Report on

Seismic Hazard Analysis of NAF Tourism Park

CLIENT:

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1. Deterministic Seismic Hazard Analysis (DSHA)

a. Site Information

The latitude and longitude of the three stations of the project site are shown in Table 1. The geographic location is also shown in Fig. 1.

Table 1: Site Information

Station Name	Latitude	Longitude	Selected Coordinate
A	20°53'30″ N	92°14'56″ E	20°54'42″ N (**20.91°N**)
B	20°54'42″ N	92°15'00″ E	92°15'00″ E (**92.25°E**)
C	20°54'49″ N	92°16'42″ E	**[Station B]**

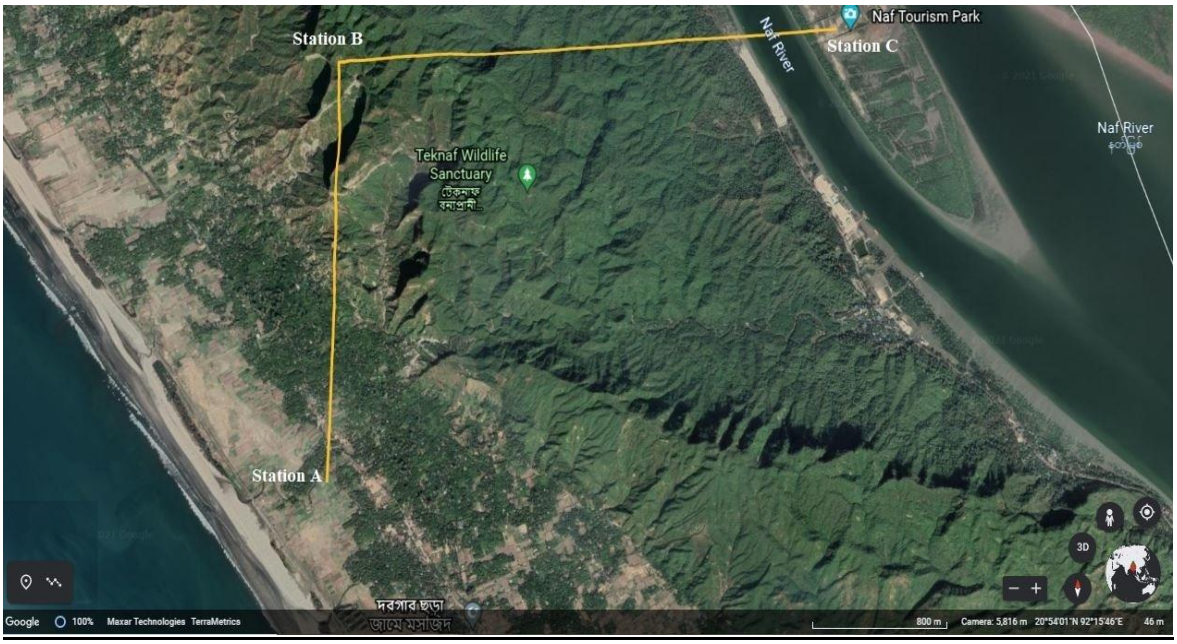


Fig. 1. Geographic location of Naf Tourism Park project

b. Source Information

There are many seismic sources around the project site. Among them, 11 seismic sources are identified which can produce large earthquakes as before. The latitude and longitude of the 11 seismic sources are shown in Table 2.

Table 2: Information of Probable Sources

Source No.	Year	Latitude	Longitude	Magnitude, **M**	Reference
1	02/04/1762	22° N	92° E	**8.8**	ISC-GEM
2	23/03/1839	21.9° N	96° E	**8**	ISC-GEM
3	24/08/1858	18.94° N	92.66° E	**8.3**	ISC-GEM
4	15/12/1865	22.3° N	91° E	**6.8**	ISC-GEM
5	19/12/1865	22.2° N	92.5° E	**6**	Indian Catalog
6	30/06/1868	24.5° N	91.5° E	**7.5**	ISC-GEM
7	10/01/1869	24° N	93.3° E	**8.3**	ISC-GEM
8	12/06/1897	25.5° N	91° E	**8**	ISC-GEM
9	08/07/1918	24.5° N	91° E	**7.6**	Indian Catalog
10	12/09/1946	23.53° N	95.71° E	**7.6**	ISC-GEM
11	13/04/2016	23.09° N	94.87° E	**6.9**	USGS

c. Source to Site Distance

The distance from source to site are calculated based on the latitude and longitude of the sources and site as shown in Table 3.

Table 3: Source to Site Distance

Source No.	Source Coordinate	Site Coordinate	Distance, **R** (km)
1	22° N, 92° E	20.91°N, 92.25°E	**124**
2	21.9° N, 96° E		**403**
3	18.94° N, 92.66° E		**223**
4	22.3° N, 91° E		**201**
5	22.2° N, 92.5° E		**146**
6	24.5° N, 91.5° E		**406**
7	24° N, 93.3° E		**360**
8	25.5° N, 91° E		**526**
9	24.5° N, 91° E		**419**
10	23.53° N, 95.71° E		**460**
11	23.09° N, 94.87° E		**363**

d. Probable PGA Calculation

The attenuation relationship used for the Deterministic Seismic Hazard Analysis is the one proposed by Cornell et al. (1979) for the mean of natural logarithm of Peak ground acceleration as per following eqn. (1).

$$\ln PGA\ (gal) = 6.74+0.859M-1.80\ln(R+25) \quad (1)$$

Table 4: Probable PGA Calculation

Source No.	Year	Magnitude, **M**	Distance, **R** (km)	lnPGA (gal)	PGA (gal)	PGA (g)
1	02/04/1762	**8.8**	**124**	5.29	198.76	**0.20**
2	23/03/1839	**8**	**403**	2.71	14.96	0.02
3	24/08/1858	**8.3**	**223**	3.95	51.70	0.05
4	15/12/1865	**6.8**	**201**	2.82	16.85	0.02
5	19/12/1865	**6**	**146**	2.64	14.00	0.01
6	30/06/1868	**7.5**	**406**	2.26	9.62	0.01
7	10/01/1869	**8.3**	**360**	3.15	23.43	0.02
8	12/06/1897	**8**	**526**	2.25	9.50	0.01
9	08/07/1918	**7.6**	**419**	2.30	9.93	0.01
10	12/09/1946	**7.6**	**460**	2.14	8.47	0.01
11	13/04/2016	**6.9**	**363**	1.94	6.94	0.01

e. Worst Case Selection

Analyzing the previous earthquakes near proposed Naf Tourism Park project, it can be said that worst case will occur at the site with maximum PGA of **0.20 g** (Table 4) if a similar earthquake occur from the epicenter of the 1762 Great Arakan Earthquake with a **magnitude of 8.8** at a **distance of 124 km from the site** as shown in Fig. 2.

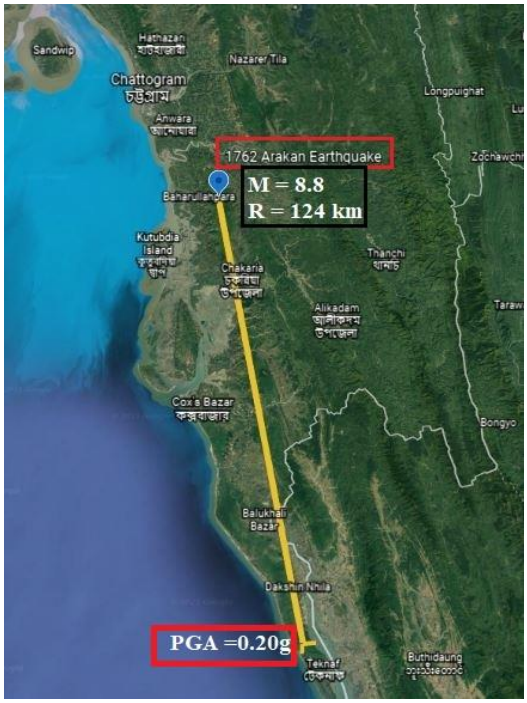


Fig. 2. Worst Seismic case around Naf Tourism Park project by DSHA

2. Probabilistic Seismic Hazard Analysis (PSHA)

Probabilistic seismic hazard analysis (PSHA) is more realistic than deterministic seismic hazard analysis (DSHA). PSHA is represented by hazard curve or map on the basis of probability of exceedance or return period. There are several studies on seismic hazard curve of Bangladesh. Among them, seismic hazard curve provided by Global Earthquake Model (GEM) and Rahman *et al.* (2020) are considered in this report. Global earthquake hazard map of GEM as shown in Fig. 3 represents peak ground acceleration (PGA) in units of g with a 10% probability of being exceeded in 50 years (Return period = 475 years), where GEM proposed a **PGA of 0.20g - 0.35g** in the region of the project site.

