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COMPARISON OF COMPUTER AIDED IMAGE ANALYSIS METHODS WITH STANDARD PHOTO METHOD FOR DETERMINATION OF MUCK PILE FRAGMENTATION

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Abstract

Blasting sector is a big expended sector globally in terms of cost and work. Determining results of blast is very important for fragmentation. In this study, muck pile fragmentation is determined by using standard photo method and Split – Desktop image analysis software. Total 21 blasting rounds were carried out and fragmentations were determined by using both methods. Obtained data were analyzed in detail by statistical analysis. It is shown that the results of both two methods were close to each other.
Keywords: Image analysis; Split - desktop software; Standard photo method; Blasting.

1 INTRODUCTION

Huge quantities of rock masses are blasted globally. Great operational costs are occurred every time. Large profits can be gained by little changes. A successful estimation of muck pile fragmentation can give a more profitable operation. A rapid determination of muck pile fragmentation evaluation should be carefully carried out. There are many studies about blast optimization. However, parameters of blasting are many and more complex. Therefore, it is necessity that blast trials to be carry out in-situ. Muck pile fragmentation obtained from blast trials must be determined rapidly. In addition, this way, we can determine the best suited blast pattern and its parameters. Fragmented limestone is used in cement production in great quantities and at building sector as an aggregate in cement mortar. The cheapest way to fragment limestone rock mass is by blasting. Blasted limestone is send to crushers to reduce its size. So producing fragments as fine as possible reduces the work of crushers thus the cost of breaking is reduced as well as the cost of loading [1,2]

Because fragmentation determination by sieving muck pile is too expensive and difficult by other methods than image analysis methods. Therefore, rapid estimation of muck pile fragmentation is very important. Evaluation from blasting tests results meaningful conclusions to be drawn for blasting trials. And test blasts can be meaningfully compared with each other [3-7]

2 IMAGE ANALYSIS METHODS

The keynote paper at Fragblast-5 workshop given by Cunningham [4] provides an excellent overview on automated measuring systems. The results of comparing FragScan, PowerSieve, Split and WipFrag image analysis systems using a photo-library of artificial muck pile to obtain their strengths and weaknesses is presented by Latham et al. [5]. The errors associated with image processing systems are commonly due to the following factors:

1. Particles on surface can be seen, but other particles at the bottom can't be seen. Particles on surface are similar to particles at the bottom, but they are not same. Image analysis can only process what is shown on the image, which represents only the surface of the objects.
2. In taking pictures, the surface must be perpendicular to viewing direction. Nevertheless, muck pile surface is sloping and neither vertical nor horizontal. Taking photo perpendicular to muck pile surface is difficult.
3. Some particles can cover the others. In addition, this way, some particles can be seen smaller than their real size.
4. Fines, specially at computer aided determining methods can cause error in determining fragmentation.
5. There are big particles generally gets collected at the bottom sides of muckpile slopes. This problem causes error in determining fragmentation.

In this study, 21 test blasts were carried out at six quarries, which they belong to four different companies. These quarries are shown in Table 1 [8]. Moreover, the 21 muck piles of blast rounds were evaluated by both standard photo method and Split – Desktop software.

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Table 1. List of quarries where test blasts are carried out

Name of Quarry	Stone type	Number of test trial
Konya Cement Factory	Limestone	10
Kartas company - Bozanonu	Limestone	2
Kartas company - Gumusgun	Limestone	3
Goltas Cement Factory	Limestone	2
Goltas Cement Factory	Clay	2
Bastas Cement Factory	Limestone	2

2.1 Standard Photographs (compa-photo) Method

Van aswegen and Cunningham [7] first introduced the estimation of fragmentation in blast muck pile by means of Standard photographs. The Rosin-Rammler distribution equation is generally used as approximating the size distribution of blast muck pile in assessment and evaluation in measurement of fragmentation. The Rosin-Rammler equation has two important parameters (S_{50} is the mean size of the muck pile and n is the index of uniformity). By determining these two parameters the size distribution can be found. The predictions of standard photograph method are found to be accurate by Ozkahraman [2]. Latham et al. [5] used standard photos (called photo-library of piles) for comparison of image analysis systems. The Rosin–Rammler distribution equation is generally accepted as approximating the size distribution of rock in blast muck pile. The equation is as follows:

$$\frac{R}{100} = e^{-0.693\left(\frac{X}{S_{50}}\right)n} \quad (1)$$

Where;

- R is the ratio of fragments larger than X in Equation (1),
- S_{50} is the mean size of the muck pile fragments (This is also the minimum screen size from which the 50% of the muck pile pass),
- n is the index of uniformity.

