart obtained from XLSTAT

MUCKPILE RESULTS OBTAINED FROM INDIAN CEMENTS (Case 3)



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.097984
R Square	0.760091
Adjusted R Square	-0.06114
Standard Error	1.050518
Observations	16

ANOVA

	Df	SS	MS	F	Significance F
Regression	1	0.149774	0.149774	0.135716	0.061809
Residual	14	15.45023	1.103588		
Total	15	15.6			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.912492	0.696148	2.74725	0.01573	0.419404	3.405581	0.419404	3.405581
pc6	0.005764	0.015645	0.368396	0.056181	-0.02779	0.039319	-0.02779	0.039319

Figure17. Obtained regression analysis with PCA components in IBM SPSS

	Component					
	1	2	3	4	5	6
Burden m	.405	.702	.034	.021	-.479	.287
Spacing m	.454	.804	.217	-.052	-.078	.202
Depth of holes m	.902	.056	-.120	.181	.287	.053
Front row burden m	.034	.645	-.373	.114	.502	.074
No of holes	-.621	.031	.695	.050	-.042	.214
No of rows	-.718	.403	.124	.443	.114	.152
Explosive quantity Kg	.228	.084	.902	.289	.026	-.014
Charge length m	.900	.109	.088	.252	.209	.100
Firing pattern	.238	-.610	-.355	.379	.049	.450
Total delay time ms	-.361	-.374	.225	.045	.678	.339
Throw m	.118	-.747	-.023	.120	-.466	.373
LW Ratio	.347	-.291	.303	-.772	.249	-.065
MKSK50	.746	-.328	.356	-.124	.027	.061

Figure18.Extracted components from matrix

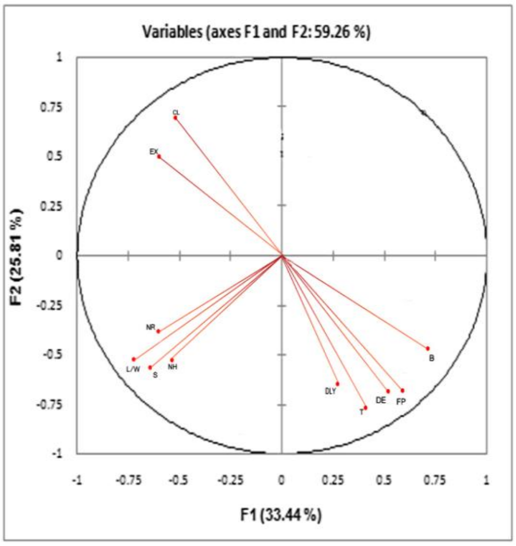


Figure19.Variable chart obtained from XLSTAT

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V. RESULTS AND DISCUSSIONS

The PCA results were drawn from component matrix according to their R^2 and F values in regression analysis and results were compared with correlation circle in XLSTAT.

SHREE CEMENTS:

Influencing parameters on MFS:

Significant parameters

1. Spacing 2.Throw 3.Depth of hole 4. Throw 5.No Rows 6.No Holes 7.L/W Ratio

Non-Significant parameters

1. Explosive 2.Burden 3. Firing pattern

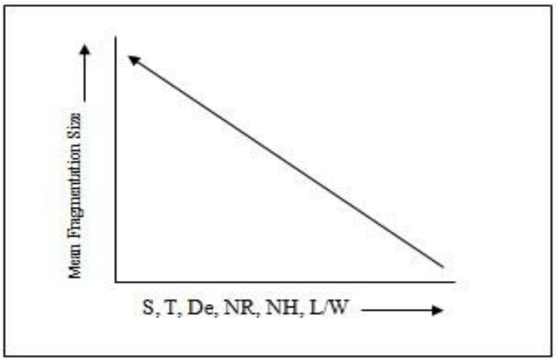

Figure20.Significant parameters

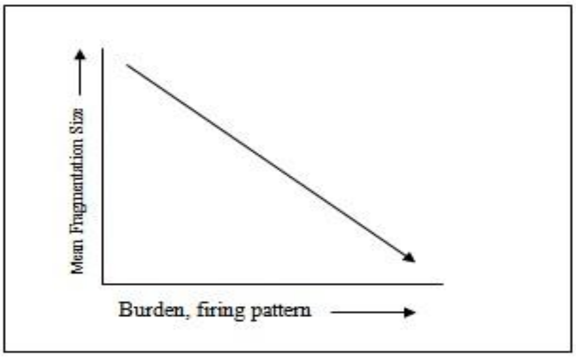

Figure21.Non-significant parameters

Influencing parameters on Muck pile:

