# Optimizing the Specific Charge for Limestone Blasting at Aruwakkalu Limestone Quarry

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**Abstract**

The largest open pit limestone mine in Sri Lanka operated by Siam City Cement Lanka Limited is located at Aruwakkalu, Puttalam. The red soil overburden is directly excavated and low grade and high grade limestone layers are drilled and blasted. Specific charge plays a vital role in open pit blast design as it affects many operational costs in mining activities. An optimum specific charge with proper fragmentation not only reduces costs but also reduces undesirable effects like ground vibration, fly rock and air blast over pressure [1]. When optimizing the specific charge, it was decided to change the charging method by creating air decks and evaluate the fragmentation of the blasted material, because it was often difficult to accomplish several elements of improvement simultaneously. Fragment size directly affects the downstream operations like loading, transporting and crushing [2]. Two computer softwares, 'JKSimBlast' and 'Split-Desktop' were used to analyse fragmentation of material where the 'JKSimBlast' was used to simulate and analyze the modelled blasts while the 'Split-Desktop' was used to analyze the blasted material. The analysis of data by the software and cost analysis reveal that top column air deck charging method would save the cost of blasting by about 11% and the Specific Charge value is reduced by 19%, resulting in reasonable fragmentation and size distribution.

**Keywords:** Air deck charging method, Fragmentation, JKSimBlast, Split-Desktop

## 1. Introduction

Specific Charge refers to the quantity of explosives required to blast a unit volume of rock [3]. In other words, specific charge is a numerical indication of the explosive distribution on a bed. Generally, when the specific charge is increased, the total operating cost, first reduces and again increases. Therefore, the optimum specific charge would be found at the minimum operating cost [4]. However, the specific charge value stipulated by the Geological Survey & Mines Bureau (GSMB) is 0.15 kg/mt at the Aruwakkalu quarry.

High capacity machines result in high operational costs due to increased fuel consumption, maintenance, accessories and so on. Therefore, quarry engineering plans are highly effective in achieving the best performance from the machines. Performance of them, especially the

excavating and transporting equipment, are largely influenced by the blast results, particularly, fragment size, distribution of the muck profile. Therefore, a well-designed blast plan has a great impact on the cost of mining [5].
As the management of company stated that the amount of explosive used is excessive in blasting process at present quarry. If the specific charge is reduced keeping other factors unchanged, lesser amount of explosives has to be charged into blast holes that would result in poor fragmentation. Thus, operating costs may increase in loading, hauling and crushing.
The current blast geometry has been applied for a number of years. In the first phase of this research carried out recently, number of test blasts has been carried out in the direction of minimizing the specific charge with changing variables and assessing the fragmentation levels.
Hence, this research is aimed at optimizing the specific charge for limestone blasting at the Aruwakkalu limestone quarry, leading to an optimum fragmentation level of the blasted rock mass with further variation of the blast design as a continuation of the first phase concluded.

## 2. Methodology

Basically, the methodology of this research can be devided into four main steps.
**Step 1** - Blast simulation and analysis using JKSimBlast software.
**Step 2** – Conducting test blasts.
**Step 3** – Fragmentation analysis using Split-Desktop software.
**Step 4** – Evaluation of cost of test blasts.

### 2.1 Blast Simulation and Analysis using JKSimBlast

All the test blasts were modelled and analyzed using JKsimblast software prior to implementations in the real field. A fragmentation curve and energy distributions at different levels were obtained using JKsimblast.

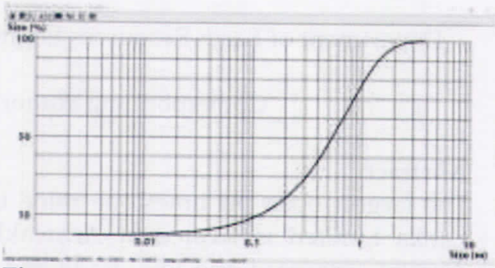

**Figure 1 – Fragmentation curve obtained from JKSimBlast**

### 2.2 Conducting Test Blasts

All simulated blasts were conducted in the field according to the measurements of modelled.