The standard photos of Ozkahraman [2] were used for comparison of image analysis systems. Each examined photo size was increased or decreased at personel computer for coupling standard photos. Fragmentation coefficients obtained from compa - photo image analysis method at different test blasts are shown in Table 2.

The evaluation of Bozanonu limestone quarry round 1 result is as follows as example work: The fragmentation was measured on digital photo as shown in Figure 1. The standard photo technique was used and the muck pile photo is compared with standard photos Ozkahraman [2] and its found that it resembles to standard photo with n = 1.25 and S_{50}= 5 mm. Thus, the size distribution was determined as follows: The diameter of the pink balls are 6 mm and 4 mm. giving reduction rate of 210/5 = 42.

Table 2. Fragmentation coefficients obtained from compa - photo image analysis method at different test blasts

Blast Tests	Photo Image	Index of uniformity	Mean Fragment size
	Reduction rate	n	S_{50} (Cm)
Konya 1	47.5	1	23.8
Konya 2	67.9	1.25	33.9
Konya 3	115.1	1	39.6
Konya 4	70.4	1	35.2
Konya 5	54.3	1.5	27.1
Konya 6	54.3	1.25	27.1
Konya 7	56.7	1	25.3
Konya 8	55.9	1	27.9
Konya 9	48.7	1	24.4
Konya 10	47.5	1	23.8
Gumusgun 1	38	1.25	19.0
Gumusgun 2	61.1	1.25	30.6
Gumusgun 3	36.7	1.5	14.7
Bozanonu 1	42	1.25	21.0
Bozanonu 2	21	1.5	10.5
Goltas Clay 1	28.7	1	14.4
Goltas Clay 2	26.4	1.5	13.2
Goltas Limes.1	47.1	1	23.6
Goltas Limes.2	48.5	1	24.3
Bastas 1	50.9	1.25	25.5
Bastas 2	37.1	1.5	18.5

The cumulative 50% passing size of muck pile is therefore is S_{50} = 42 × 5 = 210 mm.

Evaluation results of 10 rounds which were carried out at Konya Cement Factory limestone quarry is shown in Table 3. Evaluation of 5 rounds which were carried out at Kartas Company's Gumusgun and Bozanonu limestone quarries is shown in Table 4. Evaluation of 6 rounds which were carried out at Goltas Cement Factory Clay quarry, limestone quarry and Bastas Cement Factory limestone quarry is shown in Table 5.

2.2 Split – Desktop Software

Crop function is the first process at evaluations. Using crop function valuable area is separated in whole photo. We can choice rectangular area by Crop function. Then, we can further choice by mask function as rectangular, polygonal and free hand type (Figure 2). Scaling object that has a known size is used in split software method. According to Split – Desktop, there must be two scaling object at least. Otherwise, Split – Desktop will not evaluate. Scaling size can be entered as millimeter, centimeter or inch in the software programme. It is important that scaling object is spherical. Otherwise, scaling object direction and taking photo direction must be perpendicular to each other. But it is difficult. Therefore, obtained results can not be reliable.

Figure 1. Muck pile used for measuring size distribution of muckpile fragmentation by standard photograph method in Bozanonu limestone quarry round 1.