Significant parameters

1 Spacing 2.Throw 3.Depth of hole 4.MFS 5. Firing pattern 6.No Rows 7.No Holes 8.L/W

Significant parameters

1. Explosive 2.Burden

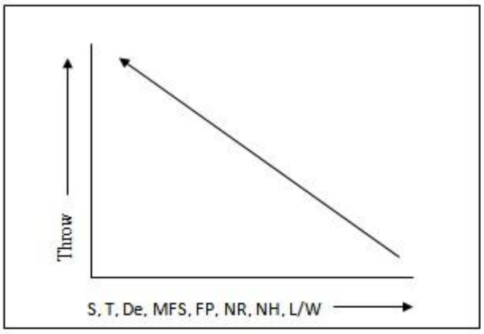

Figure22.Significant parameters

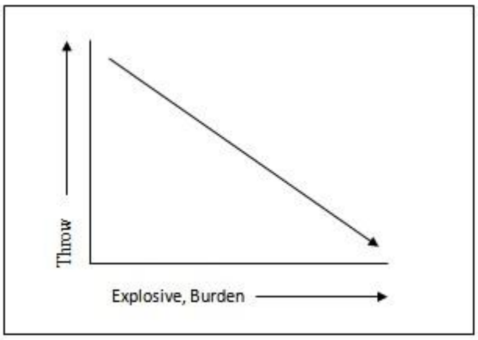

Figure23.Non-significant parameters

WONDER CEMENTS:

Influencing parameters on MFS:

Significant parameters

1 Spacing 2.Throw 3.Depth of hole 4. Throw 5. Firing pattern 6.Explosive 7.Burden 8.Charge length 9.Front row burden

Non-Significant parameters

1. No Rows 2.No Holes

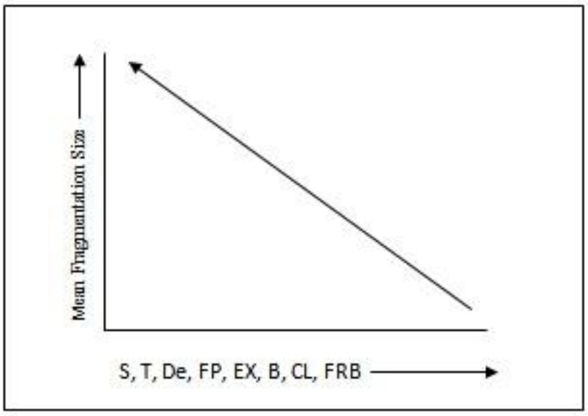

Figure 24.Significant parameters

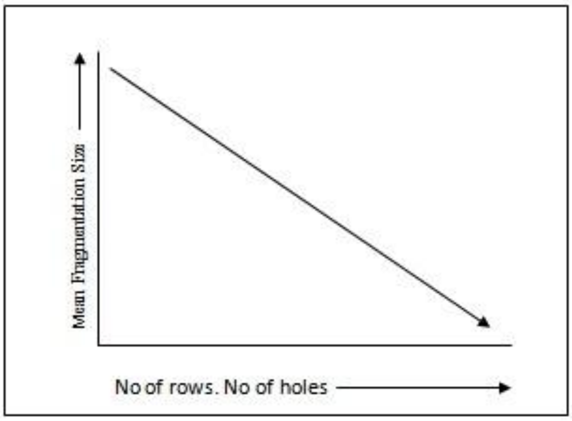

Figure25.Non-significant parameters

Influencing parameters on Muck pile:

Significant parameters

1 Spacing 2.MFS 3.Depth of hole 4. Delay 5.Firing pattern 6.Burden 7.Charge length 8.Front row burden 9.No Rows 10.No Holes

Non-Significant parameters
1. Explosive 2.L/W Ratio

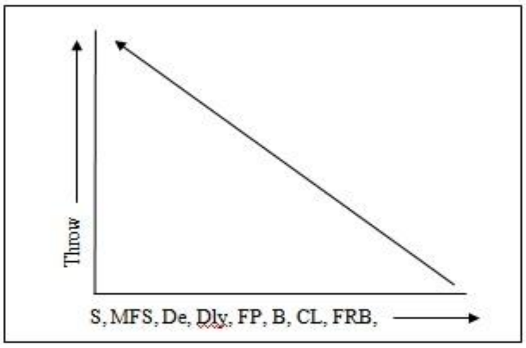

Figure 26.Significant parameters

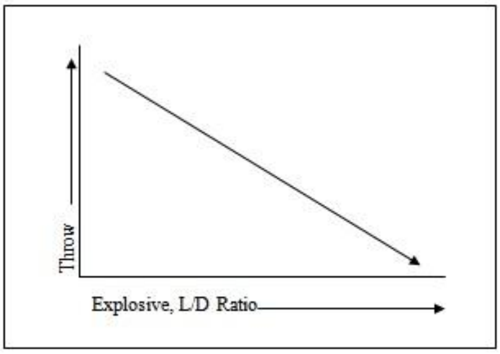

Figure27.Non-significant parameters

INDIAN CEMENTS:
Influencing parameters on MFS:

