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Application of High Speed Videography and Digital Image Processing Software to Assess Performance of Blasts In Opencast Mines: A Case Study

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ABSTRACT

Rock mass can be fragmented by the process of blasting in which a known volume of the yield is obtained by using a calculated quantity of explosive. The explosive selected for blasting depends on factors like rock mass parameters, blasting economics and blast design. Assessment of the performance of a given blast is essential in the larger economics of the mining project. A study was conducted to know the blast performance at two different mines. High speed videography was used to assess blast performance and wastage of gaseous energy. With the increase in stemming height from 1.0m to 3.5m, it was found that there is decrease in the escape of gas energy ejection from 7.42m height to 3.5m, which was almost half the height of ejection. The analysis showed that the maximum velocity of rock movement was found to be 8.97m/s in Mine-A and 12.40m/s in Mine-B with varying strength of intact rock mass. Wipfrag digital image processing software was used to determine the fragment size distribution, which gives quick and accurate measurements. Blast-4 of Mine-A with explosive charge of about 33.36kg/hole produced finer fragmentation compared to Blast-4 in Mine-B with same explosive charge, clearly showing influence of strength of rock mass.

Keywords: fragmentation assessment, high speed videography, rock mass movement, Wipfrag

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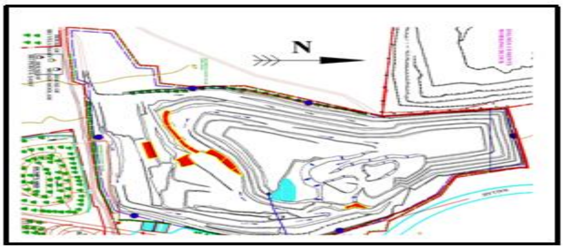
INTRODUCTION

Rock blasting is carried out to fragment and displace the rock mass in mines and quarries. In order to achieve the desired objective to be performed in the field, precise engineering application of blasting operation is required. In civil engineering projects like construction of dams, tunnels or caverns, hard rock mass has to be removed, using blasting process. Blasting process takes place in a fraction of second to few seconds and it is not possible to assess the performance of the blast with naked eye. To view and analyze the performance of mine blasts and subsequently design the blasts, high speed video camera is used, which can capture images and can be played back to view in slow motion for further analysis [1]. In increasing the cast blasting benefit, the high-speed videography is used. Fragmentation in blasted muck piles was analyzed by Wipfrag digital image processing based software [2].

This paper presents a part of the research work carried out for assessing the blast performance using High Speed Video Camera of AOS Technologies, Switzerland, in two different opencast limestone mines located in Southern India. Studies were conducted at limestone Mine-

A in Tamil Nadu and other limestone Mine-B in Andhra Pradesh as shown in Figure 1.



Mine-A

Mine-B

Fig. 1. *View of limestone mines.*

METHODOLOGY

In total, 22 blasts were conducted in the two mines to assess the performance of the blast. High speed video videography was used to record all the blasts (Figure 2).

The parameters used in blast studies are listed in Table 1. Blastholes were of 115 mm diameter in both mines A and B. Depth of blast holes was varying from 5 to 10 m in Mine-A [3], 2m to 9.5m in Mine-B [4].

Slurry explosive available in the form of cartridges was used as primer and column charge in Mine-A, whereas in Mine-B slurry explosive available in the form of cartridges was used as primer and ANFO was used as column charge.

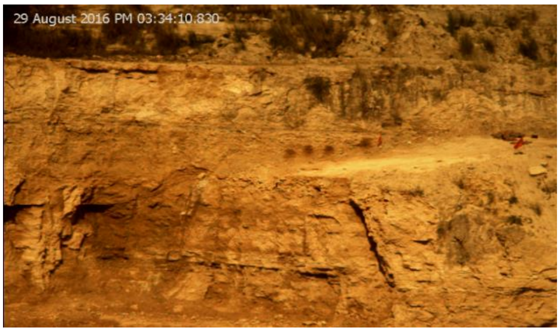
Table 1. *Summary of blast studied limestone mine-A.*