Table 3. Fragmentation size distribution, which is weight % retained (cumulative oversize) at Konya cement factory limestone quarry blasting tests (by Standard photo method)

Size(cm)	Round Number									
	I	II	III	IV	V	VI	VII	VIII	IX	X
300	0.0	0.0	0.5	0.3	0.0	0.0	0.0	0.1	0.0	0.0
200	0.3	0.2	3.0	1.9	0.0	0.0	0.4	0.7	0.3	0.3
150	1.3	1.2	7.2	5.2	0.0	0.3	1.7	2.4	1.4	1.3
100	5.4	6.9	17.4	14.0	0.7	2.9	6.5	8.4	5.8	5.4
70	13.0	18.0	29.4	25.2	5.7	10.4	14.7	17.6	13.7	13.0
50	23.2	32.5	41.7	37.4	17.7	22.6	25.5	28.9	24.1	23.2
40	31.1	42.7	49.6	45.5	28.9	32.5	33.5	37.1	32.0	31.1
30	41.7	55.2	59.1	55.4	44.7	45.6	44.0	47.5	42.6	41.7
20	55.8	69.9	70.5	67.4	64.5	62.3	57.9	60.9	56.6	55.8
15	64.6	77.9	76.9	74.4	75.2	71.9	66.3	68.9	65.3	64.6
10	74.7	86.0	83.9	82.1	85.6	82.0	76.1	78.0	75.2	74.7
5	86.4	93.9	91.6	90.6	94.7	92.0	87.2	88.3	86.7	86.4

Table 4. Fragmentation size distribution, which is weight % retained (cumulative oversize) at Kartas Company limestone quarries blasting tests (by Standard photo method)

Size(cm)	Gumusgun Round I	Gumusgun Round II	Gumusgun Round III	Bozanonu Round I	Bozanonu Round II
300	0.0	0.0	0.0	0.0	0.0
150	0.0	0.6	0.0	0.0	0.0
100	0.4	4.7	0.0	0.8	0.0
70	2.9	14.2	0.1	4.4	0.0
50	9.8	27.7	1.3	12.9	0.1
40	17.3	37.9	4.4	21.2	0.6
30	29.3	50.8	13.2	33.9	3.5
20	47.8	66.5	33.2	52.1	16.2
15	59.7	75.2	48.9	63.4	30.6
10	73.3	84.2	67.7	76.1	52.5
5	87.8	93.0	87.1	89.1	79.6

Table 5. Fragmentation size distribution, which is weight % retained (cumulative oversize) at Goltas cement factory limestone, clay quarries and Bastas cement factory limestone quarry blasting tests (by Standard photo method)

Size(cm)	Goltas Clay Round I	Goltas Clay Round II	Goltas Limestone Round I	Goltas Limestone Round II	Bastas Limestone Round I	Bastas Limestone Round II
300	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.3	0.3	0.0	0.0
150	0.1	0.0	1.2	1.4	0.2	0.0
100	0.8	0.0	5.3	5.8	2.2	0.0
70	3.4	0.0	12.8	13.6	8.6	0.6
50	8.9	0.6	23.0	24.0	20.0	4.6
40	14.5	2.6	30.9	31.9	29.6	11.1
30	23.5	9.3	41.4	42.5	42.7	24.0
20	38.1	27.5	55.5	56.5	59.9	46.0
15	48.5	43.2	64.3	65.2	69.9	60.3
10	61.7	63.3	74.5	75.2	80.6	76.0
5	78.6	85.1	86.3	86.7	91.3	90.7

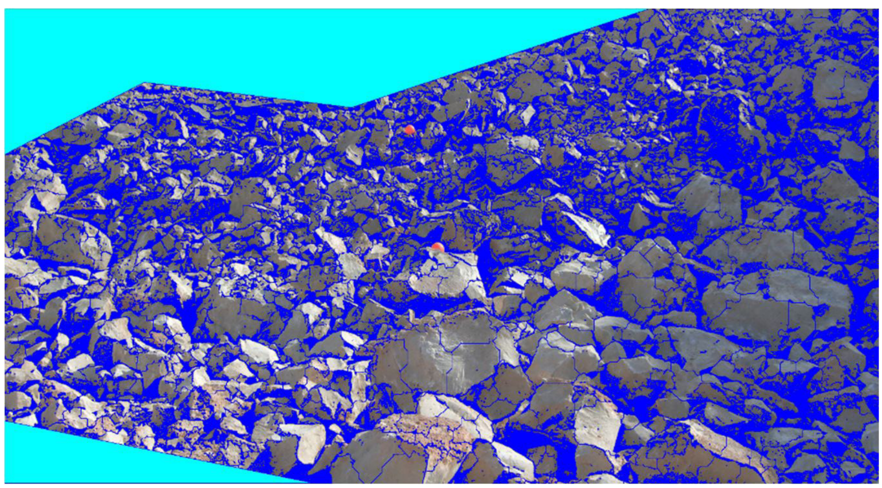

Figure 2. Using mask function at Split – Desktop.

