Chapter 3: DATA ACQUISITION AND COLLECTION

3.1 Introduction

Ground vibration waves propagate outward from the blast site in orthogonal directions and pass adjacent structures. The structures are observed to oscillate and vibrate due to incoming ground vibrations. If these ground vibrations are strong enough, the structures are damaged. The main objective of this chapter is to summarize the field data acquisition and data collection with every single parameter for the proper assessment of the ground vibrations. In this study, opencast coal mines and stone quarries are selected for observing the intensity of the blast-induced ground vibrations under various geo-mining conditions. For this purpose, an adequate number of the blasting data had been collected during the study period in the five different mines and quarries. The main focus of the study was the assessment of the impact of the blast-induced ground vibrations on the structures nearby the mine areas. An imaginary survey line was envisaged from the blast site to the last point of observation for locating the seismographs near the villages. The work also comprised of the scientific study of the blasting geometry, initiation patterns and the explosive parameters. The seismographs were located from the nearest to the furthest location from blast site on the imaginary line of observation stated above. The data acquisition continued for several days.

3.2 Open-cast Mine

Opencast mining is a surface mining technique for extracting rocks and minerals from the earth's subsurface (Serafini, 2021). Larger quantities of waste rock mass called overburden need to be removed to extract the economic rocks, ores, and minerals beneath the earth's surface. At present, many opencast coal mines and stone quarries are operational in India and the world. Various combinations of heavy earthmoving machinery and high energy explosives are being used in the extraction process to fulfil the demand. In the present research work, two different opencast coal mines (OCM) were chosen for acquisition and data collection; first one was from Chhattisgarh and the second from Madhya Pradesh.

3.2.1 Case I: Coal Mine-1 Chhattisgarh

3.2.1.1 Location and Geology

The study was conducted at coal mine-1 is located in the Chhattisgarh. The block covers an area of 12.42 km^2. It is bounded by latitude 22° 18’59” to 22° 19’43” North and longitude 82° 30’47” to 82° 33’34” E located and comes under the location map of coal mine-1 and its area as shown in Figure 3.1.

The overburdened rock mass of opencast coal mine-1 is medium to coarse grain sandstone, shale, shaly sandstone, and weathered sandstone, etc. The mine mainly consists of unconsolidated sedimentary rocks associated with the semi-bituminous to bituminous coal of the Gondwana period. Granite, Dolerite, Bauxite, fireclay, and Limestone deposits are also found in this area, and the geo-mining characteristics and dimension of the quarry is listed in table 3.1. This mine comes under coal mine-1, Chhattisgarh and its geological map as shown in Figure 3.2. The mentioned figure 3.2 is used to report the general information of the geology of the field at large scale and was taken from the literature. Hence Latitude and Longitude could not be provided, although it would have been a better option.

Table 3.1: Geo-mining characteristics and quarry dimensions

Particulars	Unit	Values
Lower Kusmunda (Comb)	m	56.70 - 70.15
Lower Kusmunda (Top)	m	34.70 - 44.85
Lower Kusmunda (Bot)	m	2.19 – 24.50
Upper Kusmunda	m	24.69-35.82
Seam E&F	m	12.70- 19.05
Specific Gravity of the seams	Mcum/t	1.58
Av. gradient of the quarry floor		1 in 9 to 1 in 17
Parting between Lower Kusmunda (Bottom) and Lower Kusmunda (Top)	m	3.00-35.56
Parting between Lower Kusmunda (Top)/(Combined) & Upper Kusmunda	m	12.17-78.63
Parting between E&F and UK	m	30.14-62.12
Top O/B	m	8.02-85.15
In-situ volume weight of O/B	T/cum	2.25-2.40

Strike length of the quarry.	Km	3.0 – 4.0
Dip rise width of the quarry	Km	2.6 – 3.2
Maximum depth of the quarry	m	250
The surface area of the quarry	Ha	1002.53

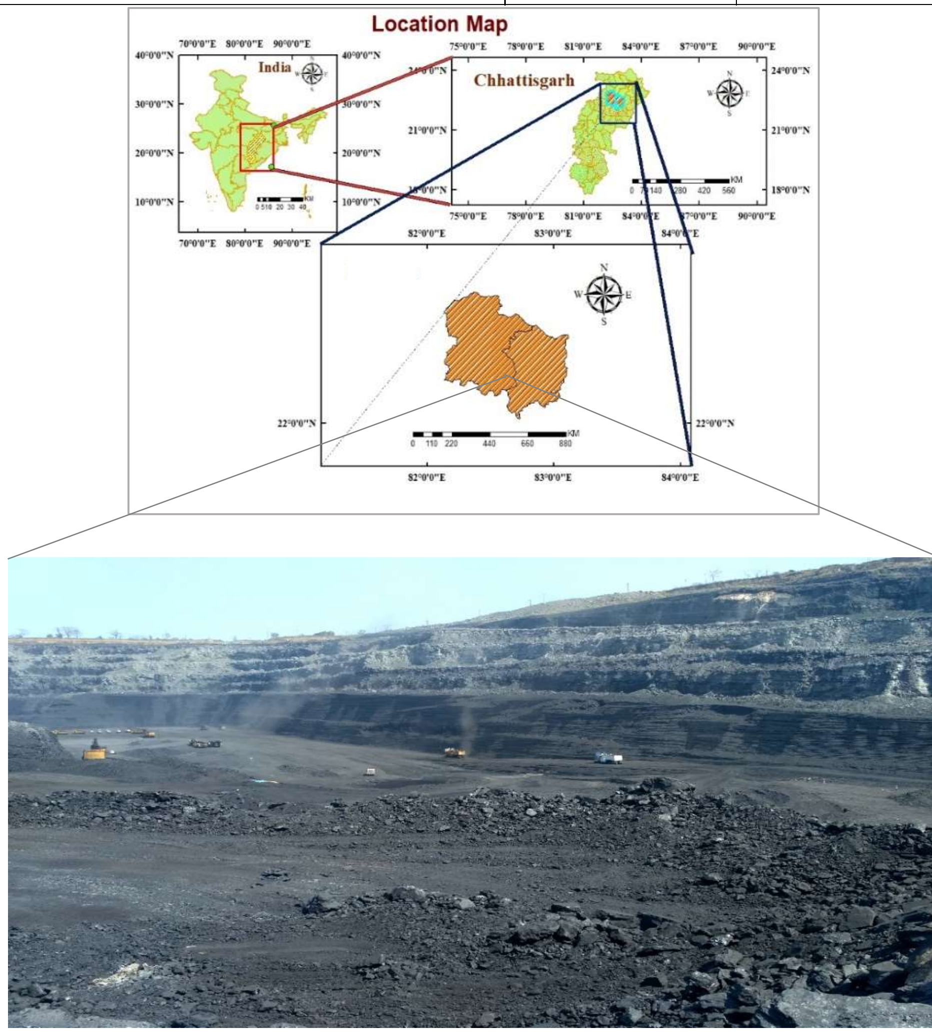


Figure 3.1 Location map of coal mine-1.

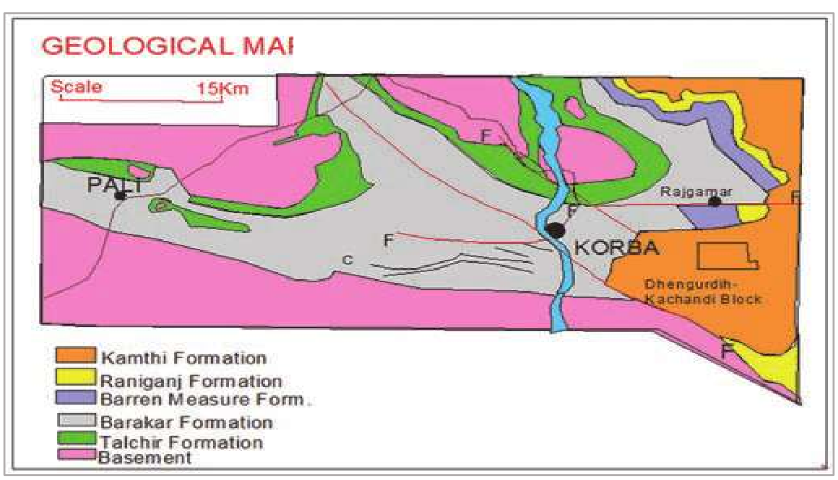
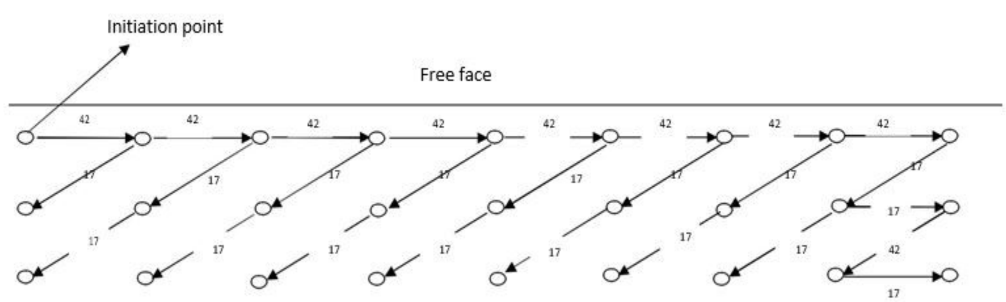


Figure 3.2 Coal mine-1, geological formation. (Sahu et al. 2016).

3.2.1.2 Blast Geometry and Dataset

Due to its rough topography and complex nature, a simple procedure is applied in the field. First, a survey line is made from the blasting site at the mine to the last observation point nearby the village (within 2000m). The ground vibration is measured in the form of PPV and their components by using four seismographs having Nomis make and another Instantel. Seismograph, having tri-axial geophone and a microphone set in the field to monitor ground vibration. A total of 24 datasets of six blast events measured at various distances from the blast site is listed in Table 3.2. The seismographs have been installed at suitable locations and specific intervals for data monitoring.

A total of 32 datasets are measured during field study to analyze these data further, as listed in Tables 3.3 and 3.4. The blast design parameters are tabulated in Table 3.5 for 40 datasets as measured by ten blast events during the certain period and measured as well as predicted values are listed in Table 3.6. Blast design parameters range such as; hole depth (3.5m-20m), hole diameter (16mm-381mm), burden (3.5m-8m), spacing (3.0m-8.5m), bench height (3.0m-20m), booster per hole (100g-1200g). The blasting pattern was used as a staggered pattern, and blast hole charging details are shown in Figure 3.3. The delay operators were used as 17ms and 42ms in line and cross line, respectively. Whereas, along with down–the–hole, a delay of 200ms- 450ms were used. The significance of this study to acquire the precise information of ground vibrations and their impacts at different locations from blast site to last observation points. All the blast events were done in the overburden materials and not in coal.