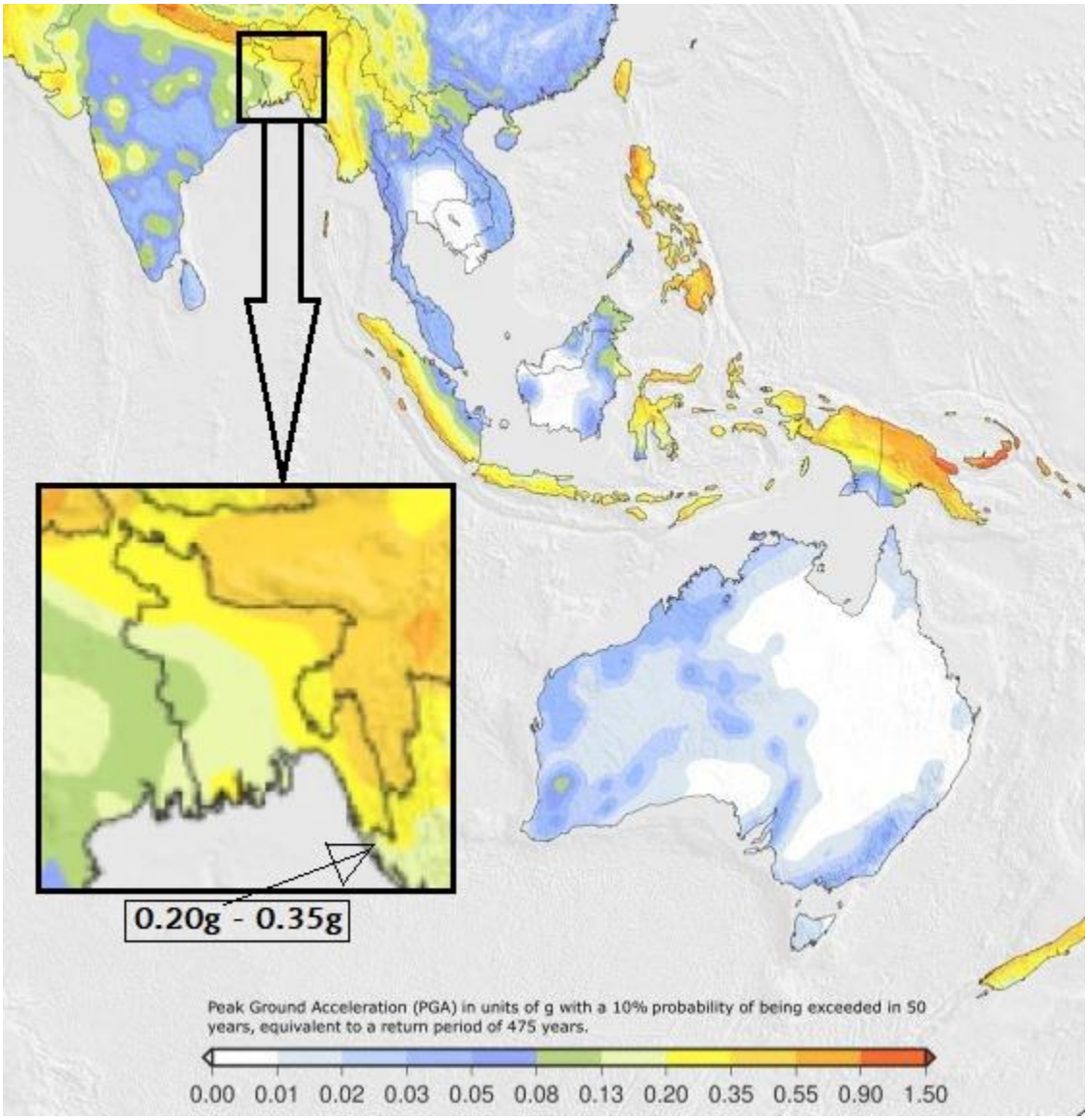


Fig. 3. Seismic hazard map representing peak ground acceleration (PGA) in units of g with a 10% probability of being exceeded in 50 years with return period = 475 years (GEM, Accessed July 13, 2021)

Recently, Rahman *et al.* (2020) developed seismic hazard map representing PGA in units of g with a 10% probability of being exceeded in 50 years with return period = 475 years, where they proposed a **PGA of 0.50g - 0.60g** at the Naf Tourism Park project site as shown in Fig. 4.

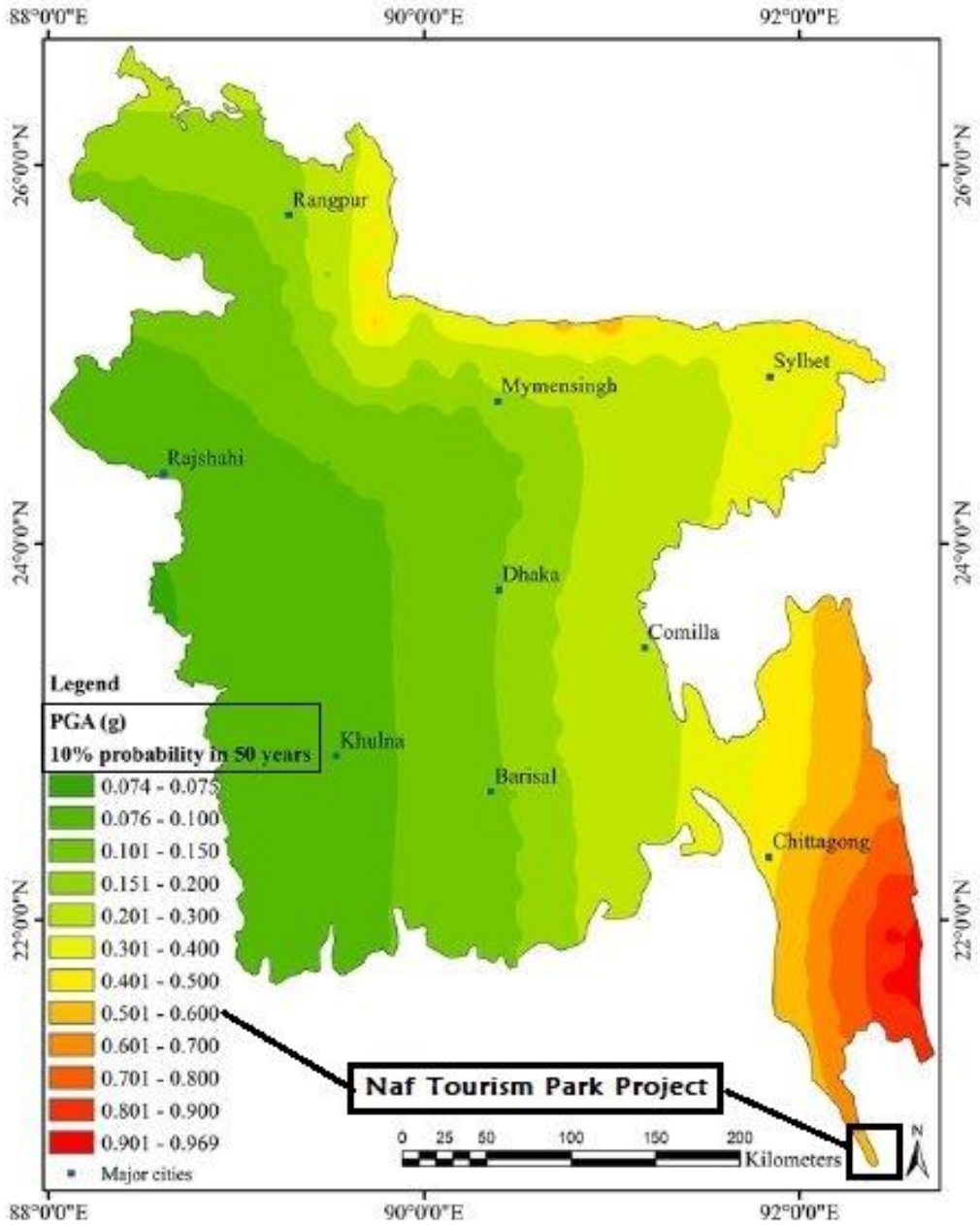


Fig. 4. Seismic hazard map representing peak ground acceleration (PGA) in units of g with a 10% probability of being exceeded in 50 years with return period = 475 years (Rahman *et al.*,2020)