Parameters which have not been changed during all the Test Blasts are tabulated in Table 1.

**Table 1 – Constant parameters**

| Parameters | Description |
|---|---|
| Spacing | 2.8 m |
| Burden | 2.5 m |
| Hole Diameter | 76 mm |
| Drilling pattern | Staggered |
| Hole inclination | vertical |
| Primary Explosive | Water Gel |
| Secondary explosive | ANFO |
| Delay interval | 25 ms |

Summeries of Test Blasts conducted are shown below in Table 2 to Table 6.

**Table 2 – Summary of Test Blast 1**

| Description | Test Blast 1 |
|---|---|
| Date of blast | 8/11/2017 |
| No. of holes | 120 |
| Hole depth (m) | 10 |
| Charging Method | Bottom Charging |
| Tonnage (mt) | 20160 |
| **Water Gel** | |
| Water Gel per hole (nos.) | 10 |
| Water Gel per hole (kg) | 1.5 |
| Water Gel per blast (kg) | 180 |
| **ANFO** | |
| ANFO per hole (kg) | 25 |
| ANFO per blast (kg) | 3000 |
| ANFO per blast (bags) | 120 |
| Diesel (L) | 240 |
| **Electric Detonators (25 ms)** | |
| 1 | 12 |
| 2 | 16 |
| 3 | 20 |
| 4 | 22 |
| 5 | 17 |
| 6 | 16 |
| 7 | 10 |
| 8 | 7 |
| Total | 120 |
| **Further details** | |
| Specific charge (kg/mt) | 0.158 |
| Specific drilling (m/mt) | 0.060 |

**Table 3 – Summary of Test Blast 2**

| Description | Test Blast 2 |
|---|---|
| Date of blast | 9/14/2017 |
| No. of holes | 32 |
| Hole depth (m) | 6 |
| Charging Method | Middle Column Air Decking (0.5m) |
| Tonnage (mt) | 3225.6 |
| **Water Gel** | |
| Water Gel per hole (nos.) | 8 |
| Water Gel per hole (kg) | 1 |
| Water Gel per blast (kg) | 32 |
| **ANFO** | |
| ANFO per hole (kg) | 10 |
| ANFO per blast (kg) | 320 |
| ANFO per blast (bags) | 13 |
| Diesel (L) | 26 |
| **Electric Detonators (25 ms)** | |
| 0 | 6 |
| 1 | 5 |
| 2 | 5 |
| 3 | 2 |
| 5 | 5 |
| 7 | 4 |
| 9 | 5 |
| Total | 64 |
| **Further details** | |
| Specific charge (kg/mt) | 0.109 |
| Specific drilling (m/mt) | 0.060 |

**Table 4 – Summary of Test Blast 3**

| Description | Test Blast 3 |
|---|---|
| Date of blast | 10/12/2017 |
| No. of holes | 28 |
| Hole depth (m) | 10 |
| Charging Method | Middle Column Air Decking (1m) |
| Tonnage (mt) | 4704 |
| **Water Gel** | |
| Water Gel per hole (nos.) | 10 |
| Water Gel per hole (kg) | 1.25 |
| Water Gel per blast (kg) | 35 |

| | |
|---|---|
| **ANFO** | |
| ANFO per hole (kg) | 20 |
| ANFO per blast (kg) | 560 |
| ANFO per blast (bags) | 23 |
| Diesel (L) | 46 |
| **Electric Detonators (25 ms)** | |
| 1 | 4 |
| 7 | 16 |
| 8 | 18 |
| 9 | 18 |
| Total | 56 |
| **Further details** | |
| Specific charge (kg/mt) | 0.126 |
| Specific drilling (m/mt) | 0.060 |

