# Application of Emulsion Explosive and Comparative Study on Water-Gel Explosives for Rock Quarrying in Sri Lanka

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**Abstract**

Dynamite has been the premier and the only high explosive used for mining and construction activities in Sri Lanka for a long period of time. Negative environmental impacts, effect on health and security hazards led to the Government of Sri Lanka (GOSL) to issue directives to find a suitable substitute for Dynamite. Subsequently, Water-Gel explosive was introduced in the year 2011. The poor performance of Water-Gels in wet conditions and it's low Velocity of Detonation encouraged the use of Emulsion explosives.

This research was focused on performing a comparative study of the performance of both Water-Gels and Emulsion explosives by analysis of the ground vibration and the blast air over pressures.

The methodology adopted was to conduct ten blasts at one single metal quarry site keeping all other parameters constant. Blasting tests were performed using Emulsion explosives and Water-Gel explosives and the resulting ground vibration and Air-Blast overpressures were measured with Blastmate 111model for each blast. Calculation of mean fragmentation was done and particle size distribution based on photographic evidence of each blast was analyzed. Analysis was carried out demarcating the resultant production pile of aggregates covering a cleared zone. Grid lines inserted on the muck pile facilitated particle counting using photographs and calculating the mean fragmentation.

**Keywords:** Air Blast Over Pressure, Emulsion, Explosive, Fragmentation, Ground Vibration, Water-gel explosives

## 1. Introduction

Dynamite was the premier and only high explosive used in Sri Lanka for mining during the period of the late nineteenth century up to year 2010.

It was very handy due to its high Velocity of Detonation and coupled with Ammonium Nitrate became very popular for a very long period. The unique property of Dynamite is its shelf life of tree years enabling it to be stored for a longer duration which had advantages and disadvantages. Storage ability for such a long period would have been an ideal property for a peaceful country, but the three decade of Eelam war in Sri Lanka the property was considered a security threat and its use was restricted during the ensuing period, thus creating a huge set back on the development process. The other main factor for the restriction of Dynamite was its high Detonating Velocity which resulted in negative impact on the environment, comparatively higher selling price coupled with health hazards for users.

These were the basic facts that initiated the GOSL to find a suitable substitution for Dynamite and after a professional study, a committee appointed by the Secretary of Defense, consisting officials from both, armed forces and professionals and a timely request by a local person to manufacture Water-Gel explosives was granted approval and was introduced in the years 2011/2012[1]. Introduction of Water-Gel explosives initially gathered a lot of criticism and due to its low detonating velocity which resulted in lower production, inability to perform in underwater wet conditions and tunnel blasting and the requirement of a detonator for initiation. Anyway, later on with adequate workshop and blasting tests conducted island wide users gradually accepted, that it can be used in open cast mining.

In the meantime, during the last decade, national mega hydropower projects which were handled by international companies opted to import Emulsion explosives, quoting the reason that Water-Gel explosives were unsuitable for underground and tunnel blasting. However, the world trend was moving forward the use of Emulsion explosives, due to its slight advantage of producing better detonating power and ability to use in wet conditions when compared with Water-Gel explosives [2].

Water-Gel explosives were manufactured by a single manufacturer and the mining industry was facing a disadvantage of a sudden breakdown of the industry. Keeping with the latest trend, the sole Water-Gel explosives manufacturer opted for the conversion of Water-Gel explosives plant, to Emulsion explosives which was granted approval. The sample production of this product has commenced, and samples are distributed island wide to be tested for its suitability in the mining industry in Sri Lanka. Breaking the monopoly of this industry, another manufacturer was also granted approval by the Ministry of Defense for the manufacture of Emulsion explosives which is a very good sign for the future of the mining industry.

## 2. Objective of the research

The main objective of this thesis is to study in detail, the application of Emulsion explosives. The comparative study of it, with Water-Gel explosives is a very appropriate study on the eve of the launch of Emulsion explosives in Sri Lanka.