Rahman *et al.* (2020) also developed seismic hazard map representing PGA in units of g with a 2% probability of being exceeded in 50 years with return period = 2475 years, where they proposed a **PGA of 1.00g - 1.20g** at the Naf Tourism Park project site as shown in Fig. 5.

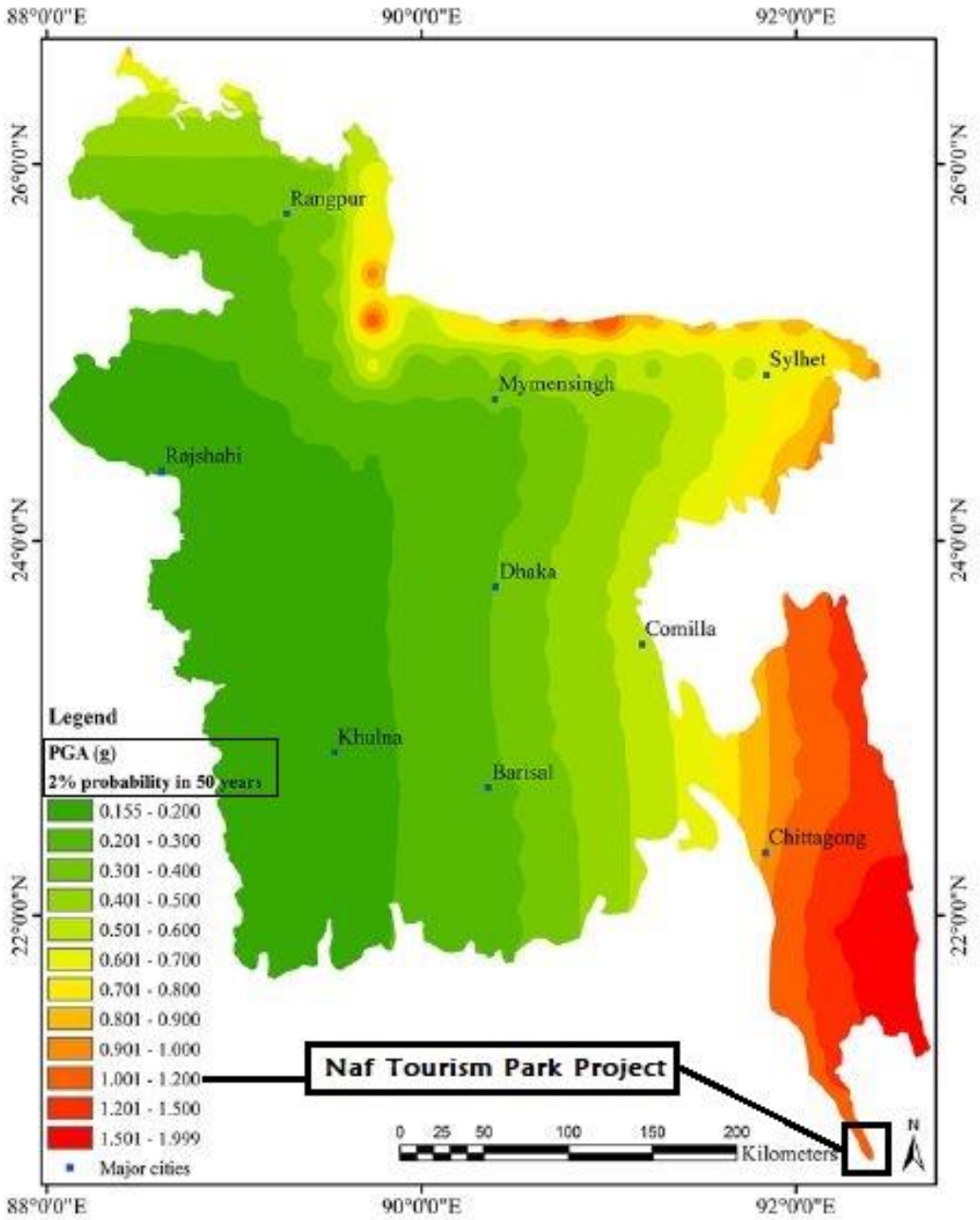


Fig. 5. Seismic hazard map representing peak ground acceleration (PGA) in units of g with a 2% probability of being exceeded in 50 years with return period = 2475 years (Rahman *et al.*,2020)

A high seismicity is found from the recent study of Rahman *et al.* (2020). They justify the reason behind this by using recently published ground motion prediction equations (GMPEs), and considering uncertainties by logic tree approach. In their study, the PGA is significantly increased in the eastern regions of Bangladesh compared to the PGA of BNBC 2020 due to increased hazard contribution from the eastern subduction seismic sources.

3. Site Specific Ground Response Analysis

a. General Specification

Borehole data source: **As provided by the Client**
Ground response calculation level: **Surface layer**
Software: Strata
Method: Equivalent Linear (1 dimensional)
Approach: Time Series
Error Tolerance: 2%
Maximum number of iterations: 30
Maximum frequency: 20Hz
Wavelength fraction: 0.2

b. Borehole Locations

A total of 21 soil boreholes are investigated to perform ground response analysis in this report. The locations of the borehole sites are supplied by the client as shown in Fig. 6.

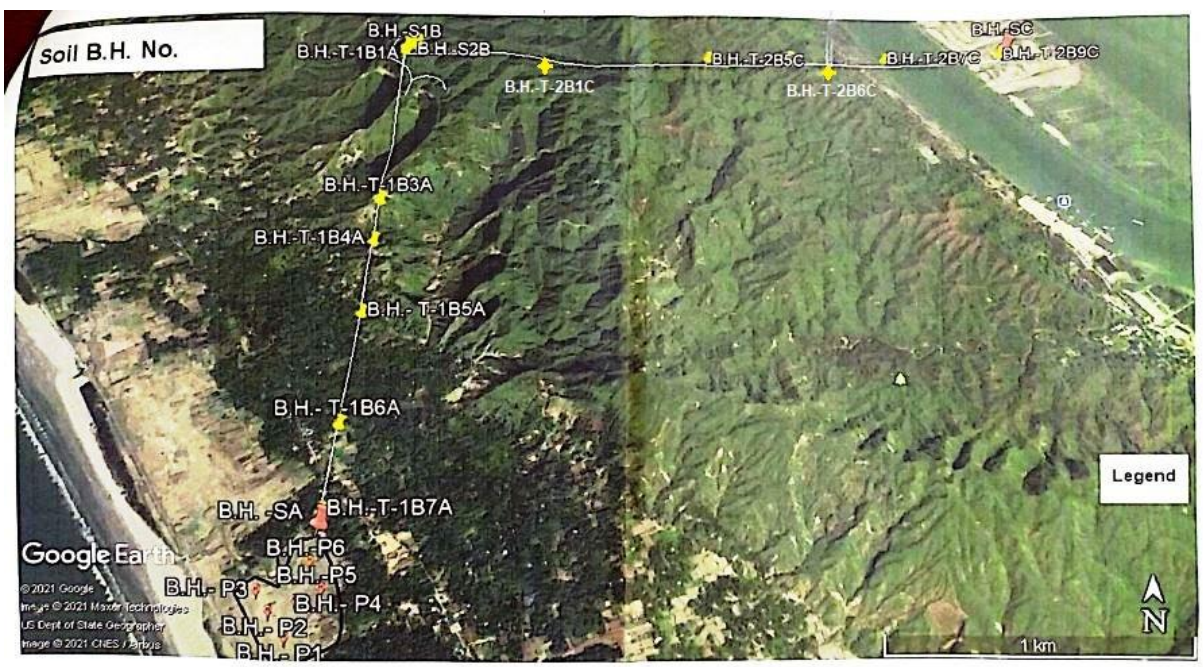


Fig. 6. Borehole locations at the project site (Provided by the client)

c. Soil Types and Properties

Depending on the soil types, unit weights of the soils are assumed based on the following Table 5. For each soil type, modulus reduction (G/G_{max}) model and damping model are also assumed as per Table 5.