Limestone mine-A					
Specifications	**Blast number**				
	1	**2**	**3**	**4**	**5**
Bench height (m)	5.0	6.0	7.0	7.5	10.0
Burden (m)	2.5	2.5	2.5	2.5	2.5
Spacing (m)	3.0	3.0	3.0	3.0	3.0
No. of blastholes	13	24	23	18	20
Explosive/hole (kg)	19.25	25.02	29.37	33.36	40.03
Total exp. charge (kg)	250.20	600.48	675.54	600.48	800.64
Stemming (m)	1.5	1.4	1.5	1.4	1.0
Limestone mine-B					
Specifications	**Blast number**				
	1	**2**	**3**	**4**	**5**
Bench height (m)	2.0	3.5	5.0	8.0	9.5
Burden (m)	2.0	2.0	3.0	2.5	3.0
Spacing (m)	3.0	3.0	5.0	5.0	6.0
No. of blastholes	17	12	10	27	15
Explosive/ hole (kg)	03.82	07.00	09.40	33.33	48.21
Total exp. charge (kg)	65.00	85.00	94.00	900.00	723.00
Stemming (m)	1.6	2.7	3.5	3.5	3.7

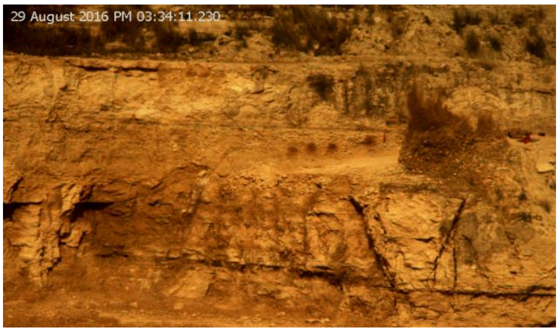
The information obtained from the high-speed videography with a capacity of 1000 frames per second was used to understand the dynamics involved in the blasts, which in turn reduce the costly trials that are necessary for optimizing the blast design. The camera provides results on the spot and recorded video is played using imaging studio software.

Fig. 2. *High speed video camera of 1000fps capacity.*

Pro-analyst software provides a series of video processing and motion analysis that can be applied to any video or image sequence which will allow users to measure the displacement and velocity of the moving fragments. It is also used to track the particles and to know the ejection of gas energy from the stemming zone of blasthole. The velocity of burden rock increases with the increase in bench height to burden ratio [5]. The sequence of blasts with specific time intervals from the time of initiation in limestone Mine-A and Mine-B are shown in Figures 3 and 4.



0 ms



400ms

600ms

800ms

1000ms

1200ms

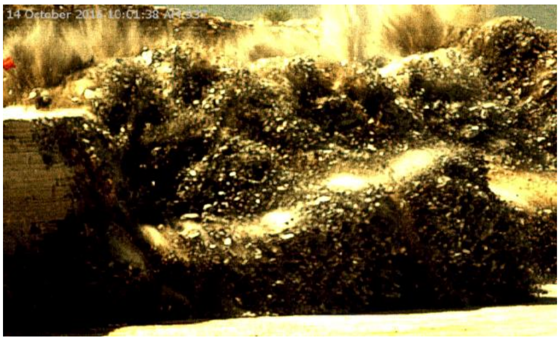
Fig. 3. *Sequence of progress of a typical blast in Mine-A.*

0ms

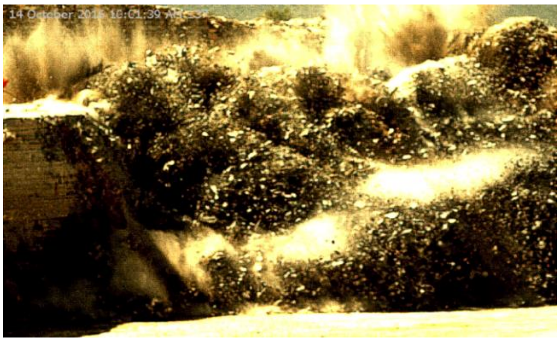
400ms

600ms

800ms



1000ms



1200ms

Fig. 4. *Progress of a typical blast in mine-B.*

Fragmentation resulting from the blasts can be assessed by taking the photos of the muck piles generated. After the blasts, photos were taken covering various layers of the entire muck pile during the process of shoveling at regular intervals till the entire muck pile was excavated. Wipfrag software was used to analyze the fragmentation. Wipfrag software uses the technique that analyze the digital image of blasted rock to predict the grain size distribution in the muck pile. Scale device was used to view the reference of each sizing zone. The muck pile was photographed and image is then transferred to Wipfrag system. Typical muck piles generated from different production scale blasts are shown in Figure 5.