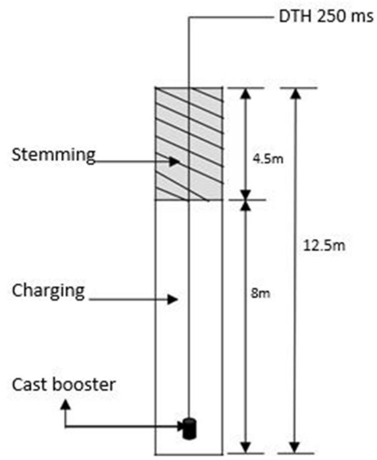


Figure 3.3 Staggered initiation pattern and blast hole details

Table 3.2: The different blast events and recording parameters

Blast Event No.	Monitoring Distance (m)	Maximum charge per Delay (Kg)	Peak particle Velocity (mm/s)	Dominant Frequency (Hz)	Peak Vector Sum (mm/s)
BM_1	50	371	119.50	148.0	127.31
	100	371	54.737	56.80	64.49
	150	371	34.925	29.40	37.76
	200	371	20.32	28.10	22.41
BM_2	250	280	11.049	11.60	14.60
	300	280	9.398	16.10	11.37
	350	280	5.334	3.80	6.49
	400	280	4.826	35.20	5.54
BM_3	450	324	6.604	8.00	7.30
	500	324	6.35	4.50	6.61
	550	324	4.064	4.30	4.60
	600	324	2.540	2.80	3.11
BM_4	650	475	3.175	24.70	3.72
	700	475	1.778	10.80	2.11
	750	475	2.651	5.70	2.04
	800	475	1.556	28	3.65
BM_5	850	470	3.048	6.30	3.05
	900	470	1.905	4.80	2.10
	950	470	1.143	6.10	1.53
	1000	470	1.159	13.90	2.45
BM_6	1150	390	0.762	4.4	0.85
	1200	390	1.524	7.10	1.61
	1300	390	0.889	5.10	1.00
	1400	390	0.635	20.40	0.820

Table 3.3: The measured and predicted values of PPV and frequency.

Sl. No.	D (m)	MCPD (kg)	TC (kg)	TB (kg)	B (m)	S (m)	NH	HD (m)	HDI (mm)	Measured Values		Predicted Values				
										PPV (mm/s)	Frequency (Hz)	DGMS PPV (mm/s)	MVRA PPV (mm/s)	MVRA frequency (Hz)	ANN PPV (mm/s)	ANN Frequency (mm/s)
1	100	85.76	2230	5.2	4	4.5	52	6.3	6.3	9.525	2.6	11.70	8.09	8.48	12.02	5.25
2	200	85.76	2230	5.2	4	4.5	52	6.3	6.3	6.096	22.2	3.79	7.22	5.52	4.13	15.14
3	300	85.76	2230	5.2	4	4.5	52	6.3	6.3	3.81	6.1	1.96	5.35	2.55	6.057	8.01
4	50	118.7	1840	3.1	4	5	31	6.8	6.8	19.609	23.24	51.17	15.06	13.63	18.25	12.05
5	150	118.7	1840	3.1	4	5	31	6.8	6.8	11.049	11.6	8.58	11.19	10.66	14.09	4.32
6	250	118.7	1840	3.1	4	5	31	6.8	6.8	4.191	6	3.74	5.45	7.70	6.97	2.35
7	350	371	8880	21	8	8.5	28	18.5	18.5	5.334	3.8	7.35	4.69	12.19	6.97	1.24
8	450	371	8880	21	8	8.5	28	18.5	18.5	4.081	6.45	4.88	3.82	9.23	3.94	3.45
9	550	371	8880	21	8	8.5	28	18.5	18.5	3.683	5.3	3.52	2.96	6.26	3.21	2.35
10	650	371	8880	21	8	8.5	28	18.5	18.5	2.413	3.3	2.68	2.09	3.29	2.17	1.25
11	400	324.1	7780	18	8	9	24	19	19	6.604	8	5.12	5.54	8.97	5.02	15.24
12	500	324.1	7780	18	8	9	24	19	19	4.064	4.3	3.56	4.67	6.00	4.23	8.14
13	600	324.1	7780	18	8	9	24	19	19	2.54	2.8	2.64	3.80	3.03	2.74	5.48
14	700	324.1	7780	18	8	9	24	19	19	1.778	0.8	2.06	2.94	0.06	2.57	3.15
15	325	102.8	3600	10.5	5	6	70	7	7	3.429	6.3	2.09	3.08	14.93	3.59	1.24
16	525	102.8	3600	10.5	5	6	70	7	7	0.895	1.982	0.960	1.34	8.99	1.11	3.48
17	725	102.8	3600	10.5	5	6	70	7	7	0.197	1.045	0.568	0.386	3.06	1.52	3.48
18	650	475	8550	21	6	7.5	18	19	19	4.826	5.2	3.505	5.92	46.01	4.32	16.14
19	750	475	8550	21	6	7.5	18	19	19	3.556	128	2.77	5.05	43.05	4.02	40.21
20	1150	475	8550	21	6	7.5	18	19	19	1.905	4.51	1.38	1.58	31.17	2.04	1.02
21	1250	475	8550	21	6	7.5	18	19	19	1.016	5.3	1.21	0.715	28.21	1.10	9.57
22	800	221.84	4160	7.5	3	4	75	6.5	6.5	1.27	2.147	1.10	1.46	5.11	1.54	5.12
23	900	221.84	4160	7.5	3	4	75	6.5	6.5	0.762	3.93	0.913	0.592	2.15	0.98	7.54
24	1000	221.84	4160	7.5	3	4	75	6.5	6.5	0.335	2.457	0.769	0.275	0.816	0.532	0.978
25	850	470	6580	16.5	6	7.5	14	19.5	19.5	4.318	11.6	2.24	3.85	13.77	3.97	16.25
26	950	470	6580	16.5	6	7.5	14	19.5	19.5	3.048	6.3	1.87	2.98	10.80	2.75	9.45
27	1100	470	6580	16.5	6	7.5	14	19.5	19.5	2.159	3.9	1.47	1.68	6.35	1.98	1.02
28	1200	470	6580	16.5	6	7.5	14	19.5	19.5	1.524	7.1	1.27	0.819	3.38	2.03	4.26
29	1050	390	8840	23.4	7	8	26	18	18	1.143	7.3	1.30	2.64	10.47	1.09	4.98
30	1300	390	8840	23.4	7	8	26	18	18	0.889	8.3	0.919	0.472	3.05	1.04	7.65
31	1350	390	8840	23.4	7	8	26	18	18	0.635	20.4	0.865	0.038	1.56	0.975	18.45
32	1400	390	8840	23.4	7	8	26	18	18	0.547	3.48	0.815	0.395	0.083	0.478	1.26

Table 3.4: The component velocities and associated frequencies.

Distance (m)	Max. charge per delay (kg)	Scaled distance (m/kg$^{0.5}$)	Peak particle velocity (mm/s)					Frequency (Hz)			
			Radial	**Transverse**	**Vertical**	**Measured**	**Predicted**	**Radial**	**Transverse**	**Vertical**	**Measured**
100	85.76	10.798	9.525	8.255	6.985	9.525	13.488	2.6	2.7	6.6	2.6
200	85.76	21.596	6.096	5.842	4.064	6.096	4.769	3.2	1.9	2.2	3.2
300	85.76	32.395	3.810	3.429	1.270	3.81	2.596	6.1	5.6	6.9	6.1
50	118.7	4.589	18.235	19.609	17.563	19.609	48.687	25.2	23.5	19.1	25.2
150	118.7	13.767	11.049	10.795	6.096	11.049	9.369	11.6	10.4	18.2	11.6
250	118.7	22.946	4.191	3.429	1.143	4.191	4.354	6	5.1	6.2	6
350	371	18.171	5.207	5.334	6.487	5.334	6.179	5	3.8	4	3.8
450	371	23.362	3.124	2.894	4.081	4.081	4.238	2.3	2.5	2.8	2.8
550	371	28.554	3.683	2.286	1.905	3.683	3.137	5.3	10	10.8	5.3
650	371	33.746	2.413	2.413	1.651	2.413	2.442	4.6	3.3	5.3	4.6
400	324.1	22.218	5.842	6.604	4.826	6.604	4.570	12.1	8	16.5	8
500	324.1	27.773	4.064	2.413	0.762	4.064	3.270	4.3	4.5	32	4.3
600	324.1	33.328	2.159	2.540	0.381	2.54	2.487	2.4	2.8	0	2.8
700	324.1	38.882	1.778	1.143	0.254	1.778	1.974	0.8	1.6	0	0.8
325	102.8	32.054	3.429	3.429	1.143	3.429	2.637	6.3	3.9	8.6	3.9
525	102.8	51.780	0.889	0.508	0.254	0.889	1.284	1.1	1.4	1.2	1.2
725	102.8	71.505	0.153	0.197	0.175	0.197	0.791	1.2	1.4	1.3	1.4
650	475	29.824	4.826	3.429	2.286	4.826	2.938	5.2	7.6	6.2	5.2
750	475	34.412	1.143	3.556	0.508	3.556	2.370	1.6	1.8	1.5	1.8
1150	475	52.765	1.905	1.651	1.270	1.905	1.248	6.2	7.4	17	6.2
1250	475	57.353	1.016	0.762	0.762	1.016	1.102	5.3	4.7	4.7	5.3
800	221.84	53.711	1.270	1.143	1.016	1.27	1.216	3.5	2.9	4.3	3.5
900	221.84	60.425	0.635	0.381	0.762	0.762	1.019	2.6	1.6	3.9	3.9
1000	221.84	67.139	0.335	0.236	0.248	0.335	0.870	1.4	1.05	1.52	1.4
850	470	39.207	4.191	4.318	2.159	4.318	1.949	2.2	1.6	0.8	2.2
950	470	43.820	3.048	2.540	1.397	3.048	1.650	6.3	6.1	8.4	6.1
1100	470	50.739	2.032	2.159	1.270	2.159	1.324	4.4	3.9	15.5	3.9
1200	470	55.351	1.524	1.524	0.254	1.524	1.162	6.3	7.1	0	7.1
1050	390	53.168	1.143	1.143	0.889	1.143	1.234	7.3	6.1	6.3	7.3
1300	390	65.828	0.889	0.889	0.254	0.889	0.896	8.3	5.1	0	5.1
1350	390	68.359	0.635	0.635	0.254	0.635	0.846	1.4	2.3	1.9	2.3
1400	390	70.891	0.421	0.547	0.364	0.547	0.801	1.2	1.46	1.14	1.46

Table 3.5: The field blast design parameters.

Blast No.	Blast Event	Burden (m)	Spacing (m)	No. of holes	Hole depth (m)	Hole diameter (mm)	Powder Factor (m^3/kg)	Total charge (kg)
1	B_1	4	5	31	6.9	159	2.20	1840
2	B_2	5	6	24	7.5	160	3.74	2880
3	B_3	4	4.5	52	6.3	160	2.64	2230
4	B_4	5	6	70	7	159	4.0	3600
5	B_5	8	9	24	19	259	4.7	7780
6	B_6	4	5	42	7	159	2.80	3780
7	B_7	8	9	28	18.5	259	4.7	8880
8	B_8	5	6	09	19	160	2.5	2030
9	B_9	7	8	18	18.5	259	4.7	2772
10	B_{10}	6	7.5	14	19.5	260	1.80	6580

Table 3.6: The measured and predicted PPV, PVS, and frequency values.