**Table 5 – Summary of Test Blast 4**

| **Description** | **Test Blast 4** |
|---|---|
| Date of blast | 10/26/2017 |
| No. of holes (nos.) | 32 |
| Hole depth (m) | 10 |
| Charging Method | Top Column Air Decking (1m) |
| Tonnage (mt) | 5376 |
| **Water Gel** | |
| Water Gel per hole (nos.) | 10 |
| Water Gel per hole (kg) | 1.25 |
| Water Gel per blast (kg) | 40 |
| **ANFO** | |
| ANFO per hole (kg) | 20 |
| ANFO per blast (kg) | 640 |
| ANFO per blast (bags) | 26 |
| Diesel (L) | 52 |
| **Electric Detonators (25 ms)** | |
| 0 | 3 |
| 2 | 4 |
| 4 | 6 |
| 6 | 7 |
| 7 | 5 |
| 9 | 6 |
| Total | 31 |
| **Further details** | |
| Specific charge (kg/mt) | 0.126 |
| Specific drilling (m/mt) | 0.060 |

**Table 6 – Summary of Test Blast 5**

| **Description** | **Test Blast 5** |
|---|---|
| Date of blast | 11/10/2017 |
| No. of holes (nos.) | 12 |
| Hole depth (m) | 10 |
| Charging Method | Bottom Charging |
| Tonnage (mt) | 2016 |
| **Water Gel** | |
| Water Gel per hole (nos.) | 10 |
| Water Gel per hole (kg) | 1.25 |
| Water Gel per blast (kg) | 15 |
| **ANFO** | |
| ANFO per hole (kg) | 25 |
| ANFO per blast (kg) | 300 |
| ANFO per blast (bags) | 12 |
| Diesel (L) | 24 |
| **Electric Detonators (25 ms)** | |
| 5 | 4 |
| 7 | 4 |
| 9 | 4 |
| Total | 12 |
| **Further details** | |
| Specific charge (kg/mt) | 0.156 |
| Specific drilling (m/mt) | 0.060 |

### 2.3 Fragmentation Analysis using Split-Desktop Software

Muck pile of each and every test blasts were photographed. Then the digital images were fed into the Splitdesk software, delineated and modified using the Splitdesk software and a fragmentation curve was obtained for each Test Blast.

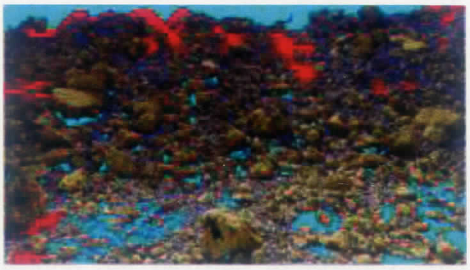

**Figure 2 – Delineated image by Split-Desktop software**

### 2.4 Evaluation of Cost of Test Blasts

Costs of each test blast is calculated considering the norms given in Table 7 which have been identified as main cost factors.

**Table 7 – Unit cost factors**

| Description | Unit Cost (Rs) |
|---|---|
| Water Gel | 632.14/kg |
| ANFO | 128/kg |
| ED | 99.46 |
| Diesel | 95/L |
| Drilling | 282.01/m |
| Labor | 400/person |

## 3. Results

Results of each test blast is summarized in Table 8.

**Table 8 – Summerized results of the Test Blasts**

| Test Blast | Specific Charge | JKSimblast 80% passing partical size (mm) | SplitDesktop 80% passing partical size (mm) | Cost per ton(Rs) |
|---|---|---|---|---|
| 1 | 0.158 | 1068 | 738 | 43.28 |
| 2 | 0.109 | 1267 | 426 | 38.99 |
| 3 | 0.126 | 1061 | 769 | 39.18 |
| 4 | 0.126 | 1148 | 570 | 38.52 |
| 5 | 0.156 | 1081 | 703 | 48.62 |