Mine-A

Mine-B

Fig. 5. *Typical muck piles obtained from the blasts.*

RESULTS AND DISCUSSION

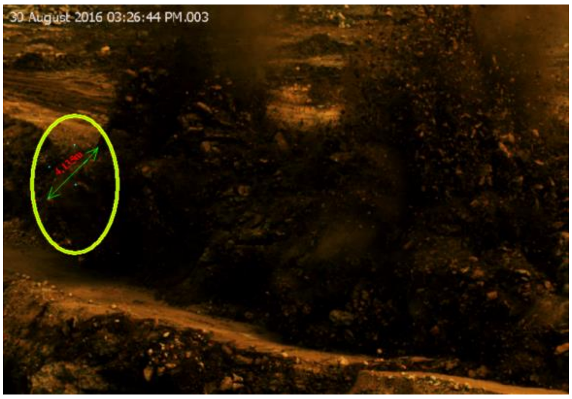
To track down the rock movement of bench face and to find out the escape of gaseous energy, Pro-analyst software was used. Study carried out revealed that the bench height of 10m in Mine-A resulted in gas ejection of 7.42m height (on average), whereas the bench height of 7.5m in the same mine resulted in gas ejection of 8.73m. Thus, it may be interpreted that wastage of gas energy was lesser in taller benches. Figure 6 shows typical case analysis in Mine-A, and Figure 7 for Mine-B.

The comparison of gas ejection from Mine-A and Mine-B revealed that the gas ejection was found to be more in Mine-A. This may be due to lesser stemming in Mine-A compared to Mine-B. The stemming height of 1.0m in Mine-A resulted in gas ejection of 7.42m, whereas the stemming height of 3.5m in Mine-B resulted in gas ejection of 3.82m, which was almost half the height in Mine-B.

Height of bench

Escape of gas energy

Tracking of burden rock mass

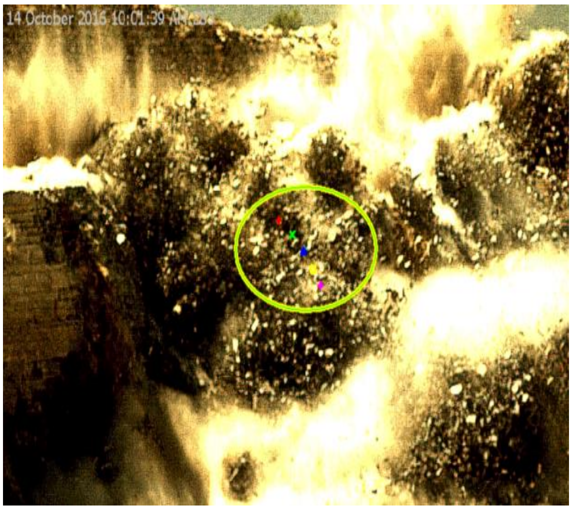


Displacement of rock mass

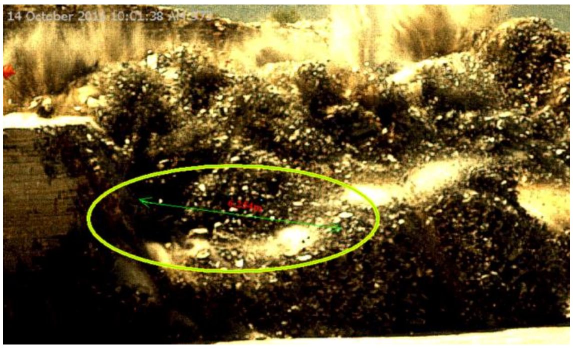
Fig. 6. *Analysis of a typical blast in Mine-A.*

Height of bench

Escape of gas energy



Tracking of burden rock mass



Displacement of rock mass

Fig. 7. *Analysis of a typical blast in Mine-B.*

The velocity of the burden rock was varying from 6.58m/s to 8.97m/s in Mine-A and 8.34m/s to 12.4m/s in Mine-B. The burden rock movement was found to be increase in both the mines with increase in Bench Height/Burden ratio. Velocity of 6.58m/s resulted with charge factor of 0.28kg/m^3 and velocity of 8.97m/s resulted with charge factor of 0.41kg/m^3 in Mine-A. In Mine-B, a burden rock velocity of 8.34m/s resulted with charge factor of 0.18kg/m^3 and 12.4m/s with charge factor of 0.25kg/m^3. Thus, in both Mine-A and Mine-B, the velocity of the burden rock was found to increase with increase in charge factor. The observed readings are tabulated in Tables 2 and 3.