Table 5: Soil Types and Properties

Soil type	Unit weight	Modulus reduction (G/G_{max}) model	Damping model
Loose sand with silt	11.77	Darendeli & Stokoe (2001)	Darendeli & Stokoe (2001)
Medium sand with silt	12.51	Darendeli & Stokoe (2001)	Darendeli & Stokoe (2001)
Dense sand or stiff clay	13.24	Darendeli & Stokoe (2001)	Darendeli & Stokoe (2001)

d. Estimation of Shear Wave Velocity

The soil types of each layer have been estimated using the shear wave velocity of each layer. As the shear wave velocities were not available in the soil report, they have been estimated with the empirical formula shown in eqn. (2) provided by Hossain and Ansary (2015) using corrected SPT values (N) provided in the soil report supplied by the client as shown in Table 6. Estimated shear wave velocities of 21 boreholes are shown in Table 7.

$$V_s = 169\, N^{0.2638} D^{0.2396} \tag{2}$$

Where,

Vs = Shear wave velocity (ft/s)
D = Depth (ft)
N = Corrected SPT value

Table 6: Corrected SPT values (N) of boreholes at project site

	Shear wave velocities, V_s (m/s)									
Depth (m)	BH-P1	BH-P2	BH-P3	BH-P4	BH-P5	BH-P6	BH-T-2B7C	BH-T-2B9C	BH-SC	BH-S1B
1.0	3	1	14	4	3	1	1	18	1	37
2.0	3	3	21	2	7	2	0	2	1	87
3.0	7	6	37	4	1	3	0	1	1	110
4.0	18	8	20	8	44	42	4	0	97	202
5.0	65	133	63	82	69	67	6	0	58	109
6.0	68	96	71	79	67	55	5	0	78	141
7.5	109	103	115	105	72	70	1	5	84	230
9.0	104	99	88	135	83	80	0	1	100	221
10.5	109	139	229	206	109	102	2	1	203	223
12.0	129	107	158	204	150	135	1	1	202	214
13.5	114	-	-	-	-	-	1	4	134	211
15.0	154	-	-	-	-	-	3	1	134	208
16.5	-	-	-	-	-	-	3	2	135	205
18.0	-	-	-	-	-	-	8	89	205	272
19.5	-	-	-	-	-	-	94	224	208	413
21.0	-	-	-	-	-	-	119	227	210	279
22.5	-	-	-	-	-	-	161	154	212	423
24.0	-	-	-	-	-	-	123	156	215	143
25.5	-	-	-	-	-	-	125	237	218	433
27.0	-	-	-	-	-	-	101	160	220	438
28.5	-	-	-	-	-	-	129	244	223	444
30.0	-	-	-	-	-	-	262	248	226	-

Depth (m)	***Corrected SPT Values (N)***									
	BH-T-1B3A	BH-T-1B4A	BH-T-1B5A	BH-T-1B6A	BH-T-1B7A	BH-SA	BH-S2B	BH-T-2B1C	BH-T-2B5C	BH-T-2B6C
1.0	3	5	13	4	2	2	62	25	47	2
2.0	52	74	38	4	10	3	74	43	52	10
3.0	220	73	40	6	9	5	110	110	48	73
4.0	135	67	67	57	67	7	45	34	45	101
5.0	218	80	73	36	145	218	109	54	48	145
6.0	141	85	106	23	106	106	71	85	60	141
7.5	230	92	153	42	92	92	115	77	65	115
9.0	221	99	147	37	147	111	147	49	111	111
10.5	223	223	149	149	223	149	112	223	149	223
12.0	214	143	143	214	214	214	143	54	107	214
13.5	422	211	141	141	281	211	211	211	106	211
15.0	416	139	208	139	139	208	139	416	105	208
16.5	410	205	164	137	205	137	137	137	104	205
18.0	409	136	204	136	204	204	136	272	105	204
19.5	413	207	138	207	165	207	138	48	107	207
21.0	209	139	209	418	209	209	209	418	109	418
22.5	423	141	423	211	211	211	211	423	111	423
24.0	214	214	428	214	-	214	143	428	113	214
25.5	433	216	433	144	-	216	216	433	115	216
27.0	438	292	292	219	-	219	146	438	117	438
28.5	444	296	222	444	-	222	148	444	119	148
30.0	449	449	-	449	-	225	449	449	121	-

Table 7: Estimated shear wave velocities (V_s) of boreholes at project site

Depth (m)	Shear wave velocities, V_s (m/s)										
	BH-P1	BH-P2	BH-P3	BH-P4	BH-P5	BH-P6	BH-T-2B7C	BH-T-2B9C	BH-SC	BH-S1B	BH-T-1B1A
1.0	90	67	138	96	90	66	67	146	67	177	227
2.0	104	111	181	92	135	102	44	92	77	263	315
3.0	146	144	231	129	98	116	49	80	98	308	332
4.0	204	166	210	167	258	256	142	52	319	387	348
5.0	303	366	300	322	308	305	163	55	294	347	417
6.0	320	351	324	333	319	303	157	57	332	389	389
7.5	382	377	388	379	343	340	122	167	357	466	466
9.0	395	390	377	423	372	369	63	125	391	482	360
10.5	415	442	505	490	414	407	147	109	489	501	450
12.0	448	426	472	505	465	453	137	136	504	512	512
13.5	446	-	-	-	-	-	142	187	465	524	524
15.0	495	-	-	-	-	-	175	144	477	536	536
16.5	-	-	-	-	-	-	180	165	489	546	490
18.0	-	-	-	-	-	-	235	447	558	601	525
19.5	-	-	-	-	-	-	462	582	570	684	569
21.0	-	-	-	-	-	-	501	594	582	627	581
22.5	-	-	-	-	-	-	552	545	594	712	712
24.0	-	-	-	-	-	-	521	556	605	543	604
25.5	-	-	-	-	-	-	531	630	616	738	663
27.0	-	-	-	-	-	-	510	576	626	751	-
28.5	-	-	-	-	-	-	551	652	636	763	-
30.0	-	-	-	-	-	-	672	663	646	-	-

Depth (m)	Shear wave velocities, V_s (m/s)									
	BH-T-1B3A	BH-T-1B4A	BH-T-1B5A	BH-T-1B6A	BH-T-1B7A	BH-SA	BH-S2B	BH-T-2B1C	BH-T-2B5C	BH-T-2B6C
1.0	90	103	135	97	81	81	204	159	189	81
2.0	230	252	211	119	150	112	252	219	230	150
3.0	370	277	236	142	158	137	308	308	248	277
4.0	348	290	290	278	290	158	260	242	260	323
5.0	417	320	312	260	375	417	347	289	280	375
6.0	389	340	360	240	360	360	324	340	310	389
7.5	466	366	419	298	366	366	388	349	334	388
9.0	482	390	433	300	433	401	433	323	401	401
10.5	501	501	450	450	501	450	417	501	450	501
12.0	512	460	460	512	512	512	460	355	426	512
13.5	629	524	471	471	566	524	524	524	437	524
15.0	643	481	536	481	481	536	481	643	448	536
16.5	655	546	515	490	546	490	490	490	457	546
18.0	669	501	557	501	557	557	501	601	467	557
19.5	684	569	512	569	537	569	512	388	478	569
21.0	581	522	581	698	581	581	581	698	489	698
22.5	712	533	712	593	593	593	593	712	500	712
24.0	604	604	725	604	-	604	543	725	510	604
25.5	738	615	738	552	-	615	615	738	520	615
27.0	751	675	675	625	-	625	562	751	530	751
28.5	763	686	635	763	-	635	571	763	539	571
30.0	775	775	-	775	-	646	775	775	549	-

e. Estimation of Natural Period at Borehole Sites

Natural period of ground site or characteristic value of soil (T_G) can be estimated by the guideline provided by JRA (2002) based on the shear wave velocity of the soil profile beneath a ground site using the following eqn. (3). Natural period of each borehole sites are calculated using eqn. (3) and tabulated in following Table 8.