Sl. No.	Blast Event	Distance (m)	MCPD (kg)	Scale Distance (m/kg0.5)	Measured (mm/s)		Measured Frequency (Hz)	Predicted PPV (mm/s) by		Predicted PVS by MVRA (mm/s)	Predicted Frequency by MVRA (Hz)
					PPV	PVS		DGMS	MVRA		
1	BE_1	50	118.7	16.78	19.60	18.25	98.20	10.20	13.23	14.24	45.76
2		150	118.7	9.69	11.04	14.5	28.60	4.26	11.09	12.03	37.84
3		250	118.7	7.50	4.19	4.38	6.00	2.84	8.94	9.82	29.92
4		350	118.7	6.34	2.47	3.54	8.02	2.17	6.80	7.60	21.99
5	BE_2	75	120	13.85	32.15	32.97	56.8	7.49	18.02	18.49	37.61
6		125	120	10.73	18.54	19.24	43.21	4.99	16.95	17.39	33.65
7		175	120	9.07	11.45	11.12	15.21	3.82	15.88	16.28	29.69
8		225	120	8.00	5.24	5.87	8.47	3.12	14.81	15.17	25.73
9	BE_3	100	85.76	8.57	9.52	14.28	22.60	3.97	8.24	10.51	25.09
10		200	85.76	6.06	6.85	9.02	64.00	2.29	6.10	8.30	67.17
11		300	85.76	4.95	3.81	4.20	6.90	1.66	3.96	6.08	9.25
12		400	85.76	4.28	1.87	2.53	8.00	1.32	1.81	3.87	1.33
13	BE_4	275	102.8	6.19	5.02	6.21	17.24	2.21	5.82	6.98	17.26
14		325	102.8	5.70	4.5	5.24	13.05	1.93	4.75	5.87	13.30
15		375	102.8	5.30	4.10	5.80	8.22	1.73	3.67	4.77	9.34
16		425	102.8	4.98	3.42	4.23	6.47	1.56	2.60	3.66	5.38

17	BE_5	500	324.1	14.49	4.06	4.6	9.30	5.48	4.48	5.07	19.99
18		600	324.1	13.23	2.54	3.11	7.80	4.74	2.34	2.8	12.07
19		700	324.1	12.24	1.77	2.11	3.54	4.20	0.20	0.65	4.15
20		800	324.1	11.45	1.42	2.30	2.90	3.77	1.93	1.55	3.77
21	BE_6	475	90	4.12	1.02	1.52	2.98	1.22	2.45	2.86	8.43
22		525	90	3.92	0.985	1.24	1.25	1.12	1.38	1.76	4.47
23		575	90	3.75	0.957	1.30	3.40	1.04	0.31	0.65	0.51
24		625	90	3.60	0.63	0.97	1.98	0.98	0.75	0.45	3.44
25	BE_7	450	371	17.48	4.08	4.15	17.98	7.02	7.39	8.06	19.80
26		550	371	15.81	3.68	3.78	12.04	5.98	5.24	5.85	11.88
27		650	371	14.55	2.41	3.36	6.24	5.24	3.10	3.63	3.96
28		750	371	13.54	1.64	2.31	4.67	10.20	0.96	1.42	3.96
29	BE_8	900	221.84	7.39	0.762	0.78	3.90	4.26	3.98	4.73	13.58
30		1000	221.84	7.01	0.335	0.865	1.40	2.84	1.83	2.52	5.66
31		1100	221.84	6.68	1.04	1.85	1.02	2.17	0.30	0.31	2.25
32		1200	221.84	6.40	0.695	1.87	0.98	7.49	2.49	1.90	10.18
33	BE_9	675	154	5.92	2.31	3.97	9.48	4.95	3.56	4.71	13.89
34		725	154	5.71	2.10	3.15	7.58	3.82	2.49	3.60	9.92
35		775	154	5.53	1.58	2.68	10.47	3.12	1.42	2.50	5.96
36		825	154	5.36	1.02	1.50	5.85	3.97	0.35	1.39	2.00
37	BE_{10}	850	470	16.12	4.31	4.94	5.46	2.29	5.98	6.63	16.81
38		950	470	15.24	3.04	3.05	6.10	1.66	3.84	4.41	8.89
39		1050	470	14.50	3.14	4.15	2.79	1.32	1.70	2.20	0.97
40		1150	470	13.85	1.78	2.35	3.15	2.21	0.43	0.75	6.94

3.2.2 Case II: Coal Mine-2 Madhya Pradesh

3.2.2.1 Location and Geology

The study was conducted at a coal mine-2, which lies between latitude 24.05° to 24.14°N and longitude 82.38° to 82.40 °E located Madhya Pradesh, India. The location map of Mine-2 is shown in Figure 3.4. The overburdened rock mass of Mine-2 is mostly medium to coarse grain sandstone, carbonaceous shale, and shaly sandstone (i.e. 90% medium to coarse grain sandstone). The geological map of the Singrauli district is shown in Figure 3.5. Bituminous coal of different grades has been present since the Gondwana age in this region.

The dimension of coal mine-2 is given below-

3.6 Km wide along the strike direction

3.5 Km wide along the dip direction and

12.6 Square km area

Types of coal seams:

Purewa top (6-7m width)

Purewa bottom (11-13m width)

Turra seam (17-18m width)

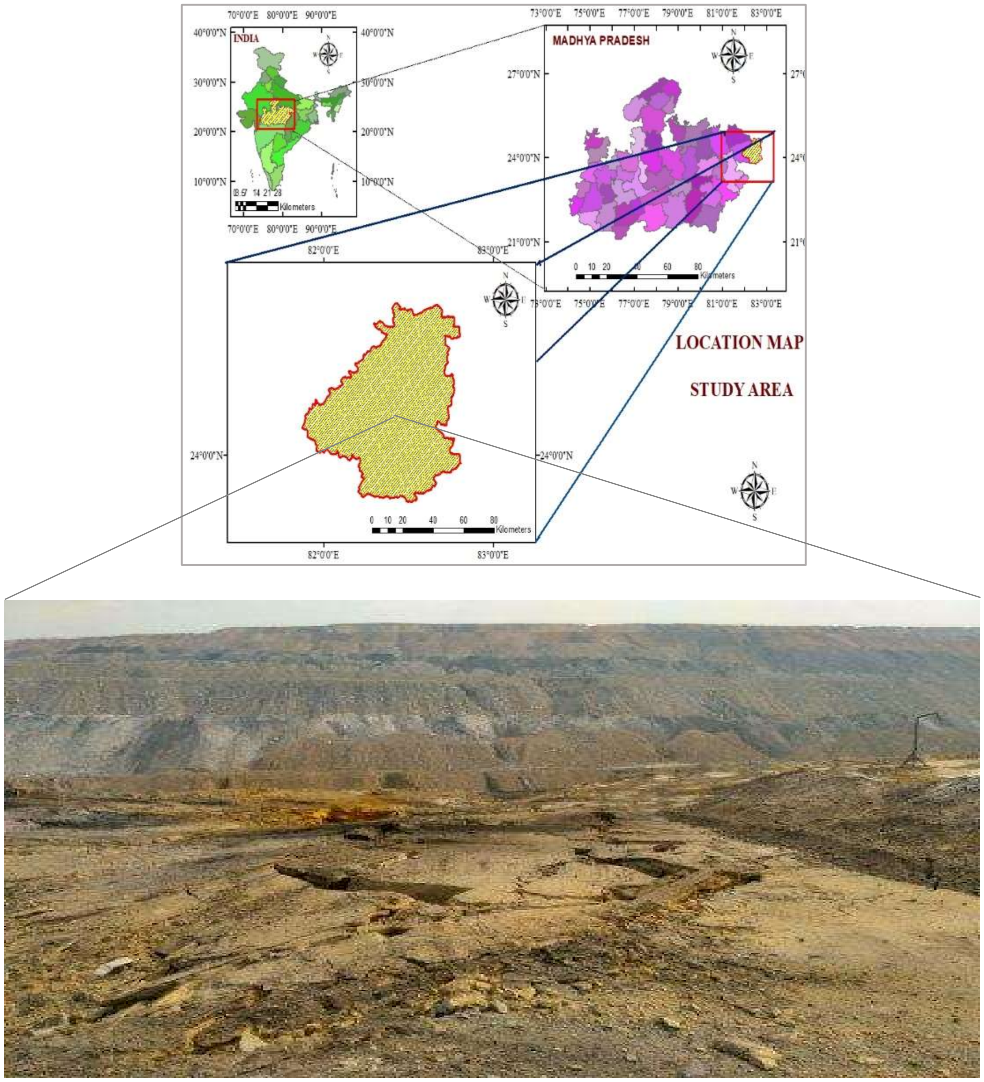


Figure 3.4 Location map of coal mine-2.

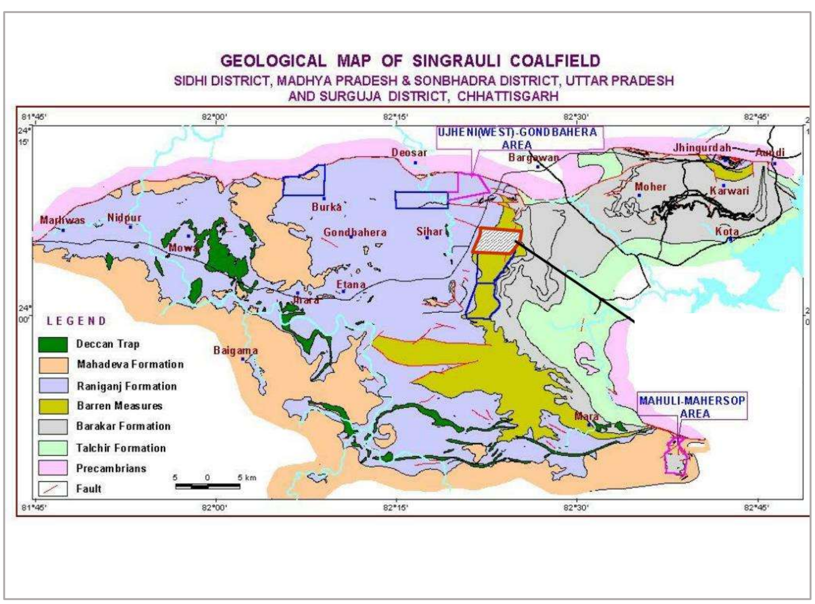


Figure 3.5 Coal mine-2, geological formation. (google.com)

3.2.2.2 Blast Geometry and Dataset

For simplicity and smooth observation, a survey line of 1300-1500m is drawn between the blast site and observation point towards nearby villages. The measured values, blast design parameters, and measured as well as predicted values of this study are tabulated in Tables 3.7, 3.8 and 3.9 respectively. The blast design parameters vary such as; burden (2-10m), spacing (3-12m), stemming (1.5-10m), hole diameter (125-311mm), hole depth (3-28m), explosive charge (1260-32,300kg), charge per meter (15-95kg/m), maximum charge per delay (225-1700kg), intra-row delay (17ms, 25ms, etc.) and inter-row delay (42ms, 63ms, 150ms, etc.) detonators whereas along with down –the- hole (DTH) delay (200ms- 450ms). In the case of the depth of the larger hole, (30% - 40%) top column charge and (60% - 70%) bottom charge was separated by decking. The staggered pattern has been used, and blast hole details are shown in Figure 3.6.