Table 2. *Comparison of velocity of rock movement with BH/B ratio.*

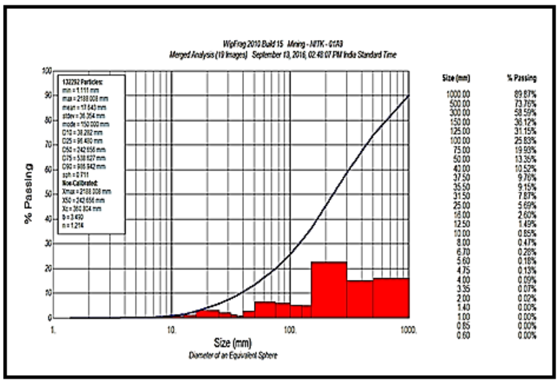
Limestone mine-A					
Parameters	**Blast number**				
	1	2	3	4	5
Time (s)	1.2	1.1	0.9	0.8	0.8
Velocity (m/s)	6.58	7.68	7.95	8.29	8.97
BH/B ratio	2.0	2.4	2.8	3.0	4.0
Limestone mine-B					
Parameters	**Blast number**				
	1	**2**	**3**	**4**	**5**
Time (s)	0.9	0.8	0.8	0.7	0.7
Velocity (m/s)	8.34	9.26	8.76	9.57	12.4
BH/B ratio	1.0	1.75	1.67	3.2	3.16

Table 3. *Comparison of Velocity of rock movement with charge factor.*

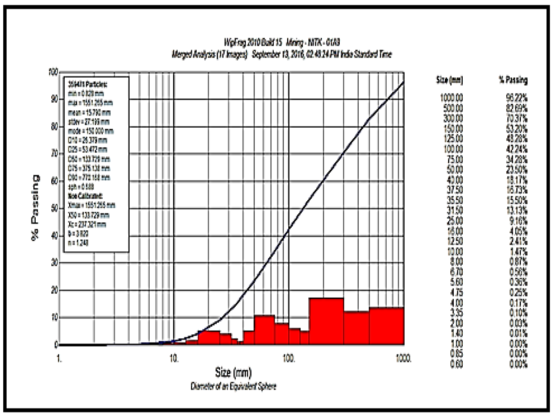
Limestone mine-A					
Parameters	**Blast number**				
	1	2	3	4	5
Volume (m^3)	900	1620	1800	1500	1950
Velocity (m/s)	6.58	7.68	7.95	8.29	8.97
Charge factor (kg/m^3)	0.28	0.37	0.38	0.40	0.41
Limestone mine-B					
Parameters	**Blast number**				

	1	2	3	4	5
Volume (m^3)	360	425	450	3750	2892
Velocity (m/s)	8.34	9.26	8.76	9.57	12.4
Charge factor (kg/m^3)	0.18	0.20	0.21	0.24	0.25

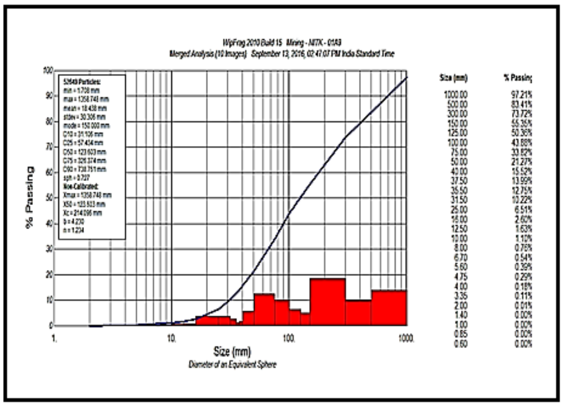
Output of the fragmentation analysis obtained from Wipfrag software consists of a cumulative size in both the limestone mines and results are shown in Figures 8 and 9.