$$T_G = 4 \times \sum_{i=1}^{n} \frac{H_i}{V_{si}} \tag{3}$$

Where,

T_G = Natural period of ground site (s)
H_i = Depth of ith layer (m)
V_{si} = Shear wave velocity of ith layer (m/s)
n = Number of soil layer

Table 8: Natural period of borehole sites

Borehole Site	T_G (s)	Frequency, f (Hz)		Borehole Site	T_G (s)	Frequency, f (Hz)
BH-P1	0.24	4.16		BH-T-1B3A	0.26	3.86
BH-P2	0.23	4.36		BH-T-1B4A	0.29	3.46
BH-P3	0.17	5.92		BH-T-1B5A	0.27	3.71
BH-P4	0.22	4.57		BH-T-1B6A	0.34	2.95
BH-P5	0.22	4.61		BH-T-1B7A	0.27	3.74
BH-P6	0.24	4.21		BH-SA	0.34	2.93
BH-T-2B7C	0.77	1.31		BH-S2B	0.27	3.64
BH-T-2B9C	0.73	1.37		BH-T-2B1C	0.28	3.59
BH-SC	0.37	2.67		BH-T-2B5C	0.30	3.29
BH-S1B	0.24	4.21		BH-T-2B6C	0.29	3.47
BH-T-1B1A	0.22	4.49				

Generally, three types of ground conditions are considered in JRA (2002), which are Ground Type-I, Type-II and Type-III. These classifications are made in accordance with the ground characteristic value, T_G as shown in Table 9.

Table 9: Ground types in seismic design (JRA, 2002)

Ground types	T_G (s)	Soil characteristics
Type-I	$T_G < 0.2$	Good alluvial ground and rock
Type-II	$0.2 \leq T_G < 0.6$	Diluvial and alluvial ground not belonging to Type-I and Type-III
Type-III	$0.6 \leq T_G$	Soft alluvial ground

From Table 8 and 9, it is clear that the natural period of borehole sites are in the range of 0.17 s to 0.77 s having all three types of ground. Among all borehole sites, BH-P3 is of ground Type-I, BH-T-2B7C, BH-T-2B9C are of ground Type-III, and rest of the borehole sites are of ground Type-II.

f. Ground Motion Records

Five historic ground motion records shown in Table 10 have been selected randomly for using as time histories in ground response analysis of borehole sites. The seismic ground motion time histories selected in Table 10 meet the following criteria according to the provisions provided by ATC-40 for far field records:

- Free-field station > 10 km from source (or ground floor of a small building)
- Stiff or medium soil site conditions
- Large-magnitude earthquake (M ≥ 6.5)
- Peak ground acceleration of at least 0.2g (before scaling)

Table 10: Seismic ground motion records (far field records)

Earthquake no.	Earthquake name	Year	Magnitude M_w	Recording station	Hypocentral distance (km)	PGA (g)
EQ-1	El Centro	1940	6.9	Imperial Valley, USA	12.2	0.35
EQ-2	Loma Prieta	1989	7.0	Capitola, CA, USA	20.1	0.47
EQ-3	Northridge	1994	6.7	Northridge, USA	19.1	0.45
EQ-4	Kobe	1995	6.9	Nishi-Akashi, Japan	19.9	0.51
EQ-5	Chamoli	1999	6.6	Gopeshwar, India	17.3	0.36

g. Matched Ground Motion Records

The selected ground motions are recorded from recording stations far away from the project site. Again, these ground motions will be applied at the end of the boreholes at a rock-like geological layer to investigate the ground response. As a result, these ground motions must be matched with the response spectra of SA type soil (Rock-like) according to BNBC 2020 (2021) as shown in Fig. 7 considering zone coefficient of CoxsBazar region (Z = 0.28). The matching of ground motions are done with SeismoMatch (2020) software. Matched ground motion records are shown in Fig. 8 to Fig. 12. After matching, the PGA values are reduced as shown in Table 11.

Table 11: Matched ground motion records

Earthquake no.	Earthquake name	Year	PGA (g)
EQ-1	El Centro	1940	0.29
EQ-2	Loma Prieta	1989	0.26
EQ-3	Northridge	1994	0.30
EQ-4	Kobe	1995	0.31
EQ-5	Chamoli	1999	0.36

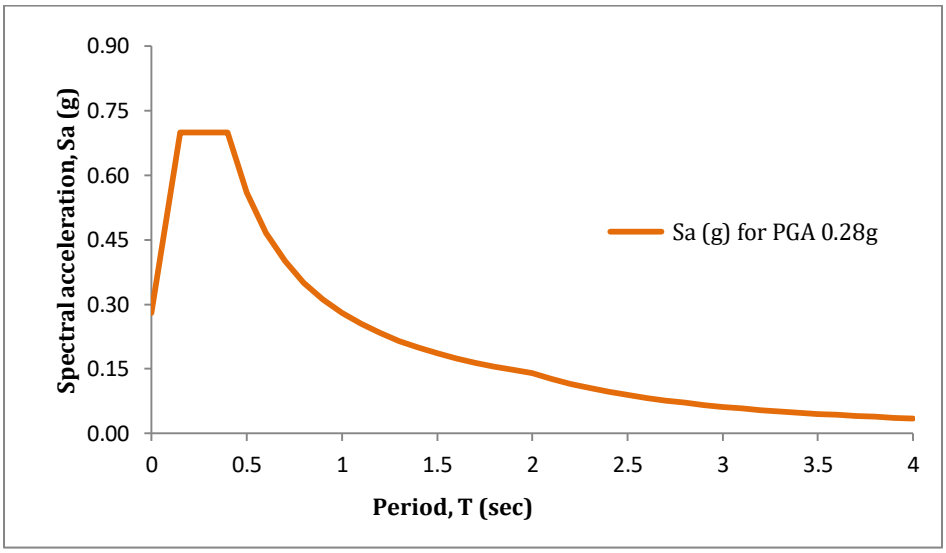


Fig.7: Response spectra for SA type soil in regions with Z = 0.28 (BNBC 2020)

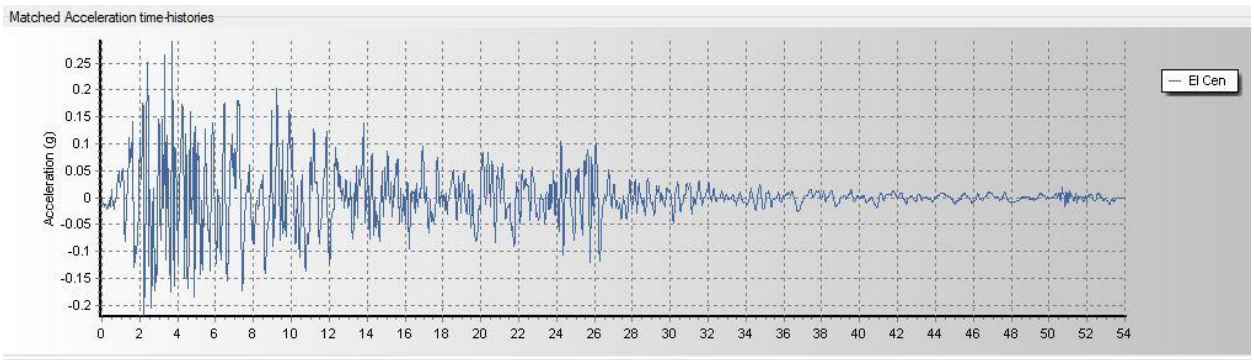


Fig.8: Ground motion time history for El-Centro-1940 matched to SA type soil in regions with Z = 0.28