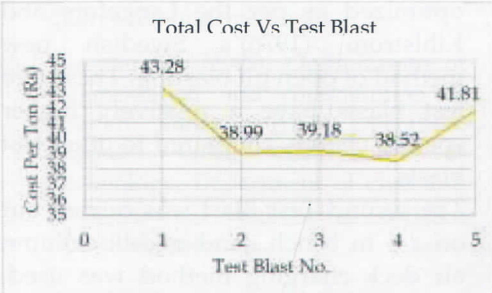


**Figure 3 – Total cost variation**

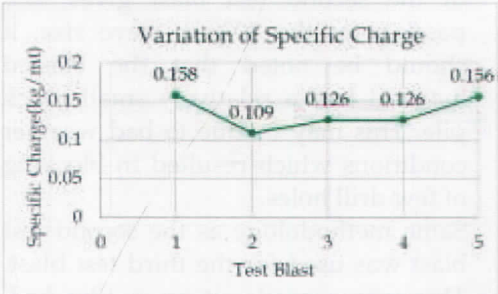


**Figure 4 – Specific Charge variation**

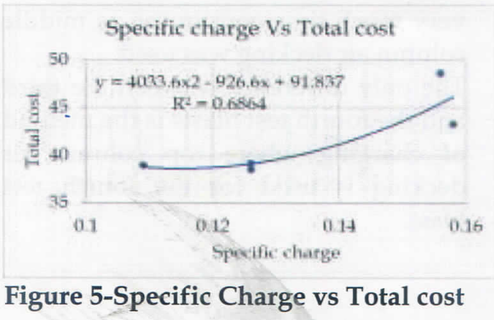


**Figure 5-Specific Charge vs Total cost**

## 4. Discussion

Five test blasts were carried out to evaluate the impact of charging method in limestone blasting at Aruwakkalu quarry. First test blast was mainly conducted to get a basic idea about the blasting procedure at the site and to analyse the resultant particle size distribution. Existing blasting technique and blasting parameters being practiced at the quarry were used in the first test blast as well as the fifth test blast. At Aruwakkalu, bottom charging method is normally followed. It also indicated that blasting parameters such as spacing and burden are already optimized as per the Langefors and Kihlstrom (1976)'s Swedish new method of open pit blasting. These two test blasts have a relatively higher specific charge, compared to other test blasts.

The second Test Blast was carried out on a 6 m bench, And middle column air deck charging method was used. Although the fragmentation analysis of the second test blast gives 99% passing for the 800mm sieve size, it should be noted that the blasted material had a relatively small muck pile. This may be due to bad weather conditions which resulted in blocking of few drill holes.

Same methodology as the second test blast was used for the third test blast. This was carried out on a 10m bed. Both second and third test blasts were very much time consuming as middle column air decking was used.

The only difference between the third and the fourth test blasts is the method of charging where top column air decking is used for the fourth test blast.

## 5. Conclusions

• According to the variation of Specific Charge vs. Total cost, the total cost of blasting would be optimized when specific charge is 0.119 kg/mt.

• Analysis of the first test blast and the fifth test blast shows that the existing methodology being adopted at the quarry has a higher total cost with fragmentation analysis in the both test blasts resulting in 84% passing through 800 mm sieve.

• The results of the second test blast were inconclusive as the blast was a partial misfire due to a number of drill holes getting blocked.

• Fragmentation analysis of the fourth test blast resulting in 89% passing through 800 mm sieve consuming relatively lesser charge time compared with test blasts two and three resulting in the least cost. Relatively better muck pile was also observed in this blast with a higher energy concentration at the bottom compared with the previous two blasts. Therefore, the blast geometry with top column air deck will be more effective than the others when costs and charged times are concerned.

• In comparison with simulations conducted with JKSimblast, Split-Desktop software gives relatively a higher fragmentation in all blasts (Refer Table 13 and Table 14). This may be due to geological variations.

• According to the results from the Split-Desktop software, the mean fragmentation is comparatively lower in the test blasts conducted with air decking.

• Finding a relationship among specific charge and other related blasting parameters could not be completed due to lack of data and time constraints.

• Rainy weather negatively affected conducting all the blasts.

• It is recommended that the optimization process should be repeated evaluating the impact of more blasting parameters such as blast hole diameter, explosive type, etc

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