We have to prefer spherical objects to overcome this difficulty in scaling for successful evaluation. Better boundary editing provides better confident results (Figure 3).Corners of rocks can be sensed by Split - Desktop as if two part rocks. In this way we must help to Split – Desktop for right evaluation. This is serious problem. Other serious problem is that two collocation parts can be sensed as if one part. This problem can often be seen. We must help to Split – Desktop for solving this problem by using boundary editing function. Sometime, a few parts can be sensed one parts by Split – Desktop. We have to help to Split – Desktop for right evaluation. It is expected that Split – Desktop will be improved in future. Split – Desktop serves photo-editing function as mask, crop and fines. Superiority of Split – Desktop can be increased by well determining fines area. Because of important effect on result, value of fines must be chosen properly.By using menus of the software, at Results options, sieve series, graph types and fonts, graph color, replaced data on result can be determined (Figure 4). Determined sieve series can be saved as a file. The help menu contains widely information and examples.

Any work can be saved as a project file which is extended .desk, completely scaling, the determined sieve, boundary editing, mask, fines etc. Split – Desktop can serve graph result, table or excel file and can send printer. For whole success, carefully computer drawing must be done for delineating, masking, boundary editing. It is need for this processes that patient, time and skill. Almost taking photo is very important for successful evaluation. Photo must be clear and as much close-up as possible. In addition, it is important that angle of arrival of the light to muck pile and sun light direction according to taking photo direction. Although it has some inefficiency in the evaluation of the muck pile fragmentation results, Split – Desktop is an important alternative in measuring fragmentation. The obtained results of Split – Desktop software are as follows: Totally

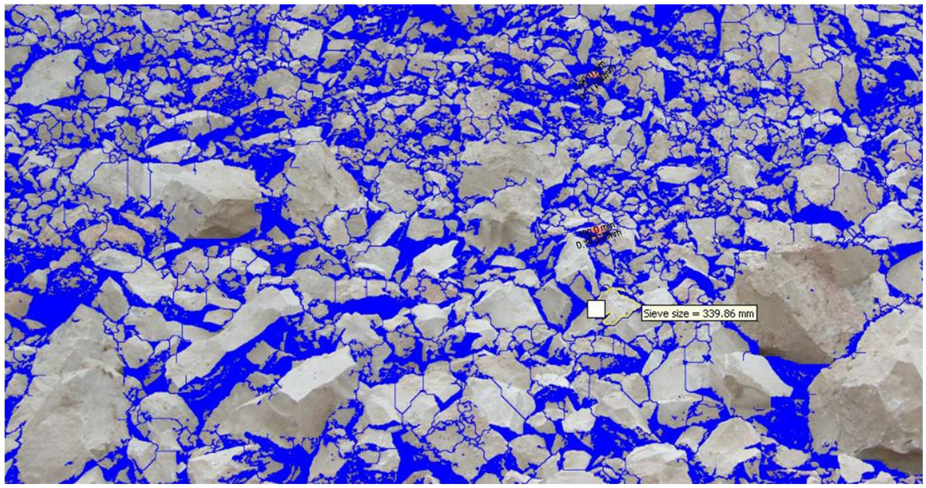

Figure 3. Screen of boundary editing and delineating.