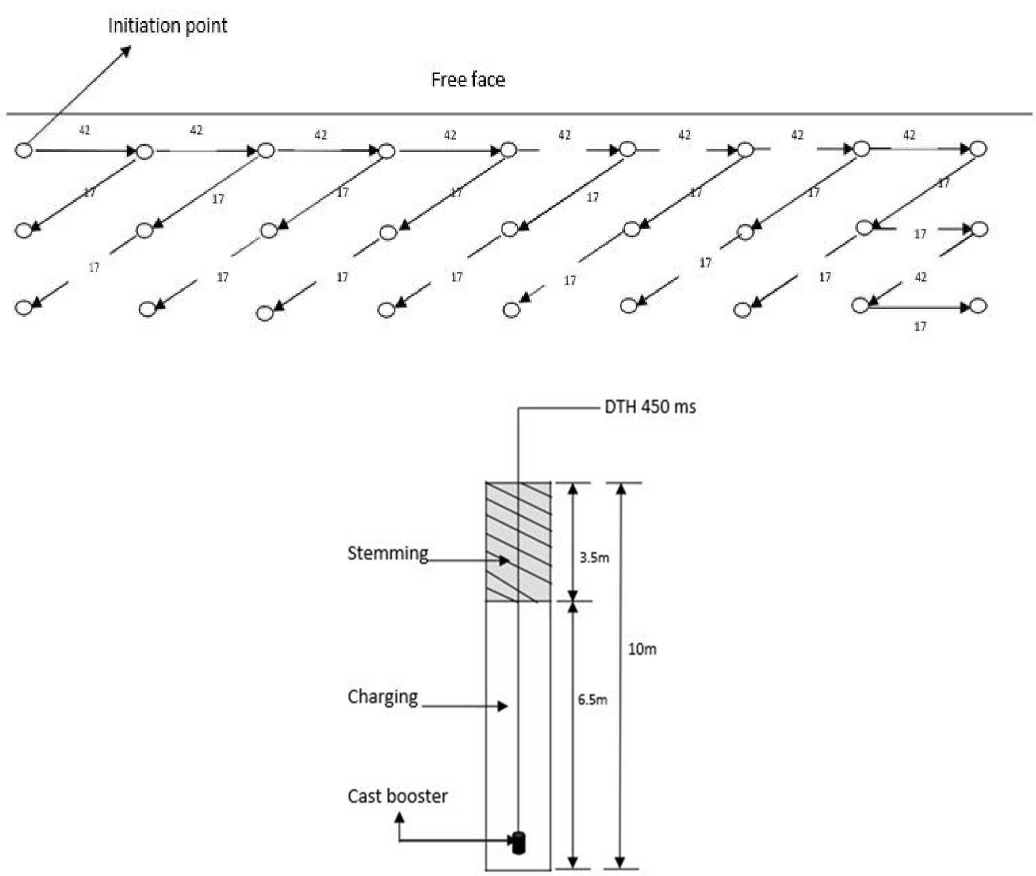


Figure 3.6 Staggered initiation pattern and blast hole details

Table 3.7: The measured PPV and frequency

Blast event No.	**Sl. No.**	**Monitoring distance (m)**	**Maximum charge per delay (Kg)**	**Peak particle velocity (mm/s)**	**Dominant frequency (Hz)**	**Peak vector sum (mm/s)**
BEN_1	1	50	950	91.57	5.5	104.84
	2	100	950	38.86	3.7	40.23
	3	150	950	21.72	3.0	23.35
	4	200	950	9.73	9.8	10.36
BEN_2	5	250	645	7.62	3.6	8.83
	6	300	645	6.73	20.4	6.26
	7	350	645	5.58	42.6	6.04
	8	400	645	4.7	5.8	5.71
BEN_3	9	450	704	6.2	17.6	6.85
	10	500	704	4.45	36.5	4.71
	11	550	704	3.81	56	4.45
	12	600	704	3.30	12.4	3.78
BEN_4	13	650	540	2.92	36.5	2.93
	14	700	540	1.53	3.7	2.02
	15	750	540	1.39	17.2	1.71
	16	800	540	1.3	85.3	1.28
BEN_5	17	850	815	2.28	9.1	2.56
	18	900	815	2.03	6.1	2.11
	19	950	815	1.7	32	2.0
	20	1000	815	1.02	12.8	1.16
BEN_6	21	1050	480	1.14	24.3	1.20
	22	1100	480	0.889	9.3	0.92
	23	1150	480	0.762	8.0	0.81
	24	1200	480	0.635	46.5	0.9
BEN_7	25	1250	735	2.159	56	2.52
	26	1300	735	1.9	9.6	2.35
	27	1350	735	1.65	56.8	1.8
	28	1400	735	1.27	4.4	1.43

Table 3.8: The measured field blast design parameters

Blast No.	Blast Event	Burden (m)	Spacing (m)	No. of holes	Hole depth (m)	Hole diameter (mm)	Powder Factor (m^3/kg)	Total charge (kg)
1	B_1	4	5	31	6.9	125	2.20	1840
2	B_2	5	6	24	7.5	160	3.74	2880
3	B_3	4	4.5	52	6.3	160	2.64	2230
4	B_4	5	6	70	7	125	4.0	3600
5	B_5	8	9	24	19	259	4.7	7780
6	B_6	4	5	42	7	159	2.80	3780
7	B_7	8	9	28	18.5	259	4.7	8880
8	B_8	5	6	09	19	160	2.5	2030
9	B_9	7	8	18	18.5	311	4.7	2772
10	B_{10}	6	7.5	14	19.5	311	1.80	6580
11	B_{11}	8	9	24	19	311	2.30	5420
12	B_{12}	4	5	44	7	160	4.7	1250
13	B_{13}	8	9	28	18	259	4.0	3400
14	B_{14}	5	6	32	7.5	160	2.80	1320
15	B_{15}	6.5	7.5	16	7	160	3.50	1200
16	B_{16}	4	5	34	6	159	2.5	940
17	B_{17}	5	6	54	6.5	160	3.7	980
18	B_{18}	8	9	20	18	259	4.5	3200
19	B_{19}	6	7	18	8	160	4.7	1060
20	B_{20}	7	8	20	19	311	3.80	4550
21	B_{21}	4	5	25	6	159	1.80	960
22	B_{22}	4	5	15	6	160	2.5	960
23	B_{23}	4.5	5.5	20	6.5	125	2.5	1050
24	B_{24}	6	8	19	8	159	3.5	880
25	B_{25}	7	9	10	19	259	1.8	4500
26	B_{26}	6	7	22	8	160	4.0	950
27	B_{27}	7	8	16	18	259	4.7	4650
28	B_{28}	6	8	14	18	311	3.80	5250
29	B_{29}	5	6	12	7.5	159	3.5	1050
30	B_{30}	5	6	18	7.5	160	2.80	1050
31	B_{31}	7	9	20	19	311	3.80	3680
32	B_{32}	6	7	18	19	311	4.0	6800
33	B_{33}	4	5	28	7.5	159	1.8	1350
34	B_{34}	5	6	26	18	259	3.8	3250
35	B_{35}	5	6	25	18	259	4.0	3250
36	B_{36}	4	5	35	7	159	2.5	880
37	B_{37}	6	7	19	12	259	3.8	1460
38	B_{38}	5.5	6.5	14	9	160	1.8	1130
39	B_{39}	5.5	6.5	24	9	160	2.5	1130
40	B_{40}	4	5	26	12	159	3.8	1560
41	B_{41}	6	7	21	18	259	4.0	3440
42	B_{42}	7	8	20	19	259	3.80	5050
43	B_{43}	4.5	5.5	47	12	160	2.3	1540
44	B_{44}	4.5	5.5	49	12	160	2.5	1600
45	B_{45}	5	6	23	9	125	3.80	980
46	B_{46}	5	6	21	9	125	2.5	980

Table 3.9: The measured and predicted value of PPV.

Sl. No.	D (m)	Q (Kg)	Scale Distance				Measured PPV (mm/s)	Predicted PPV (mm/s)				
			Duvall	**Langefors**	**Ambraseys**	**Indian Standard**		**Duvall**	**Langefors**	**Ambraseys**	**General predictor**	**Indian Standard**
1	50	950	1.6222	8.4762	5.2038	71.8461	50.673	195.335	37.2382	196.928	197.417	37.2382
2	100	950	3.2444	6.7431	10.4076	45.4698	38.862	60.973	20.006	59.1263	61.1849	20.006
3	150	240	9.682458	2.9648	24.5822	8.79004	11.43	9.7171	2.1474	13.300	10.110	2.1474
4	200	240	12.9094	2.6962	32.7763	7.2699	9.729	5.9934	1.6594	8.0721	6.2175	1.6594
5	225	665	8.7251	4.3170	26.3421	18.6372	21.717	11.574	5.958	11.795	11.6388	5.958
6	250	665	9.6945	4.1695	29.2690	17.3852	14.732	9.6967	5.4219	9.8244	9.7404	5.4219
7	275	576	11.4583	3.7603	33.7592	14.1404	8.001	7.3230	4.0956	7.6685	7.3798	4.0956
8	300	576	12.500	3.6539	36.8283	13.3512	6.731	6.3273	3.788	6.5935	6.3707	3.788
9	325	700	12.2838	3.9230	37.4111	15.3905	5.588	6.5154	4.5949	6.4162	6.5173	4.5949
10	350	700	13.2287	3.8283	40.2889	14.6559	4.191	5.7528	4.2997	5.6418	5.750	4.2997
11	375	510	16.6052	3.1941	47.9218	10.2025	5.461	3.9269	2.6291	4.1747	3.9588	2.6291
12	400	510	17.7123	3.1268	51.1165	9.7771	4.318	3.5234	2.4814	3.7323	3.5498	2.4814
13	425	1600	10.625	5.4286	37.2416	29.4702	5.08	8.3133	11.1023	6.4670	8.0939	11.1023
14	450	1600	11.250	5.3272	39.4323	28.3791	3.931	7.5522	10.5479	5.8562	7.3486	10.5479
15	475	700	17.9533	3.4613	54.6778	11.9806	2.54	3.4443	3.270	3.3205	3.4319	3.270
16	500	700	18.8982	3.4032	57.5556	11.5818	2.286	3.1600	3.1232	3.0376	3.146	3.1232
17	525	280	31.3747	2.1180	81.7705	4.4859	2.794	1.3486	0.8614	1.6512	1.3789	0.8614
18	550	280	32.8687	2.0857	85.6644	4.3502	1.905	1.2472	0.8263	1.5231	1.2747	0.8263
19	575	360	30.3051	2.3305	82.4305	5.4315	1.905	1.4295	1.1169	1.6283	1.4495	1.1169
20	600	360	31.6227	2.2980	86.0144	5.2810	1.778	1.3309	1.0751	1.5124	1.3489	1.0751
21	625	350	33.4076	2.235598	90.43521	4.9978	1.524	1.2136	0.9975	1.3864	1.2306	0.9975