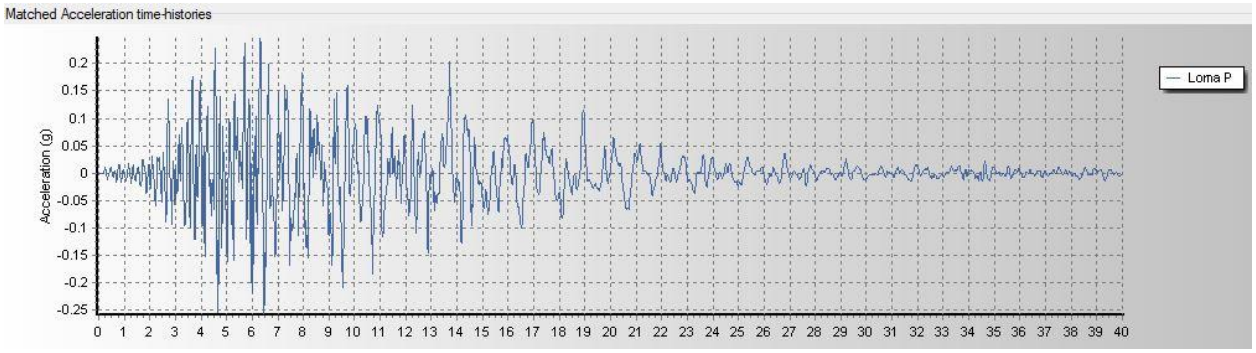


Fig.9: Ground motion time history for Loma Prieta-1989 matched to SA type soil in regions with Z = 0.28

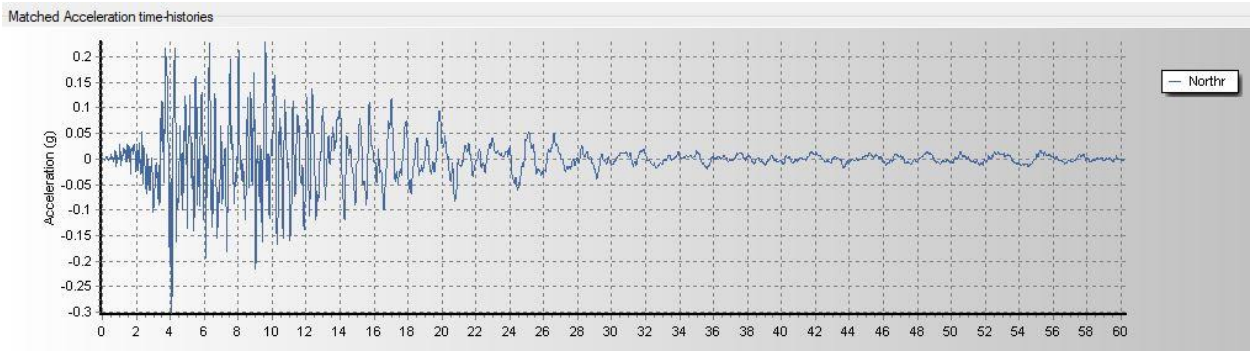


Fig.10: Ground motion time history for Northridge-1994 matched to SA type soil in regions with Z = 0.28

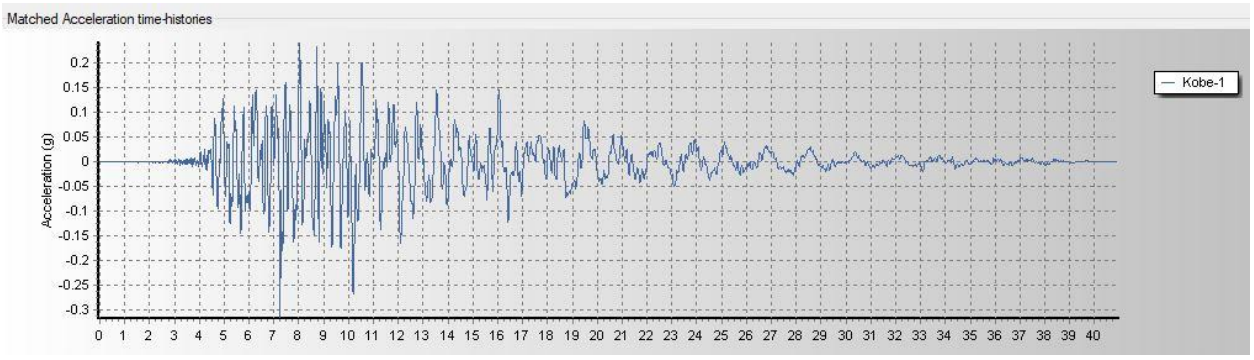


Fig.11: Ground motion time history for Kobe-1995 matched to SA type soil in regions with Z = 0.28

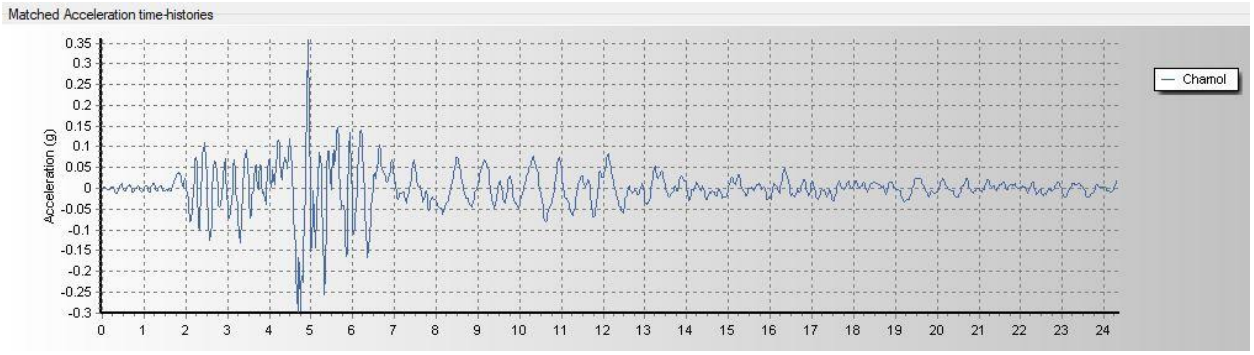
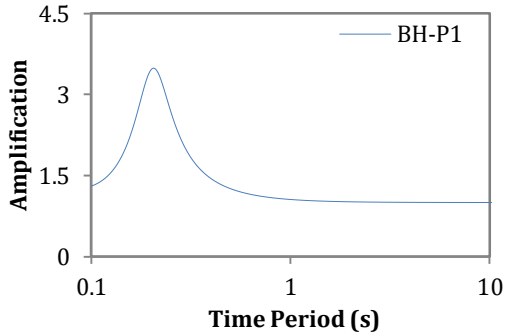


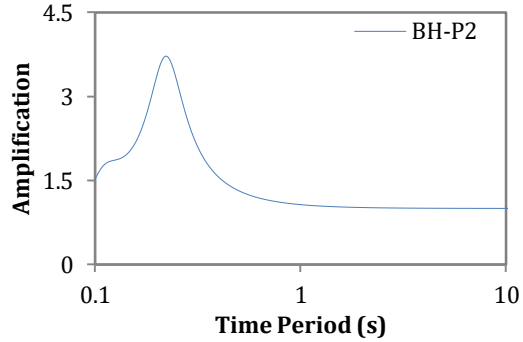
Fig.12: Ground motion time history for Chamoli-1999 matched to SA type soil in regions with Z = 0.28

h. Ground Response Analysis of Borehole Sites

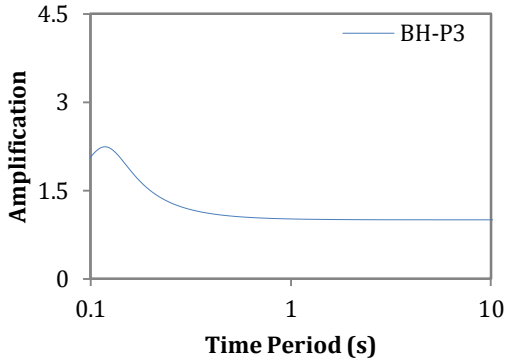
Ground response of the borehole sites are evaluated by computing the acceleration transfer function at the surface layer by applying selected matched input ground motions at the bedrock layer. The value of acceleration transfer function represents the site amplification with respect to frequency or time period. Site amplification of the borehole sites with respect to time period are shown in Fig. 13. In this figure, the acceleration transfer functions showing the maximum amplification are selected among the five ground motions.