## 3. Methodology

To perform, study and compare the performance of both Water-Gel, and Emulsion explosives by analyzing ground vibration and the blast air over pressure which was performed in the same site using identical parameters for each couple of blasts are as per Table 1.

Blasting tests were all performed at one single site in order to keep all other parameters the same. Six blasting tests were performed on the first day, and four blasting tests were performed the other day, as per

<table>
<tr><th colspan="6">Table 1- Blasting test schedule</th></tr>
<tr><th>Date</th><th>Location</th><th>Phase</th><th>Explosives Used</th><th>Constant Parameter</th><th>Readings</th></tr>
<tr><td rowspan="6">2016-07-15</td><td>Identical to phase 8</td><td>1</td><td>Emulsion</td><td rowspan="10">Burden<br>Spacing<br>Type of Explosive s<br>Quantity of explosives</td><td rowspan="10">1. Ground Vibration<br>2. Air Blast air Over Pressure<br>3Fragmenta tion<br>distribution</td></tr>
<tr><td>Identical to phase7</td><td>2</td><td>Water-Gel</td></tr>
<tr><td>Identical tophase10</td><td>3</td><td>Emulsion</td></tr>
<tr><td>Identical to phase 9</td><td>4</td><td>Water-Gel</td></tr>
<tr><td>Identical to each other</td><td>5</td><td>Emulsion</td></tr>
<tr><td>Identical to each other</td><td>6</td><td>Water-Gel</td></tr>
<tr><td rowspan="4">2016-08-05</td><td>Identical to phase 2</td><td>7</td><td>Emulsion</td></tr>
<tr><td>Identical to phase 1</td><td>8</td><td>Water-Gel</td></tr>
<tr><td>Identical to phase 4</td><td>9</td><td>Emulsion</td></tr>
<tr><td>Identical to phase 3</td><td>10</td><td>Water-Gel</td></tr>
</table>

Table 1. In both days, the adjacent holes were filled with Water-Gel and emulsion explosives while keeping all other parameters constant with the idea of performing an accurate comparison. The second day same locations were selected while keeping all the other parameters the same, as the earlier day, the holes which were filled with Emulsion was changed to Water-Gel explosives and vice versa and the idea was to compare the same location with either Water-Gel or Emulsion explosives. The result readings were recorded by installing two blast mates which were facilitated by the Geological Survey and Mines Bureau with the assistant of Mining Engineer and Technical Officers.

## 3.1 Calculation of Fragmentation by Using a Manual Methodology

The fragmentation analysis was carried out by the following manual procedure. The test blasting was performed at the end of the quarry face, and the resultant production of rubble fell into a cleared zone which was exactly 20m below the face. Eleven zones were demarcated starting from zone A to zone K. These demarcated zones were photographed separately. Grid lines, as illustrated below, with identical spacing's were developed in all images for easy calculation purpose.

Ten areas were randomly selected in each image, with grid lines and the following analysis was done to separate rock sizes in the following manner, below 5 cm in length, between 5 cm to 10 cm in length, between 10 cm to 20 cm in length, over 20 cm in length. Manual counting to separate sizes of rock was performed and an average calculation was done for each image. There after an average calculation of mean fragmentation was done for all the zones, starting from zone A to zone K.


**Figure 1 - Demarcated zones**

## 4. Result and Discussion

Dynamite was the prime high explosive that was used during the 16th to the 21st centuries, just before the invention of the Water-Gel and Emulsion explosives in the 21st century. Dynamite was highly accepted by the past miners, due to its very high shattering power, resulting in more yields over the negative impact on the environment and health was not considered a prime factor.

Thereafter during the last couple of decades, the world attention was aimed more towards the environment conversation and green technologies which have a direct result for the switching over from Dynamite to slurry explosives. Some countries have totally banned the use of dynamite and most of the other countries have switched over to the use of slurries.

The following major factors were the main causes for rejection of dynamite:

• The negative impact on the environment with a large amount of complains received by the relevant authorities, and some metal quarries closing down.