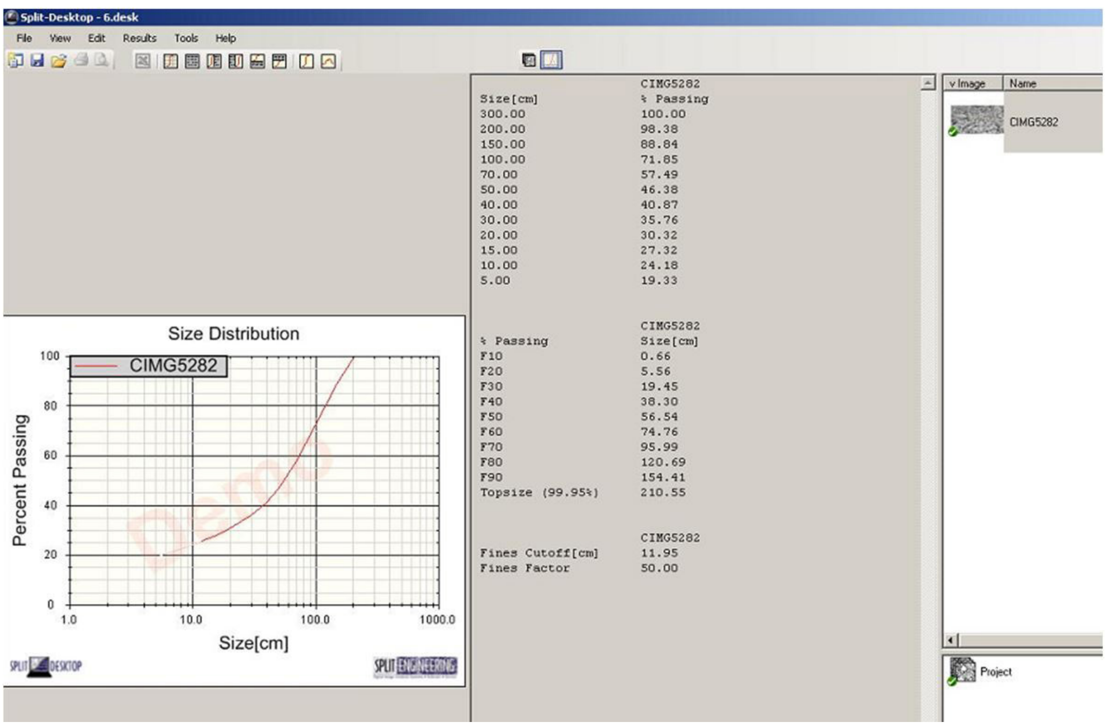

Figure 4. Screen of result of Split - Desktop.

10 rounds muck pile that were carried out Konya cement factory limestone quarry fragmentation results are shown in Table 6. Totally 5 rounds muck pile which were carried out Kartas company's Bozanonu and Gumusgun limestone quarries fragmentation results are shown in Table 7.

Totally 6 rounds muck pile which were carried out Goltas cement factory limestone quarry, clay quarry and Bastas cement factory limestone quarry fragmentation results are shown in Table 8.

3 RESULTS AND STATISTICALLY ANALYSES

At each size fraction, data obtained according to weight percent retained cumulative oversize, descriptive statistics and paired samples t- test results are shown in Table 9 for Konya cement factorys' limestone quarry; in Table 10 for Kartas company's Bozanonu and Gumusgun limestone quarries; in Table 11 for Goltas cement factory limestone quarry, clay quarry and Bastas cement factory

Table 6. Fragmentation size distribution, which is weight % retained (cumulative oversize) at Konya cement factory limestone quarry blasting tests (by Split - Desktop)

Size (cm)	Rounds									
	I	II	III	IV	V	VI	VII	VIII	IX	X
300	0.0	0.0	4.7	15.1	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	6.7	24.6	28.5	0.0	0.0	1.5	0.0	0.0	0.0
150	2.6	14.1	37.1	33.2	3.5	2.0	9.3	5.1	0.0	0.5
100	7.4	25.1	46.9	39.5	17.8	16.7	22.2	13.1	9.1	10.1
70	12.7	35.9	53.2	45.7	28.8	31.1	32.9	19.1	24.8	23.6
50	22.4	45.1	57.9	50.5	38.3	42.4	41.7	28.8	39.5	38.7
40	30.5	49.9	60.4	52.8	45.3	48.4	46.9	37.7	47.2	47.2
30	41.6	54.6	63.2	55.7	54.2	54.3	52.7	48.8	54.9	55.1
20	53.9	59.5	66.0	59.7	63.8	60.8	58.6	60.1	63.0	63.1
15	61.2	63.2	68.0	62.3	69.4	65.3	62.5	66.7	68.0	68.5
10	69.5	67.9	70.6	65.7	75.9	70.7	67.4	74.2	74.0	74.7
5	79.8	74.5	74.6	70.9	84.0	78.2	74.4	83.3	81.8	82.7