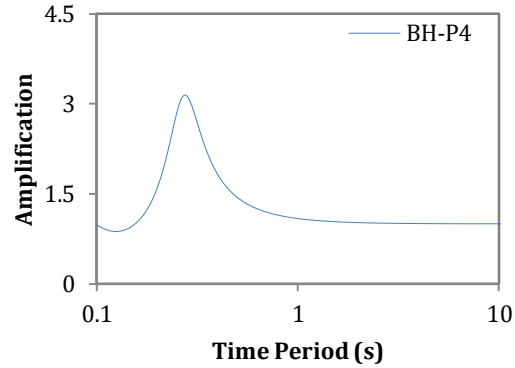
(a) BH P1



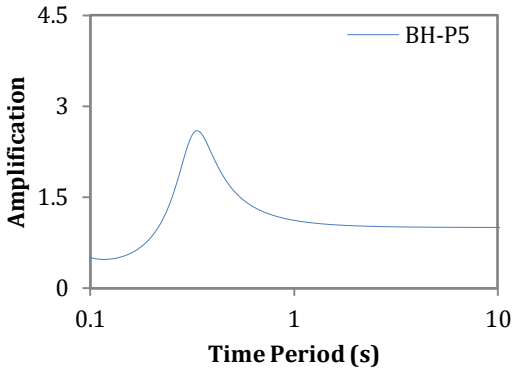
(b) BH P2



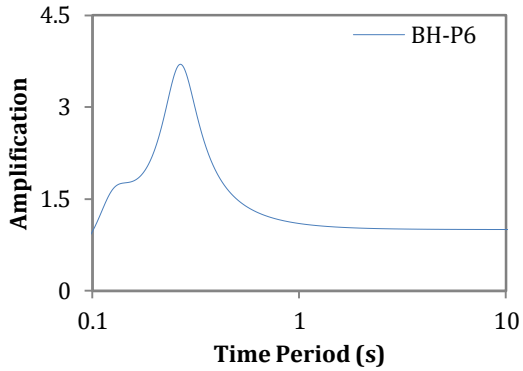
(c) BH P3



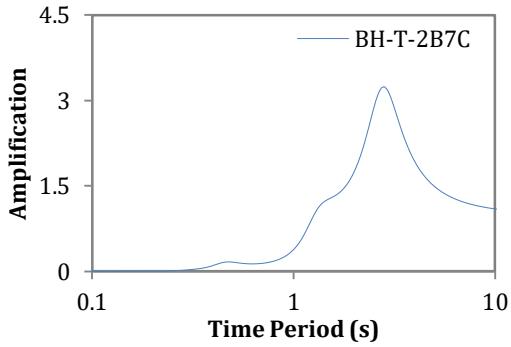
(d) BH P4



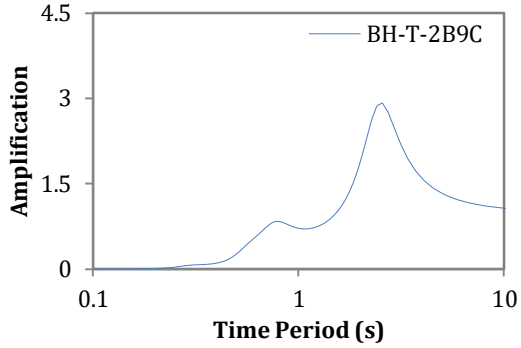
(e) BH P5



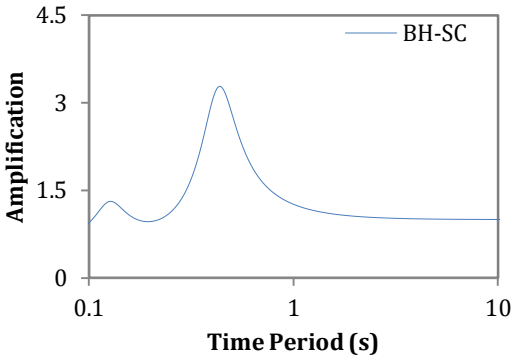
(f) BH P6



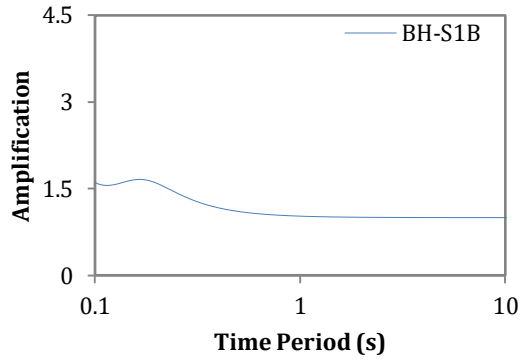
(g) BH-T-2B7C



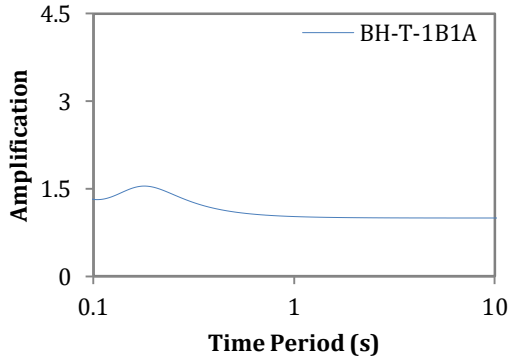
(h) BH-T-2B9C



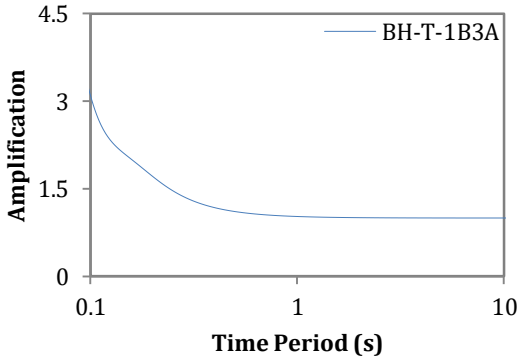
(i) BH-SC



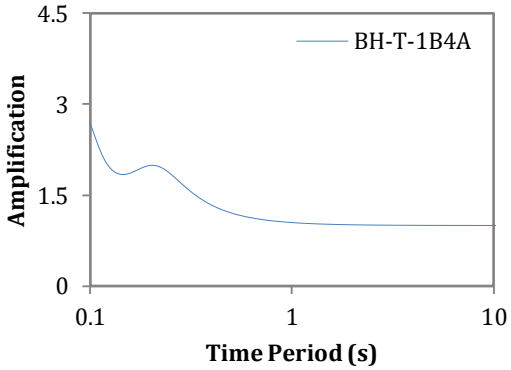
(j) BH-S1B



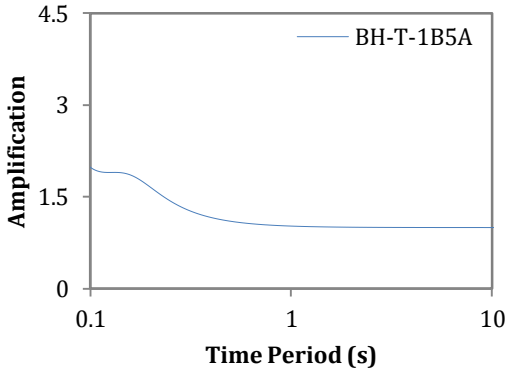
(k) BH-T-1B1A



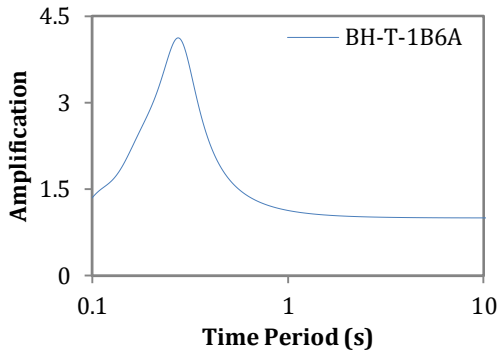
(l) BH-T-1B3A



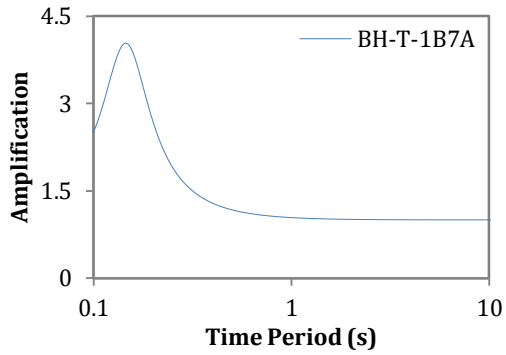
(m) BH-T-1B4A



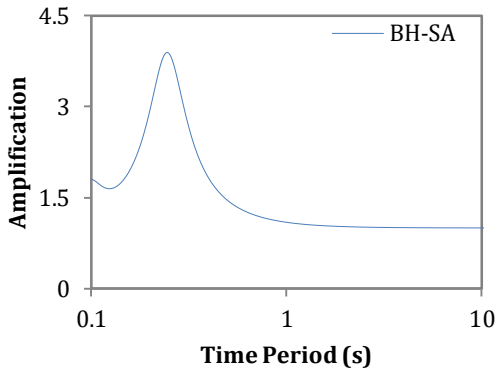
(n) BH-T-1B5A



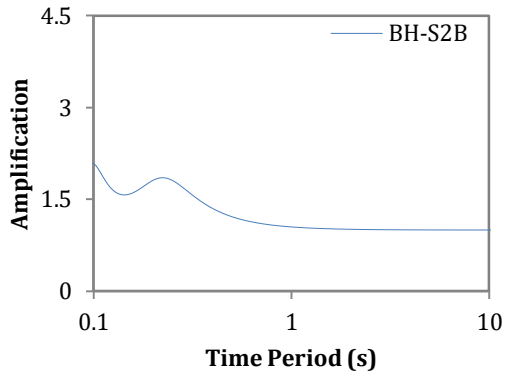
(o) BH-T-1B6A



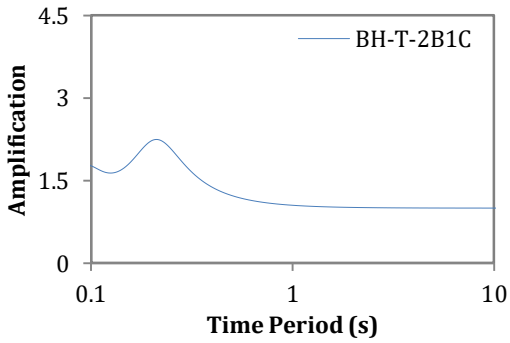
(p) BH-T-1B7A