• The huge price difference and the cost of Water-Gel explosives being much less than Dynamite.

• The country was in the midst of the Eelam war and the Ministry of Defense and the relevant Security establishments were in the opinion that Dynamite can be used for insurgent activities.

• Dynamite was an imported commodity which resulted in short supply if procurement procedures fail, whereas Water-Gel and Emulsion explosives are manufactured locally.

Comparative studies and blasting tests were performed using locally produced Water-gel explosives and Emulsion explosives, samples under similar parameters. Summary of the above test blasts and the following observations were received.

Test blasts in phases 1, 2, 3, 4, 5 and 6 were performed on the first day, where 1, 3 and 5 phases were charged using Emulsion explosives and the rest of the phases, 2, 4 and 6 were charged using Water-Gel explosives. Test blasts for phases 7, 8, 9 and 10 were performed the next day with phases 7 and 9 being charged with Emulsion explosives, and 8 and 10 charged with Water-Gel explosives. This sequence of testing was performed in a way that phases 1 and 8, 2 and 7, 3 and 10, 4 and 9, 5 and 6 were performed in the identical location, thereby keeping all parameters equal but varying the type of explosives only. This methodology will create an accurate comparison between the two explosives. This charging methodology created another way of comparison because adjacent holes were again charged with different kinds of explosives, thereby creating another system to compare between the adjacent holes, which were in both ways and thereby enabling to get an accurate prediction.

**Table 2 - Comparison of GV and ABOP**

| Phase | Type of Explosive | Blast Mate Readings | | | |
|---|---|---|---|---|---|
| | | Blast mate A | | Blast mate B | |
| | | GV (m/s) | AOP (dB) | GV (m/s) | AOP (dB) |
| 07 | Emulsion | 0.440 | 115.4 | 0.20 | 94.0 |
| 02 | Water-Gel | 0.59 | 111.8 | 2.97 | 110.5 |
| 01 | Emulsion | 0.399 | 116.7 | 0.18 | 100.0 |
| 08 | Water-Gel | 0.912 | 103.5 | 0.26 | 102.8 |
| 03 | Emulsion | 0.102 | 104.2 | 0.22 | 100.0 |
| 10 | Water-Gel | 0.446 | 115.7 | 5.02 | 116.4 |
| 09 | Emulsion | 0.87 | 102.8 | 6.49 | 119.1 |
| 04 | Water-Gel | 0.085 | 103.5 | 3.88 | 120.0 |
| 05 | Emulsion | 0.197 | 110.9 | 0.22 | 100.0 |
| 06 | Water-Gel | 0.0794 | 101.9 | 1.93 | 107.0 |
| 01 | Emulsion | 0.399 | 116.7 | 0.18 | 100.0 |
| 02 | Water-Gel | 0.59 | 111.8 | 2.97 | 110.5 |
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**Table 3 - Summary of the aboveTable1**

| Phase | Blast Mate Readings | | | |
|---|---|---|---|---|
| | Blast mate A | | Blast mate B | |
| | GV (m/s) | AOP (dB) | GV (m/s) | AOP (dB) |
| 07&02 | less in Emulsion | less in Water-Gel | less in Emulsion | less in Emulsion |
| 01&08 | less in Emulsion | less in Water-Gel | less in Emulsion | less in Emulsion |
| 03&10 | less in Emulsion | less in Emulsion | less in Emulsion | less in Emulsion |
| 09&04 | less in Water-Gel | less in Emulsion | less in Water-Gel | less in Emulsion |
| 05&06 | less in Water-Gel | less in Water-Gel | less in Emulsion | less in Emulsion |
| 01&02 | less in Emulsion | less in Water-Gel | less in Emulsion | less in Emulsion |
| 01&04 | less in Water-Gel | less in Water-Gel | less in Emulsion | less in Emulsion |
| 03&02 | less in Emulsion | less in Emulsion | less in Emulsion | less in Emulsion |
| 07&10 | less in Emulsion | less in Emulsion | less in Emulsion | less in Emulsion |
| 09&07 | less in Emulsion | less in Water-Gel | less in Emulsion | less in Emulsion |
| 07&08 | less in Emulsion | less in Water-Gel | less in Emulsion | less in Emulsion |
| GV<br>AOP | less in Emulsion-8<br>less in Water-Gel-3 | less in Emulsion-4<br>less in Water-Gel-7 | less in Emulsion-10<br>less in Water-Gel-1 | less in Emulsion-11<br>less in Water-Gel-0 |
| GV<br>AOP | Less In Emulsion- 18<br>Less In Emulsion- 15 | Less In Water-Gel- 4<br>Less In Water-Gel -7 | | |