Table 7. Fragmentation size distribution, which is weight % retained (cumulative oversize) at Kartas company's Bozanonu and Gumusgun limestone quarries blasting tests (by Split - Desktop)

Size (cm)	Gumusgun Round I	Gumusgun Round II	Gumusgun Round III	Bozanonu Round I	Bozanonu Round II
300	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	0.0
150	0.0	0.0	0.0	0.0	0.0
100	0.0	4.1	0.3	0.1	0.0
70	1.6	19.1	2.8	2.0	0.0
50	8.8	36.3	9.4	10.7	0.0
40	17.1	45.2	17.5	21.5	0.5
30	31.0	52.8	29.3	37.7	5.4
20	49.1	60.7	43.5	57.0	20.3
15	58.2	66.2	50.7	66.7	32.3
10	68.7	72.6	59.9	76.9	47.1
5	81.0	80.9	71.7	87.7	63.7

Table 8. Fragmentation size distribution, which is weight % retained (cumulative oversize) at Goltas cement factory limestone quarry, clay quarry and Bastas cement factory limestone quarry blasting tests (by Split - Desktop)

Size (cm)	Goltas Clay Round I	Goltas Clay Round II	Goltas Limestone Round I	Goltas Limestone Round II	Bastas Limestone Round I	Bastas Limestone Round II
300	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.0	0.0	0.0	2.1	0.0
150	0.0	0.0	3.4	0.0	9.4	0.0
100	0.0	0.0	9.1	2.3	18.8	0.3
70	0.8	0.0	16.3	13.5	26.1	5.3
50	5.7	0.2	26.2	26.2	34.4	14.7
40	11.9	1.9	33.8	33.4	40.0	22.1
30	22.9	8.3	42.9	40.3	46.8	30.6
20	38.2	27.9	52.6	47.9	55.0	39.0
15	47.2	42.2	58.7	53.4	59.0	44.7
10	56.7	56.8	65.9	60.2	64.5	51.9
5	69.6	74.1	75.5	69.5	72.2	62.1

Table 9. Descriptive statistics and paired samples t- test results for Konya cement factory limestone quarry blasting tests (n=12)

	Mean	Std. Error	P*	Correlation	P§
Round1(St.Photo)	33.125	8.9650	0.099	0.999	0.000
Round1(Split D.)	31.800	8.3027			
Round2(St.Photo)	40.367	10.2668	0.805	0.957	0.000
Round2(Split D.)	41.375	7.1880			
Round3(St.Photo)	44.233	9.4366	0.120	0.903	0.000
Round3(Split D.)	52.267	6.0152			
Round4(St.Photo)	41.617	9.3919	0.210	0.955	0.000
Round4(Split D.)	48.300	4.7878			
Round5(St.Photo)	34.808	10.5711	0.150	0.956	0.000
Round5(Split D.)	40.083	8.7207			
Round6(St.Photo)	35.208	9.9721	0.269	0.948	0.000
Round6(Split D.)	39.158	8.2631			
Round7(St.Photo)	34.483	9.0637	0.139	0.955	0.000
Round7(Split D.)	39.175	7.4782			
Round8(St.Photo)	36.567	9.1891	0.841	0.998	0.000
Round8(Split D.)	36.408	8.6134			
Round9(St.Photo)	33.642	9.0040	0.035	0.974	0.000
Round9(Split D.)	38.525	8.8976			
Round10(St.Photo)	33.125	8.9650	0.018	0.975	0.000
Round10(Split D.)	38.683	8.9431			

*Significant level of paired samples t- test. §Significant level of Correlations.