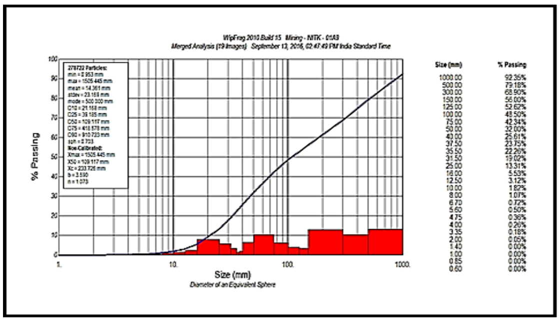
Blast-1



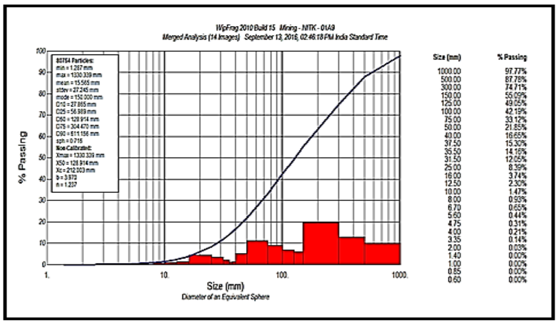
Blast-2



Blast-3

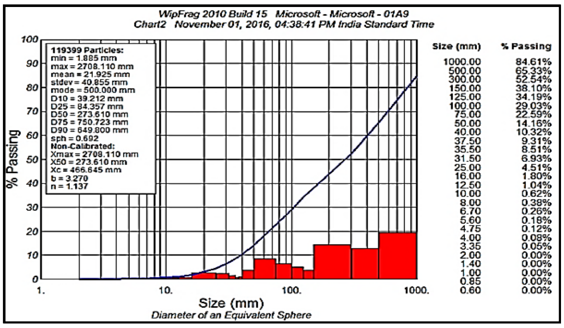


Blast-4

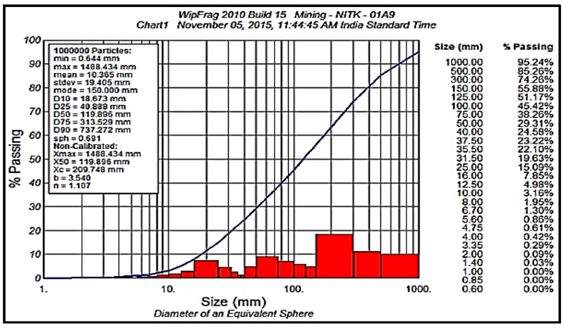


Blast-5

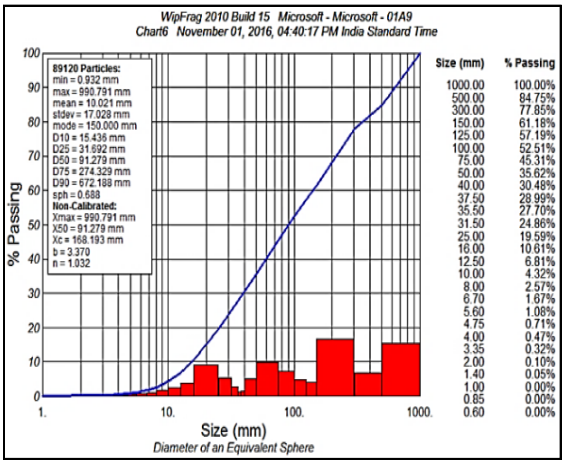
Fig. 8. *Fragmentation analysis of different blasts in mine-A.*