## 5. Overall Analysis

The tests recorded twenty two readings, with regard to ground vibration recordings and the overall situation is that in eighteen cases, recordings show that the ground vibration readings were low in emulsion explosives and were high in Water-Gel explosives. There were only four cases which recorded that Water-Gel explosives, recorded lower readings than Emulsion explosives.

In the four cases, only one blast recorded both reading with the less ground vibration for Water-Gel explosives and there were two other cases where only one blast mate recorded Water-Gel with lower readings and the other blast mate recorded Emulsion explosives with lower readings.

With regards to the air over pressure, same amount of readings were recorded by both the blast mates. The overall tally of recordings with less ground vibration in the air over pressure readings for Emulsion explosives was fifteen, and less ground vibration in the air over pressure readings for Water-Gel explosives was seven. There were no instances where both the readings in one blast test recorded higher value of air over pressure readings for Water-Gel explosives.

The overall analysis is that the percentage of Emulsion explosives recording lower ground vibration than Water-Gel was very high as 82%.

The overall analysis is that the percentage of Emulsion explosives recording lower ground vibration than Water-Gel was higher with 68 %.

Therefore it can be assumed, that the overall situation is that Emulsion explosives record lower ground vibration and air over pressure than the Water-Gel explosives.

## 6. Conclusion

The world trend has changed from Dynamite, to slurry explosives, and the local quarry industry experienced the transformation of Dynamite to Water-Gel explosives. Most of the countries worldwide had the transformation from Dynamite to Emulsion explosives, but the local scenario is different due to the factor that the local manufacture opted to produce Water-Gel explosives only. The quarry owners had no option but to get used to Water-Gel explosives. The disadvantage of Water-Gel explosives is that it could not be used under water and in underground mining projects. Due to this factor the major national project proponents who required high explosives were granted approved to import their consignment of Emulsion explosives by themselves. The present scenario is now different, and there are two manufacturers who have been granted approval for the manufacture of Emulsion explosives and presently samples are manufactured.

The main aim of this thesis is to study the application of Emulsion explosives and comparative study the two explosives Water-Gel explosives which are being presently used in Sri Lanka and Emulsion explosives promoted to substitute Water-Gel explosives in future.

As per instructions of my supervisors, comparative study which included ten blasting tests comprising of 100 bore holes was performed with the participation of the three supervisors, two officials from Geological Survey and Mines Bureau, Mining Engineers from the relevant quarry project and myself. The ten blasting tests were performed in two days where both

Water-Gel and Emulsion explosives used keeping all parameters such as location, space, burden and quantity same. The results were recorded at two locations by using blast mates provided by Geological Survey and Mines Bureau and Two Technical Officials from the Bureau.

Emulsion explosives are now being locally manufactured by one manufacturer, with the aim of marketing in future and presently only used at the experimental level by mainly major national projects in the country and the same samples were used for these tests. Water-Gel, which is available in the market, was used for these tests.

The evaluation of the above practical tests clearly indicates that Emulsion explosives when compared with Water-Gel explosives in ideal conditions, exhibits less ground vibration and less air over pressure and accompanies less environmental hazards in the usage.

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Blasting tests were performed at “Metal Mix” quarry, and hence wish to extend my gratitude to the staff who extended their valuable support on site.

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