Table 10. Descriptive statistics and paired samples t- test results for Kartas company's Bozanonu and Gumusgun limestone quarries blasting tests (n=12)

	Mean	Std. Error Mean	P*	Correlation	P§
Round1(St.Photo)	27.3525	9.21362	0.156	0.998	0.000
Round1(Split D.)	26.2958	8.75433			
Round2(St.Photo)	37.9175	10.14742	0.488	0.987	0.000
Round2(Split D.)	36.4808	8.89059			
Round3(St.Photo)	21.3158	8.87747	0.356	0.964	0.000
Round3(Split D.)	23.7483	7.62927			
Round4(St.Photo)	29.4867	9.45834	0.447	0.998	0.000
Round4(Split D.)	30.0158	9.72267			
Round5(St.Photo)	15.2592	7.54608	0.452	0.991	0.000
Round5(Split D.)	14.1017	6.37873			

*Significant level of paired samples t- test. §Significant level of Correlations.

Table 11. Descriptive statistics and paired samples t- test results for Goltas cement factory limestone quarry, clay quarry and Bastas cement factory limestone quarry blasting tests (n=12)

	Mean	Std. Error Mean	P*	Correlation	P§
Round1(St.Photo)	23.1650	7.87649	0.022	0.997	0.000
Round1(Split D.)	21.0875	7.33971			
Round2(St.Photo)	19.2967	8.48029	0.123	0.998	0.000
Round2(Split D.)	17.6292	7.60180			
Round3(St.Photo)	32.9617	8.95286	0.530	0.995	0.000
Round3(Split D.)	32.0292	7.77509			
Round4(St.Photo)	33.5750	8.99949	0.034	0.991	0.000
Round4(Split D.)	28.8975	7.38638			
Round5(St.Photo)	33.7533	9.85895	0.604	0.960	0.000
Round5(Split D.)	35.6883	7.12133			
Round6(St.Photo)	26.1067	9.65145	0.362	0.967	0.000
Round6(Split D.)	22.5642	6.53285			

*Significant level of paired samples t- test. §significant level of Correlations.

limestone quarry. Examination of this study, descriptive statistics were accounted and paired t test was used comparing two method. Statically analyses were made by SAS software [9]. According to Table 9, there is only significantly difference between Split Desktop and Standard Photo for Round9 and Round10 (P*<0,05). There is no significantly difference other Rounds (P>0,05). All pairs were found to be highly significantly positively correlated (P§<0,001). According to Table 10, there is no significantly difference all Rounds (P>0,05). All pairs were found to be highly significantly positively correlated(P§<0,001). According to Table 11, there is only significantly difference between Split Desktop and Standard Photo for Round1 and Round4 (P*<0,05). There is no significantly difference other Rounds (P*>0,05). All pairs were found to be highly significantly positively correlated (P§<0,001).

4 CONCLUSION

According to results obtained, at 17 trials of total 21 trials, p value is over 5%. This means both methods give close values to each other. Nevertheless, p values at other four trials are also close to 5%. It is estimated at the four trials, quality of photo and daylight of muck pile are not sufficient. At total 21 blast tests, all values of Sig. at paired samples correlations are zero. In addition, linear relations are good. All values of correlation are higher than 90%. Especially, at image analyses methods such as Split – Desktop image analysis which is a computer aided method, the photos must be clear and as much close-up as possible, giving a more detailed view. Also the angle of arrival of the light and sun light direction according to taking photo direction is important. At standard photo method, poor of photo image quality can be tolerated little. However, at image analyses method computer aided, quality of photo image is very important. For example, little shadows of fragments on photo image affect fragmentation result. According to statistically evaluations, estimation of muck pile fragmentation at both standard photo (compa – photo) and Split – Desktop software method, successfully results can be obtained. Although some weaknesses features which they can be solved in future, in the evaluation of the muck pile fragmentation results, Split – Desktop is important alternative. Sometime, a few thin particle in contact can be sensed as one particle by Split - Desktop. This is caused by programme error in delineating fragment boundaries. Therefore it is recommended that computer aided methods for image analyses such as Split – Desktop will be improved accordingly.

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