22	650	350	34.7439	2.2068	94.0526	4.8701	1.397	1.1362	0.9631	1.2951	1.1517	0.9631
23	675	225	45.00	1.7475	113.0013	3.0538	0.978	0.7358	0.5109	0.9417	0.7553	0.5109
24	700	225	46.6667	1.7266	117.1866	2.9813	0.899	0.6922	0.4945	0.8841	0.7102	0.4945
25	725	320	40.5287	2.0354	108.0534	4.1431	1.905	0.8772	0.7732	1.0179	0.8905	0.7732
26	750	320	41.9262	2.0128	111.7794	4.0514	1.651	0.8287	0.7501	0.9597	0.8409	0.7501
27	775	336	42.2797	2.0403	113.6605	4.1629	0.895	0.8171	0.7782	0.9323	0.827	0.7782
28	800	336	43.6435	2.0190	117.327	4.0766	0.854	0.7746	0.7568	0.8823	0.7844	0.7568
29	825	1600	20.625	4.3614	72.2926	19.0221	1.397	2.7284	6.1267	2.0449	2.6383	6.1267
30	850	1600	21.250	4.3186	74.4833	18.6510	1.27	2.5949	5.9649	1.9416	2.5085	5.9649
31	875	350	46.7707	2.0006	126.6093	4.0026	0.953	0.6896	0.7378	0.7731	0.6969	0.7378
32	900	490	40.6578	2.3452	116.5407	5.5004	1.015	0.8726	1.1361	0.8927	0.872839	1.1361
33	925	270	56.2937	1.7252	145.8115	2.9765	0.762	0.5051	0.4935	0.6050	0.5140	0.4935
34	950	270	57.8151	1.7101	149.7523	2.9245	0.462	0.4830	0.4818	0.5776	0.4914	0.4818
35	975	570	40.8382	2.4635	120.1063	6.0692	0.934	0.8661	1.2986	0.8472	0.8618	1.2986
36	1000	570	41.8853	2.4430	123.186	5.9686	0.731	0.8300	1.2694	0.8107	0.8257	1.2694
37	1025	450	48.3189	2.1531	136.5098	4.6359	0.589	0.6529	0.9007	0.6783	0.6538	0.9007
38	1050	450	49.4974	2.1360	139.839	4.5627	0.457	0.6270	0.8815	0.6506	0.6277	0.8815
39	1075	1700	26.0725	4.1196	92.333	16.9714	1.651	1.8404	5.2474	1.3372	1.7717	5.2474
40	1100	1700	26.6789	4.0885	94.4810	16.7158	1.397	1.7707	5.1404	1.2846	1.7042	5.1404
41	1125	1600	28.125	3.9371	98.5809	15.5009	1.524	1.6205	4.6398	1.1936	1.5620	4.6398
42	1150	1600	28.750	3.9086	100.7716	15.2777	1.016	1.5618	4.549	1.1489	1.5050	4.549
43	1175	855	40.1841	2.8370	126.6161	8.0489	0.798	0.8899	1.9054	0.7730	0.8733	1.9054
44	1200	855	41.0391	2.8174	129.3101	7.9379	0.712	0.8590	1.8697	0.7452	0.8428	1.8697
45	1225	1520	31.4205	3.7311	109.1761	13.9211	0.691	1.3453	4.0096	0.9998	1.297	4.0096
46	1250	1520	32.0618	3.7063	111.4042	13.7367	0.635	1.3004	3.9376	0.9653	1.2540	3.9376

3.3 Limestone Quarry

The term mine and quarry are the different because of the mining is the process of extracting buried material below the earth surface. Whereas, the quarrying refers to extracting materials directly from the surface.

3.3.1 Case III: Limestone Quarry-3 Chhattisgarh

3.3.1.1 Location and Geology

The study was conducted at a limestone quarry-3 situated in Chhattisgarh. The block covers an area of 1.67 km^2 and is bounded by latitude 21^0 45' 57.11" N to 21^0 48' 38.15" N and longitude 82^0 13' 42.60" E to 82^0 17' 47.33" E and location map of quarry-3 is shown in Figure 3.7. The limestone deposits of the district of quarry-3 region consists of the sedimentary rocks of the Chhattisgarh basin. Deposition of rocks are almost horizontal, thick-bedded and classified as stromatolitic limestone of the Raipur Group. Other associated rocks are dolomitic limestone and shale. The overburden consists of hard murrum and clay with an average thickness of 3.0m. underlying this, the limestone and shale are structurally disturbed by the vertical and horizontal fissures and joints. This results in difficulties in drilling and poor fragmentation.

Further, the deposit is highly contaminated up to nearly 7m depth with clay and murrum, which, if not separated, renders the whole strata unusable for making cement. The deposit is being worked in one pit. The average height of the benches varies from 6.0-6.5m (Singh, 2004 and RD NCCR, 2012).

3.3.1.2 Blast Geometry and Dataset

The measurement has been done with four different seismographs, which contains tri-axial geophone. The tri-axial geophone measure three components of PPV corresponding dominant frequencies along the radial, vertical, and transverse direction. Seismographs were installed simultaneously at specific intervals for data monitoring. The nearest distance of the seismograph was kept, 75m from the blast site. Seismograph move along survey line with certain intervals up to last observation point towards a nearby village. The staggered initiation system was used, and blast hole details are shown in Figure 3.8. The specific gravity of limestone and average powder factor is listed in Table 3.10. During the trial blasts, charging was done with SME explosives of M/s Orica and connected by Nonel. In a blast hole, a single column charge is required. The blasting parameters used as; blast hole diameters (115mm), depth varies from 5.8 to 6.7m, burden, spacing, stemming, charge per hole, the maximum charge per delay, etc., are tabulated in Table 3.11. The arrangement of the delay detonators in a minefield like a hole to hole in a row delay of 17ms and inter-row delay of 42ms has been made along with the down-the-hole (DTH) delay of 450ms. A total of 31 data sets of 10 blast events with different measured parameters and predicted PPV values are listed in Table 3.12, and one another measured datasets are tabulated in Table 3.13.

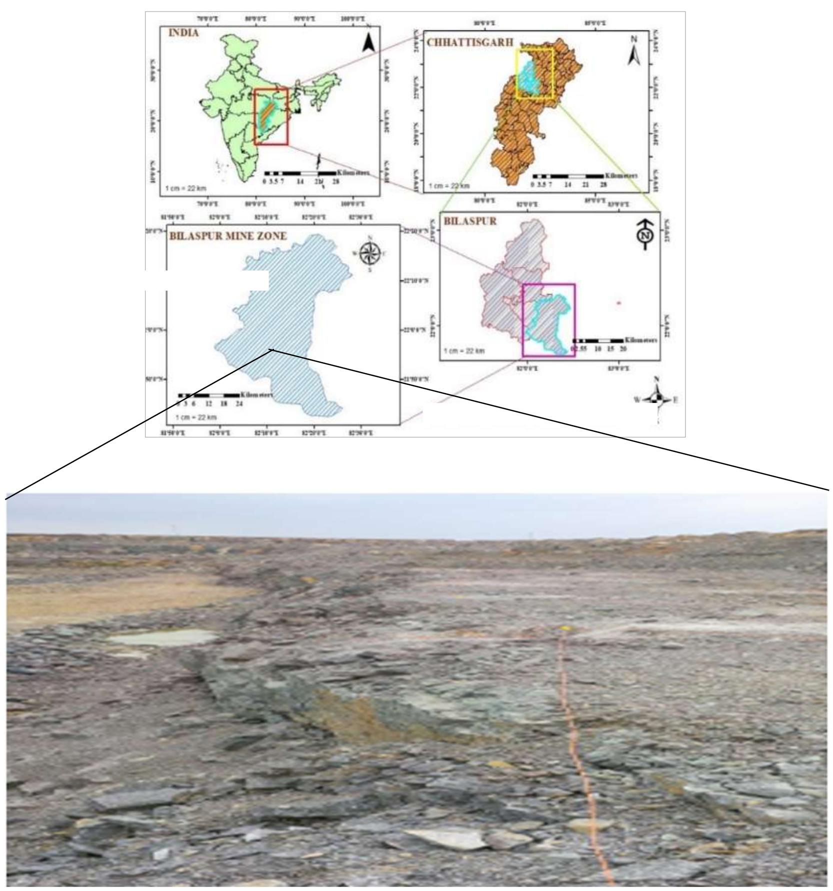


Figure 3.7 Location map of limestone quarry-3.

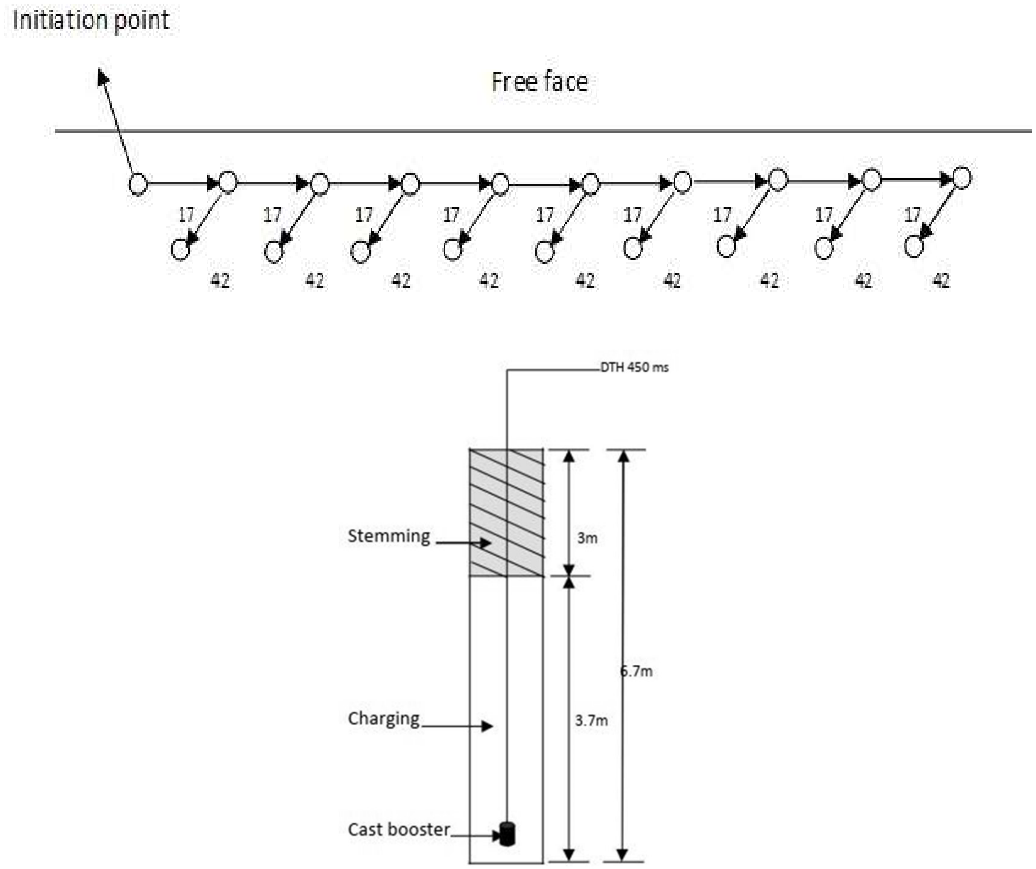


Figure 3.8 Staggered initiation pattern and blast hole details

Table 3.10: The Specific gravity and powder factor.