Significant parameters
1. Delay 2.No Rows 3.No Holes 4.Depth of hole 5.L/W Ratio

Non-Significant parameters
1. Front row burden 2.Burden 3.Spacing 4.Firing pattern 5.Throw

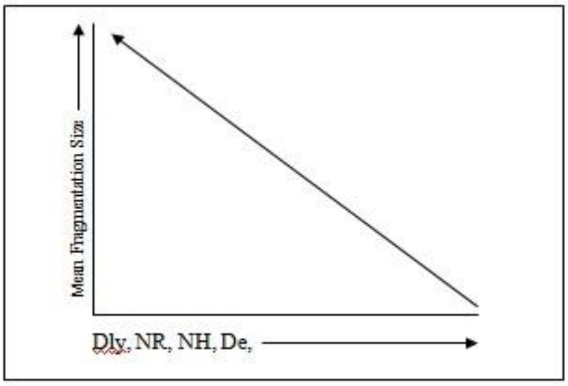

Figure 28. Significant parameters

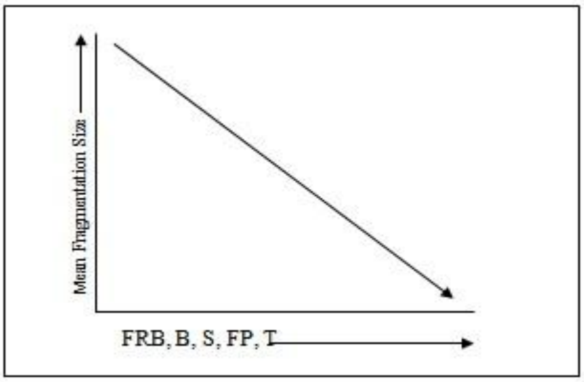

Figure 29.Non-significant parameters

Influencing parameters on Muck pile:
Significant parameters
1. Front row burden 2.Burden 3.Delay 4.Depth of hole 5.L/W Ratio 6. MFS
Non-Significant parameters
1. Spacing 2.No Rows 3.No Holes 4.Se/Be 5. Firing pattern

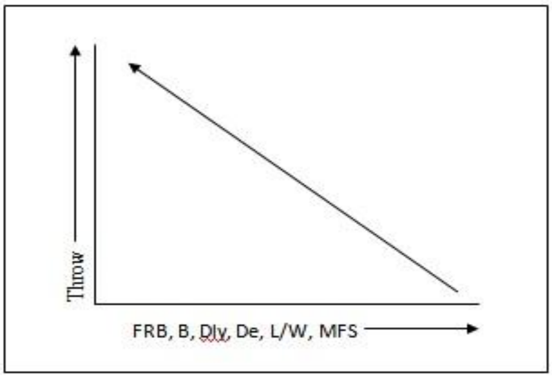

Figure 30.Significant parameters

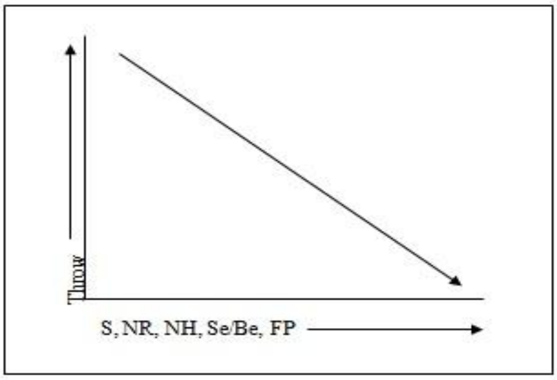

Figure 31.Non-significant parameters

VI. CONCLUSION

- PCA found that if Burden, Front Row Burden and Spacing decreases MFS will increase these are inversely proportional and from XLSTAT results given that Burden is negatively, Front Row Burden is positively and Spacing is orthogonally correlated

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- PCA found that if Explosive charge, Delay, Depth of the hole, No of holes, spacing burden ratio increase MFS will increase these are directly proportional and from XLSTAT results given that Explosive, Delay, Depth of the hole, No of holes, spacing burden ratio are positively correlated
- PCA found that if Burden, Front Row Burden, Firing pattern decrease/change throw will decrease both are directly proportional and from XLSTAT results given that Burden is positively. Front Row Burden positively correlated and firing pattern negatively correlated
- PCA found that if Explosive charge, Delay, Depth of the hole, spacing burden ratio increase throw will decrease both are inversely proportional and from XLSTAT results given that Explosive is negatively correlated and delay, depth of the hole, spacing burden ration positively correlated

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