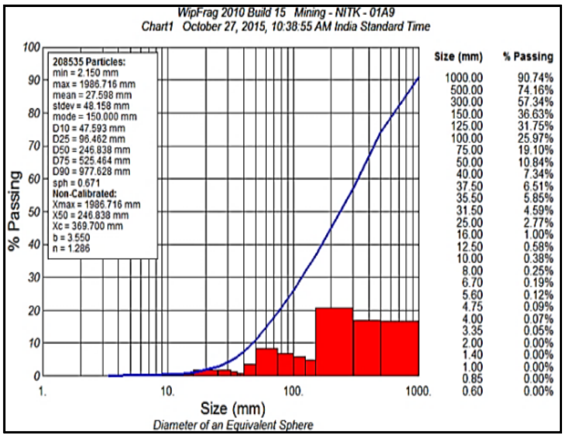
Blast-1



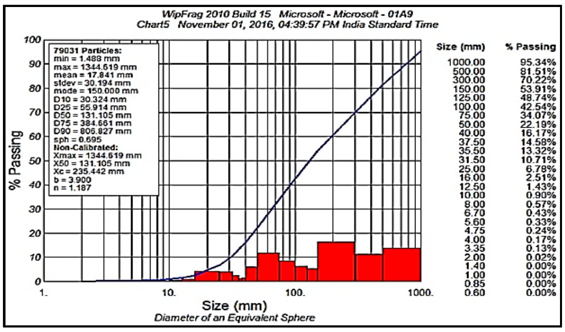
Blast-2



Blast-3



Blast-4



Blast-5

Fig. 9. *Fragmentation analysis of different blasts in mine-B.*

In Mine-A, Blast-4 with explosive charge of about 33.36kg/hole produced coarser fragmentation compared to Blast-5 with explosive charge of about 40.03kg/hole. In mine-B, Blast-4 with explosive charge of about 33.33 kg/hole produced coarser fragmentation compared to Blast-5 with explosive charge of about 48.21 kg/hole.
In Mine-A, Blast-4 with explosive charge of about 33.36 kg/hole produced finer fragmentation compared to Blast-4 in Mine-B with similar explosive charge. The observed fragmentation values of Mine-A and Mine-B are tabulated in Tables 4 and 5.

Table 4. *Fragmentation values obtained from blasts in mine-A.*

Blast number	**Number of holes**	**Percentage passing**				
		1000 (mm)	**500 (mm)**	**300 (mm)**	**150 (mm)**	**100 (mm)**
1	13	89.87	73.76	58.59	36.12	25.83
2	24	96.22	82.69	70.37	53.20	42.24
3	23	97.21	83.41	73.72	55.35	43.88
4	18	92.35	79.18	68.90	56.00	52.62
5	20	97.77	87.78	74.71	55.09	42.19

Table 5. *Fragmentation values obtained from blasts in mine-B.*

Blast number	**Number of holes**	**Percentage passing**				
		1000 (mm)	**500 (mm)**	**300 (mm)**	**150 (mm)**	**100 (mm)**
1	17	84.61	65.33	52.54	38.10	29.03
2	12	95.24	85.26	74.26	55.88	45.42
3	10	100.00	84.75	77.85	61.18	52.51
4	27	90.74	74.16	57.34	36.63	25.97
5	15	95.34	81.51	70.22	53.91	42.54

CONCLUSIONS

High speed videography is a very good tool for analyzing the performance of blast in mines and quarries, in terms of tracking down the burden rock movement, behavior of bench with different explosive loading and initiation pattern, ejection of stemming from stemming zone and role of structural discontinuities, etc. Similarly, the digital image processing techniques predicts the fragmentation size resulting from blasts quite effectively. Following are the major conclusions from the study carried out in two limestone mines.

- From the analysis made, it was observed that bench height of 10m resulted in 7.42m of stemming ejection (on average) and bench height of 7.5m resulted in 8.73m of stemming ejection (on average). Hence, it may be concluded that increase in bench height results in lesser stemming ejection, and better utilization of explosive energy. This is due to the fact that taller benches result in lesser stiffness coefficient.
- Results have clearly indicated higher burden rock movement with increase in charge factor. Velocity of 6.58m/s resulted with a charge factor of 0.28kg/m^3, whereas velocity of 8.97m/s resulted with increased charge factor of 0.41kg/m^3. This indicates that any increase in explosive charge results in finer fragmentation.
- Velocity of rock mass movement increased clearly with increase in bench height, due to more flexibility in the bench. BH/B ratio of 2.0 resulted in burden movement of 6.58m/s, whereas BH/B ratio of 2.8 resulted in increased burden rock movement of 7.95m/s.

It is expected that more similar studies involving advanced instrumentation and softwares will improve the blasting results leading to better project economics.

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