Blast Hole Diameter	Specific Gravity of Limestone	Average Powder Factor
115 mm	2.5 g/cc	4.75 TE/Kg

Table 3.11: The field blast design parameters

Trial No.	Face/ Bench	No. of Holes	Spacing (m)	Burden (m)	Hole Depth (m)	No. of Rows	Charge / Hole (Kg)	Maximum Charge/ Delay (Kg)	Charge /round (Kg)	Total Yield (TE)	Powder Factor (TE/Kg)
1	B2W	43	4.5	2.5	5.8	2	42.01	42	1806.45	7026	3.89
2	B2S	26	4.5	2.5	5.6	3	39.77	40	1033.90	4124	3.99
3	B4E	27	4.5	2.5	5.5	2	38.67	39	1044.05	4192	4.01
4	B3N	35	5	3	5.5	2	30.44	30	1065.25	7193	6.75
5	B2N	23	5	3	6.7	2	54.06	54	1243.45	5753	4.63
6	B3S	19	5	2.75	5.8	2	32.41	32	615.85	3782	6.14
7	B2S	19	5	2.75	6	2	43.41	43	824.85	3782	4.58
8	B2W	15	5	2.6	6	2	45.15	45	677.25	2969	4.38
9	B3N	19	5	2.7	6.5	2	41.57	41	789.75	4180	5.29
10	B2N	15	5	2.7	6.7	2	43.92	44	658.75	3392	5.15

Table 3.12: The measured and predicted PPV and PVS.

Blast No.	Bench	Instrument No.	Distance (m)	Max. Charge /Delay (Kg)	Component Velocity (mm/s)			Component Frequency (Hz)			Dominant Frequency (Hz)	Scaled Distance m/kg$^{0.5}$	Measured Velocity (mm/s)		Predicted Velocity (mm/s) by IS	
					R	T	V	R	T	V			PPV	PVS	PPV	PVS
1	B2W	5472	200	39	4.75	7.12	4.38	22.5	68.5	68.5	68.5	32.03	7.12	7.303	7.19	9.61
		NoMiS	100	39	10.29	11.81	10.28	56.8	73.1	73.1	73.1	16.01	11.81	13.16	12.19	18.73
2	B2S	5472	100	40	8.38	8.89	9.65	63.0	57.5	45.5	45.5	15.81	9.65	12.08	12.56	15.56
		NoMiS	245	40	2.90	2.66	4.19	21.3	73.1	85.3	85.3	38.73	4.19	5.30	6.35	5.74
3	B4E	5472	200	42	15.59	13.21	14.48	43.5	40.5	84.5	43.5	30.86	15.59	16.53	7.84	25.04
		NoMiS	250	42	2.80	2.28	3.17	128	170.6	39.3	39.3	38.57	3.17	3.62	6.61	4.80
4	B3N	5472	75	30	20.32	27.43	8.89	58	49.5	27	49.5	13.69	27.43	29.69	11.22	35.27
		4537	200	30	2.41	2.73	0.445	86.5	76	86.5	76	36.51	2.73	2.81	5.31	3.66
		BE10076	75	30	14.10	10.79	4.318	128	36	49.5	128	13.69	14.10	14.76	11.22	18.27
		NoMiS	125	30	2.80	4.95	3.175	3.10	9.3	1.80	9.3	22.82	4.95	5.15	7.60	6.51
5	B2N	5472	125	54	7.36	10.92	3.55	25	126.5	126.5	126.5	17.01	10.92	12.43	14.98	13.63
		4537	75	54	17.8	28.40	6.10	25	25.5	50.5	25.5	10.20	28.40	28.5	22.09	34.06
		NoMiS	100	54	9.52	10.16	9.27	20.4	32	56.8	32	13.60	10.16	13.59	17.75	16.72
6	B3S	5472	200	32	3.87	3.81	5.27	15	13.5	37.5	37.5	35.35	5.27	5.41	5.73	7.56
		NoMiS	250	32	3.3	2.03	3.43	64	85.3	36.5	36.5	44.19	3.43	4.62	4.83	5.17
7	B2S	5472	100	43	5.08	6.85	7.87	21	17.5	32.5	32.5	15.26	7.87	11.46	13.65	11.60
		4537	150	43	3.49	4.06	2.92	17.5	87.5	62.5	87.5	22.87	4.06	5.18	10.02	6.09
		BE10076	75	43	9.90	23.62	14.6	33.75	32.75	32.75	32.75	11.49	23.62	27.16	16.99	29.48
		NoMiS	125	43	4.82	2.28	3.55	21.3	17	56.8	21.3	19.06	4.82	5.63	11.54	6.40
8	B4E	5472	100	45	6.85	5.20	4.82	21	20.5	63	21.0	14.90	6.85	7.55	14.38	9.85
		4537	200	45	2.48	0.953	0.699	95	92	96	95	29.84	2.48	2.67	8.48	2.74
		BE10076	125	45	1.14	4.82	4.82	193	19.25	43.25	19.25	18.63	4.82	5.67	12.14	6.91
		NoMiS	250	45	1.27	0.635	1.14	14.3	73.1	56.8	14.3	37.28	1.27	1.58	7.16	1.82
9	B3N	5472	170	41	5.71	4.44	3.36	23.5	155	53	5.71	26.54	23.5	6.39	8.62	7.97
		4537	220	41	3.18	2.41	2.22	18	24.5	14.5	3.18	34.33	18	4.05	7.09	4.56
		BE10076	100	41	8.01	5.46	5.58	24.5	25	48	8.01	15.61	24.5	8.59	12.92	11.18
		NoMiS	200	41	5.20	3.68	2.92	21.3	19.6	48.4	5.20	31.25	21.3	5.25	7.62	7.00
10	B2NW	5472	125	44	5.08	2.03	3.49	14	13.5	46.5	5.08	18.84	14	5.44	11.82	6.48
		4537	175	44	1.97	3.24	1.71	100	98	74.5	3.24	26.38	98	3.67	9.15	4.15
		BE10076	100	44	1.52	5.96	8.0	181.5	19	43	5.96	15.07	19	8.0	14.01	10.09
		NoMiS	220	44	2.28	1.77	1.39	32	56.8	51.2	2.28	33.16	56.8	2.99	7.69	3.20

Table 3.13: The measured PPV and frequency

Blast event No.	Sl. No.	Monitoring distance (m)	Maximum charge per delay (Kg)	Peak particle velocity (mm/s)	Dominant frequency (Hz)	Peak vector sum (mm/s)
BEN_1	1	50	140	14.09	8.6	17.36
	2	100	140	7.24	34.1	7.27
	3	150	140	6.60	5.2	6.9
	4	200	140	6.62	8.0	7.30
BEN_2	5	250	110	5.70	4.3	7.09
	6	300	110	5.45	5.7	5.67
	7	350	110	5.05	13.1	5.70
	8	400	110	4.82	4.6	5.20
BEN_3	9	450	75	2.95	5.7	3.5
	10	500	75	2.41	4.6	3.4
	11	550	75	2.16	12.8	2.20
	12	600	75	1.50	4.60	1.84
BEN_4	13	650	95	3.05	17.6	3.54
	14	700	95	2.90	18.9	3.20
	15	750	95	1.65	3.0	1.82
	16	800	95	0.76	6.7	0.82
BEN_5	17	850	80	1.77	9.1	1.85
	18	900	80	1.395	5.6	1.63
	19	950	80	0.763	3.8	0.92
	20	1000	80	0.64	6.6	0.7
BEN_6	21	1050	135	2.16	3.9	2.45
	22	1100	135	1.52	7.1	1.61
	23	1150	135	1.02	2.0	1.05
	24	1200	135	0.889	7.3	0.92
BEN_7	25	1250	120	1.0	1.4	1.14
	26	1300	120	0.762	11.9	0.78
	27	1350	120	0.65	25.6	0.82
	28	1400	120	0.635	8.5	0.79

3.4 Stone Quarry

3.4.1 Case IV: Stone quarry-4 Bihar

3.4.1.1 Location and Geology

The study was conducted at stone quarry-4, which lies between latitude 24° 39’ 16” to 24° 39’ 22” North and longitude 85° 31’ 22” to 85° 31’ 32” East and located in Bihar. The location map of the stone quarry is shown in Figure 3.9. The northern part is a plain area underlain by alluvial soils covering this district, Warisaliganj, Pakhribarwan and parts of Hisua, Narhat, Govindpur, Akbarpur and Kauakol blocks. Consequently, it is densely populated and has a rich historical background. The southern part is hilly and undulating with a gentle ascent towards the south merging into hills and is part of the southern fringes of the

Chhottanagpur Plateau. The entire southern boundary of the district is a conglomeration of ridges and spurs. The crystalline rocks in the district are mica schists, granite gneiss, quartzite and quartz schist, hornblende schist and mica pegmatite etc. These rock types constitute the hill ranges and cover the south and eastern parts of Rajauli block, southern parts of Sirdala block north-central and south parts of Govindpur blocks and south, south-eastern and northern parts of Kauakol block. The Archaeans are the oldest rock formation in the state. The most predominant rock type is mainly gneisses and granitic rocks with fewer schists, quartzite, basic intrusive, and pegmatite. The geological map of Bihar is shown in Figure 3.10. They are exposed in Aurangabad, Gaya, Nawada, Jamui, Bhagalpur and Banka districts. The Construction material kind of rock is exploited in stone quarry-4.

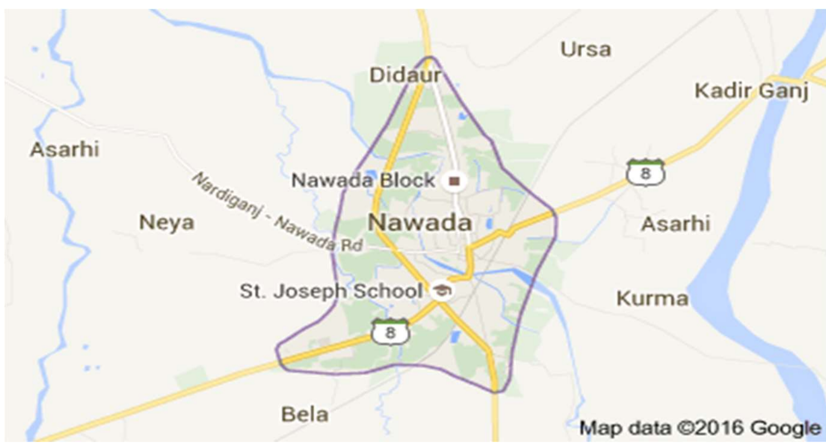


Figure 3.9 The location map of stone quarry-4. (From Google Earth)

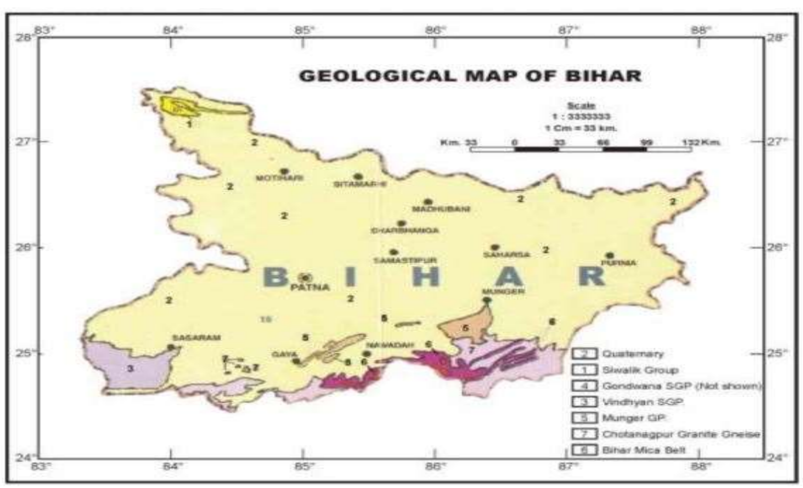


Figure 3.10 Geological map of Bihar (Source: Statement of Environment Report, Feb 2007, BPCB)

3.4.1.2 Blast Geometry and Dataset

The conventional drilling and blasting method carried out the excavation. The holes are drilled by a pneumatically operated crawler mounted drill machine. The blast holes have a diameter of 100mm, and the average depth of blast holes was 7m. Since fissures crisscross the blocks, drill holes are generally drilled on a staggered pattern. The oversized boulders, which cannot be handled, are further fragmented by secondary blasting. The burden and spacing for 100mm diameter holes are around 2 m by 2 m, respectively. Aqua-dyne and energel each of weight 1625 gm were used for blasting. Hence total charge in each round of blast should be used as 3250 Kg. The measured blast design parameters and predicted values are tabulated in Tables 3.14, 3.15, and 3.16, respectively. A shock tube initiation system is used for firing. Down-the-hole (DTH) delays of 250 milliseconds were used. In secondary blasting for breaking the oversized boulders, power-gel and codex were used in average blast hole depth of 5ft and diameter of 31mm. The maximum charge used in a single shot is 25Kg. The village population is almost beyond 1700m from the periphery of the blasting site. One permanent temple is situated approximately 1500m from the blasting site. All the highways are almost located more than 2600m from the blasting site. The mine office is nearly at a distance of about 1900m from the quarry. The office falls under the category of Industrial Buildings belonging to the owner.

First, a survey line is made from the blasting site to the last observation point (800m-900m). The ground vibration is measured in the form of PPV and their components by using four seismographs of Nomis make, which has a tri-axial geophone. The seismographs were installed at every 100m interval and data monitored. The staggered initiation pattern of blast holes is shown in Figure 3.11.

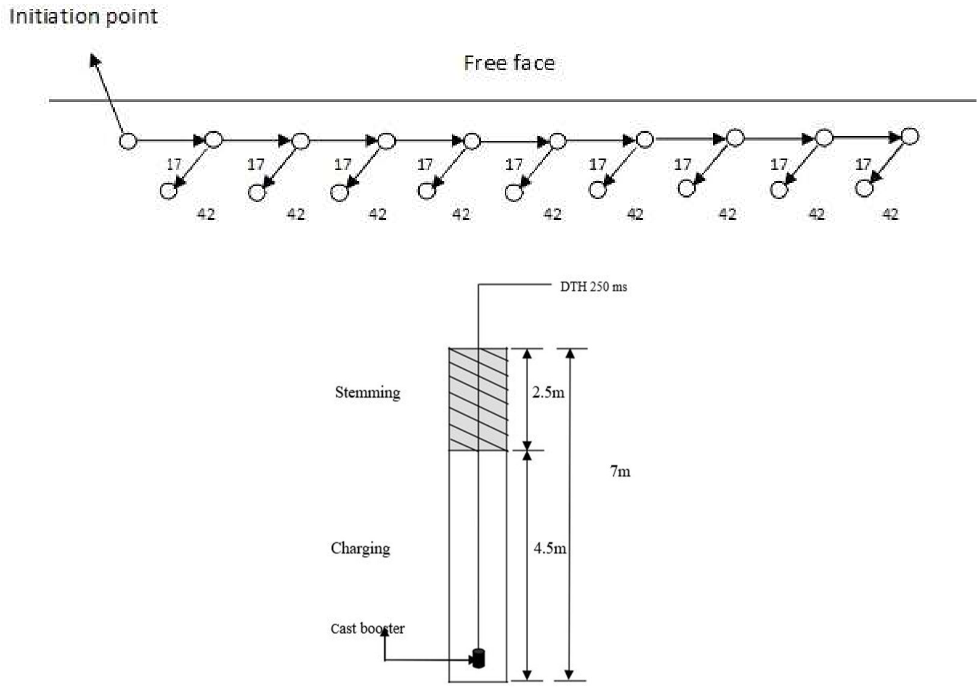


Figure 3.11 The staggered initiation system and blast hole details.

Table 3.14: The measured PPV and frequency

Blast event No.	Sl. No.	Monitoring distance (m)	Maximum charge per delay (Kg)	Peak particle velocity (mm/s)	Dominant frequency (Hz)	Peak vector sum (mm/s)
BEN_1	1	50	210	25.02	3.4	26.23
	2	100	210	20.83	2.7	22.6
	3	150	210	14.73	5.9	16.35
	4	200	210	11.43	3.3	11.97
BEN_2	5	250	195	8.90	56.8	8.28
	6	300	195	8.0	56.8	8.29
	7	350	195	5.50	3.4	5.64
	8	400	195	4.56	46.5	6.28
BEN_3	9	450	145	2.66	8.3	3.70
	10	500	145	1.34	6.8	1.54
	11	550	145	1.14	6.3	1.20
	12	600	145	0.76	19.6	0.80
BEN_4	13	650	110	1.43	4.30	1.17
	14	700	110	1.02	4.3	1.18
	15	750	110	0.889	4.0	0.98
	16	800	110	0.635	3.7	0.70
BEN_5	17	850	90	1.016	3.5	1.15
	18	900	90	0.763	3.3	0.82
	19	950	90	0.64	4.1	0.73
	20	1000	90	0.63	2.70	0.78
BEN_6	21	1050	235	2.03	3.9	2.62
	22	1100	235	1.778	5.0	1.94
	23	1150	235	1.27	14.2	1.84
	24	1200	235	1.10	5.0	1.23
BEN_7	25	1250	180	1.53	5.1	1.66
	26	1300	180	1.016	4.0	1.37
	27	1350	180	0.77	8.6	0.84
	28	1400	180	0.64	0.82	5.6

Table 3.15: The blast design parameters.

Blast No.	Blast Event	Burden (m)	Spacing (m)	No. of holes	Hole depth (m)	Hole diameter (mm)	Powder Factor (m^3/kg)
1	BEN_1	2	2	31	6.9	100	2.20
2	BEN_2	2	2	24	7.5	100	3.74
3	BEN_3	2	2	52	6.3	100	2.64
4	BEN_4	2	2	70	7	100	4.0
5	BEN_5	2	2	24	8	100	4.7
6	BEN_6	2	2	42	7	100	2.80
7	BEN_7	2	2	19	8	100	3.64
8	BEN_8	2	2	20	7	100	3.89
9	BEN_9	2	2	28	7.5	100	2.75

Table 3.16: The measured and predicted values.

Blast Event No.	Distance (m)	MCPD (kg)	Scaled Distance ($m/kg^{0.5}$)	Scaled Distance ($kg/D^{0.66}$)	Measured PPV (mm/)	Predicted by USBM	Predicted by IS
	50	210	3.45	15.88	25.02	36.27	35.13
	100	210	6.95	10.05	20.83	17.24	17.71
	150	210	10.35	7.691	14.73	11.15	11.86
BE_1	200	210	13.80	6.36	11.43	8.19	8.93
	250	195	17.90	5.09	8.9	6.19	6.42
	300	195	21.48	4.51	8	5.09	5.35
	350	195	25.06	4.08	5.5	4.32	4.59
BE_2	400	195	28.64	3.73	4.56	3.7	4.029
	450	145	37.37	2.57	2.66	2.81	2.30
	500	145	41.52	2.39	1.34	2.51	2.07
	550	145	45.67	2.25	1.14	2.26	1.88
BE_3	600	145	49.82	2.12	0.76	2.06	1.73
	650	110	61.97	1.53	1.43	1.6	1.05
	700	110	66.74	1.45	1.02	1.51	0.98
	750	110	71.50	1.39	0.889	1.40	0.918
BE_4	800	110	76.27	1.33	0.635	1.30	0.862
	850	90	89.59	1.04	1.016	1.10	0.601
	900	90	94.86	1.01	0.763	1.03	0.568
	950	90	100.13	0.97	0.64	0.97	0.538
BE_5	1000	90	105.40	0.94	0.63	0.92	0.512
	1050	235	68.49	2.38	2.03	1.46	2.05
	1100	235	71.75	2.31	1.778	1.39	1.96
	1150	235	75.01	2.24	1.27	1.33	1.87
BE_6	1200	235	78.27	2.18	1.1	1.27	1.79
	1250	180	93.16	1.62	1.53	1.05	1.15
	1300	180	96.89	1.58	1.016	1.01	1.11
	1350	180	100.62	1.54	0.77	0.97	1.07
BE_7	1400	180	104.34	1.50	0.64	0.93	1.03
	1450	195	103.83	1.59	1.38	0.94	1.12
	1500	195	107.41	1.56	1.29	0.90	1.09
	1550	195	110.99	1.52	1.17	0.87	1.05
BE_8	1600	195	114.57	1.49	1.095	0.858	1.02
	1650	265	101.35	1.99	1.97	0.964	1.57
	1700	265	104.43	1.95	1.72	0.934	1.52
	1750	265	107.50	1.91	1.43	0.905	1.48
BE_9	1800	265	110.57	1.88	1.29	0.878	1.44

3.4.2 Case V: Stone quarry-5 Uttar Pradesh

3.4.2.1 Location and Geology

The study was conducted at stone quarry-5 which lies between latitude 27° 80’50” to 27° 82’ 25” North and longitude 70° 31’ 50” to 70° 33’50” East and located in Uttar Pradesh. The location map of the stone quarry-5 is shown in Figure 3.12. The area is dominated by in-situ outcrops of Kajarahat limestone capped by a thin layer of red soil. The upper half of Kajarahat limestone, which has a low CaO concentration, became dolomitic and was thus classified as dolostone. The dolostone of the mine region is a portion of Kajarahat limestone, characterized by dark brown colour and covered by 1.0-2.0 metre soil and semi-weathered dolostone, often showing current bedding and load cast structures, indicating a dry and eolian deposition environment. Bijagarh shale having a thickness of 0.5-1.0 metres is observed in intercalation with dolostone. The bulk density of dolostone is around 2.5gm/cc.

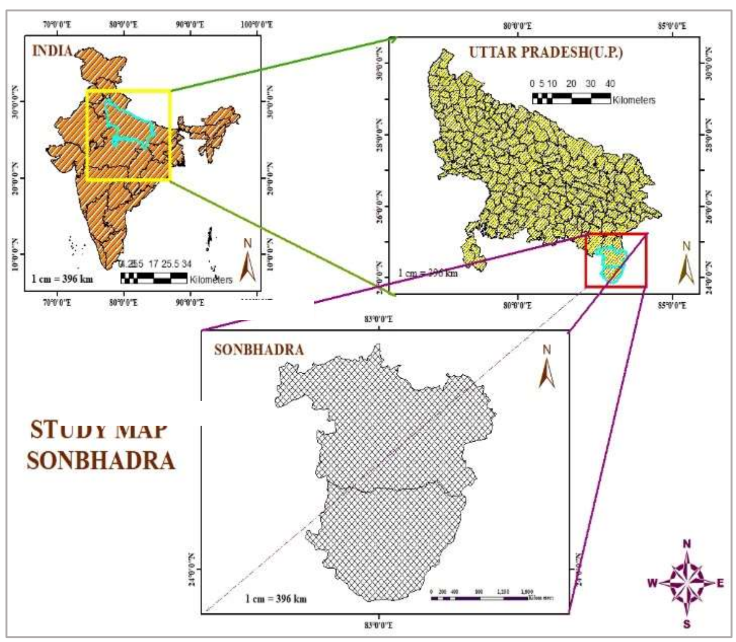


Figure 3.12 Location map of stone quarry-5.

3.4.2.2 Blast Geometry and Dataset

The benches are formed horizontally along particular horizons and vary 3 feet to 8 feet in thickness, and are mined by the vertical slicing method. However, the maximum height of the bench is maintained up to 8 feet for effective and efficient collection of blasted material at the base after blasting operations. The conventional drilling and blasting method carry out the excavation. A tractor-mounted pneumatic drill machine drills the blast holes. The blast-holes have a diameter of 38 mm. The blast holes are normally drilled in a staggered pattern. The oversized boulders, which cannot be handled manually, are further fragmented manually. The burden, as well as the spacing between the rows of blast holes, is around 1 m. Slurry explosive cartridges of 25 mm diameter having 200mm length and 125 gm weight are used for blasting. An electronic detonator initiation system is used for shot firing. A delay of 65millisecond is used between two rows. The residential population is almost beyond 1.0 Km from the periphery of the blasting site in general except for some RCC structured buildings which are situated on the south-western side of the quarry. These structures are approximately 220m from the blasting site. All the highways are more than 3.0 Km from the blasting site.

First, a survey line is made from the blasting site to the last observation point. The ground vibration is measured in the form of PPV and frequency tabulated in Table 3.17 using four seismographs Nomis make, which has a tri-axial geophone. A total of 40 datasets of ten blast events have been measured during the study period and tabulated in Table 3.18. The staggered initiation pattern has been used, as shown in Figure 3.13 with blast hole details. The delay operators as 17ms, 65ms are used in line and cross line, respectively, along with down-the-hole (DTH) delays of 200ms- 250ms. As mentioned above, research components include the instruments, materials, activities, participants, methods and techniques involved the research. Familiarity to those. components are required in order to get more comprehensive understanding of research.

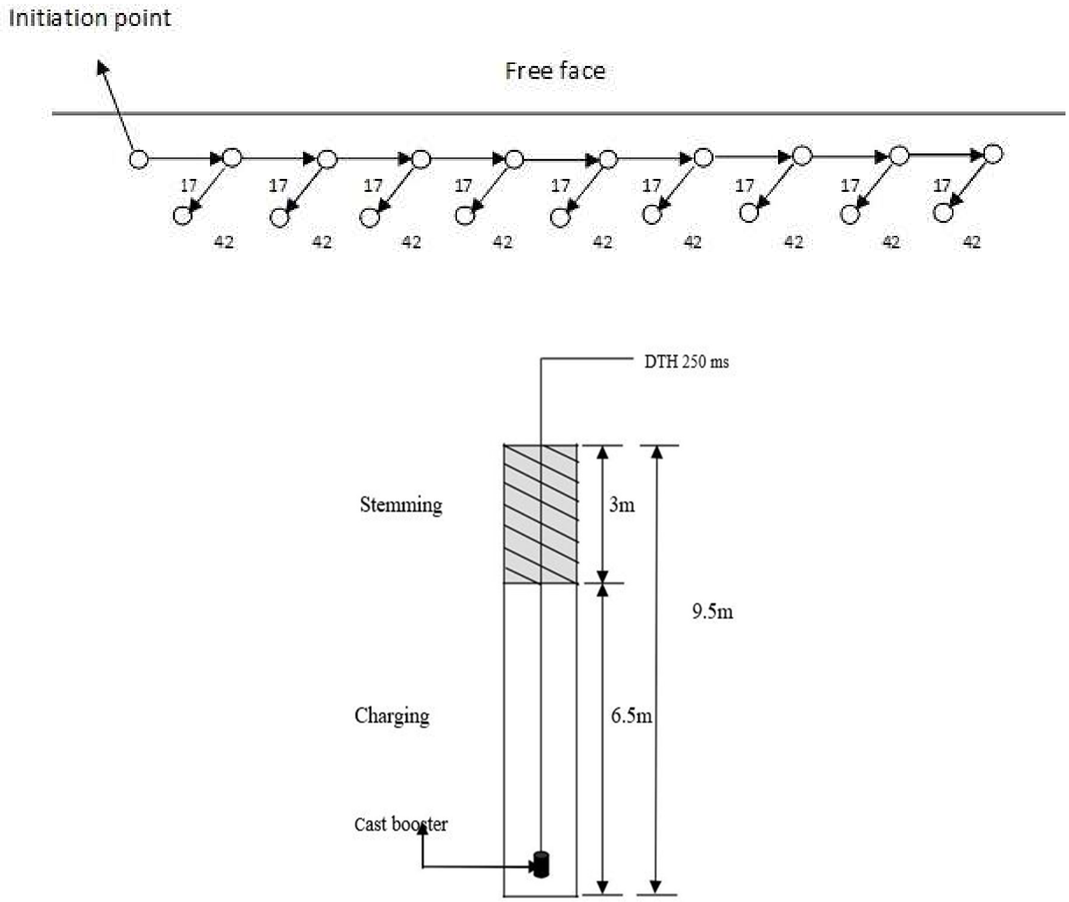


Figure 3.13 The staggered initiation system and blast hole details.

Table 3.17: The measured PPV and frequency

Blast event No.	Sl. No.	Monitoring distance (m)	Maximum charge per delay (Kg)	Peak particle velocity (mm/s)	Dominant frequency (Hz)	Peak vector sum (mm/s)
BEN_1	1	50	160	21.20	56	21.78
	2	100	160	17.53	34.6	18.62
	3	150	160	13.08	28	13.16
	4	200	160	9.2	3.7	9.96
BEN_2	5	250	225	10.79	1.50	10.80
	6	300	225	8.0	6.4	8.31
	7	350	225	6.85	64	7.38
	8	400	225	5.20	23.2	5.98
BEN_3	9	450	124	2.67	1.6	2.70
	10	500	124	1.90	14.2	1.91
	11	550	124	1.78	8.9	2.18
	12	600	124	0.89	4.3	0.90
BEN_4	13	650	190	4.32	11.3	5.44
	14	700	190	3.68	56.8	3.90
	15	750	190	2.41	14.6	2.45
	16	800	190	1.02	2.5	1.09
BEN_5	17	850	215	1.9	4.8	2.57
	18	900	215	1.79	20.4	1.89
	19	950	215	1.14	5.0	1.23
	20	1000	215	0.762	39.2	0.78
BEN_6	21	1050	170	2.54	2.8	3.11

	22	1100	170	1.39	9.8	1.57
	23	1150	170	1.14	15.5	1.15
	24	1200	170	0.89	25.6	0.93
BEN_7	25	1250	175	0.88	56.8	1.05
	26	1300	175	0.76	6.2	1.0
	27	1350	175	0.64	3.0	0.72
	28	1400	175	0.63	7.4	0.84

Table 3.18: The measured and predicted values.

Blast Event No.	**Distance (m)**	**MCPD (kg)**	**Scaled Distance ($m/kg^{0.5}$)**	**Scaled Distance ($kg/D^{0.66}$)**	**Measured PPV (mm/s)**	**Predicted (mm/s) by USBM**	**Predicted (mm/s) by IS**
	50	160	3.95	12.10	21.2	31.95	33.06
	100	160	7.90	7.65	17.53	15.60	14.81
	150	160	11.85	5.86	13.08	10.25	9.26
BE_1	200	160	15.81	4.84	9.2	7.61	6.64
	250	225	16.66	5.88	10.79	7.21	9.32
	300	225	20.0	5.21	8.0	5.97	7.55
	350	225	23.33	4.71	6.85	5.09	6.31
BE_2	400	225	26.66	4.31	5.2	4.43	5.41
	450	124	40.41	2.19	2.67	2.88	1.66
	500	124	44.90	2.05	1.9	2.58	1.47
	550	124	49.39	1.92	1.78	2.34	1.31
BE_3	600	124	53.88	1.81	0.89	2.14	1.19
	650	190	47.15	2.64	4.32	2.45	2.29
	700	190	50.78	2.51	3.68	2.27	2.10
	750	190	54.41	2.40	2.41	2.12	1.94
BE_4	800	190	58.03	2.30	1.02	1.98	1.80
	850	215	57.96	2.50	1.9	1.98	2.08
	900	215	61.37	2.41	1.79	1.87	1.95
	950	215	64.78	2.32	1.14	1.77	1.83
BE_5	1000	215	68.19	2.25	0.762	1.67	1.73
	1050	170	63.90	2.73	2.54	1.79	2.43
	1100	170	66.94	2.65	1.39	1.71	2.31
	1150	170	69.98	2.57	1.14	1.63	2.19
BE_6	1200	170	73.03	2.50	0.89	1.56	2.08
	1250	175	94.49	1.58	0.88	1.19	0.931
	1300	175	98.27	1.54	0.76	1.15	0.890
	1350	175	102.05	1.50	0.64	1.10	0.851
BE_7	1400	175	105.83	1.46	0.63	1.06	0.816
	1450	220	97.75	1.80	2.14	1.15	1.17
	1500	220	101.13	1.76	1.94	1.11	1.12
	1550	220	104.50	1.72	1.25	1.07	1.08
BE_8	1600	220	107.87	1.68	1.05	1.04	1.04
	1650	254	103.53	1.91	1.5	1.09	1.29
	1700	254	106.66	1.87	1.27	1.05	1.25
	1750	254	109.80	1.83	1.16	1.02	1.21
BE_9	1800	254	112.94	1.80	1.1	0.995	1.17
	1850	275	111.55	1.91	1.89	1.00	1.30
	1900	275	114.57	1.88	1.48	0.981	1.26
	1950	275	117.58	1.85	1.36	0.955	1.22
BE_{10}	2000	275	120.60	1.82	1.24	0.931	1.19