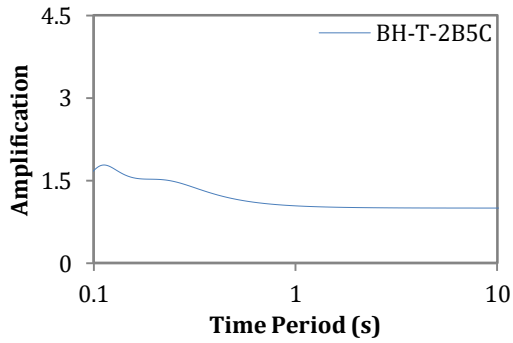
(q) BH-SA



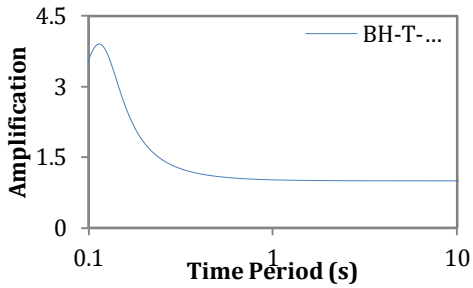
(r) BH-S2B



(s) BH-T-2B1C



(t) BH-T-2B5C



(u) BH-T-2B6C

Fig. 13: Site amplification of the borehole sites with respect to time period

i. Estimation of Site Amplification

Site amplification has been estimated based on two approaches:

i) Site amplification corresponding to natural period of ground site
ii) Maximum site amplification in the range of predominant time period of ground response

i) Site amplification corresponding to natural period of ground site

Site amplification can be estimated corresponding to the natural time period of the site soil (T_G) as shown in Fig. 14. Based on this approach, site amplification of 21 borehole sites has been estimated as shown in Table 12.

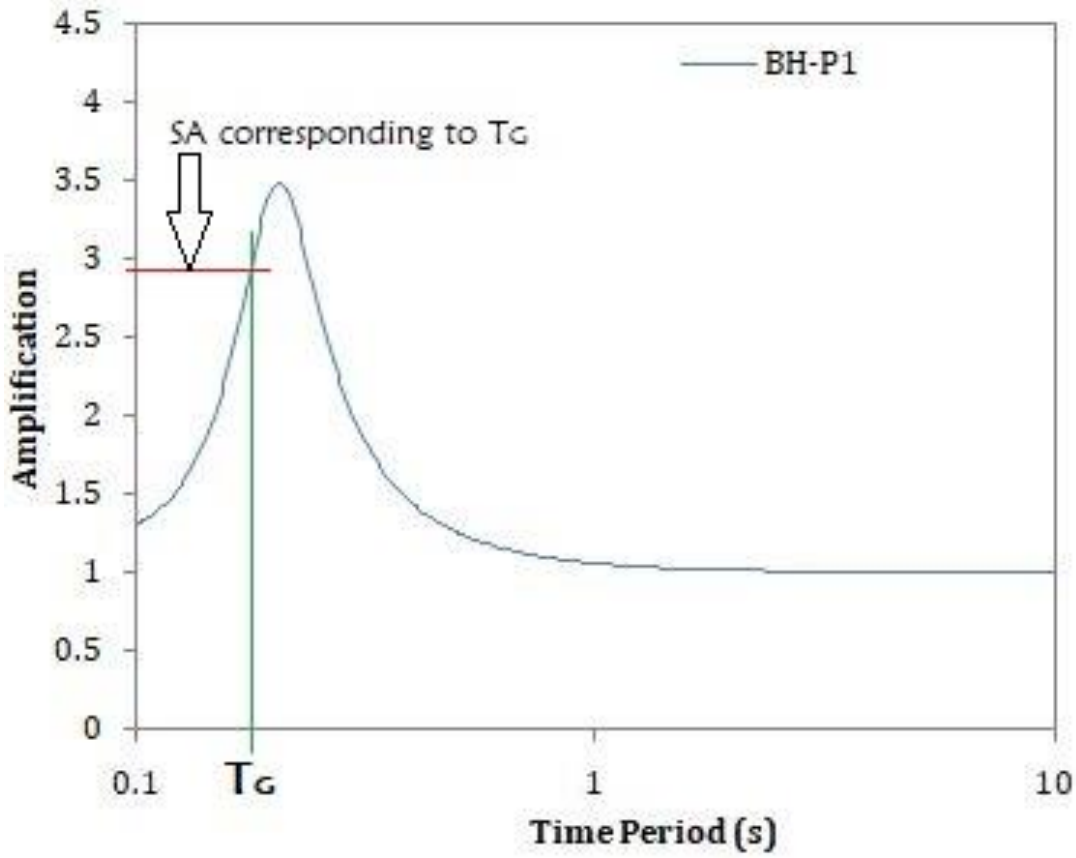


Fig. 14: Estimation of site amplification of the borehole sites corresponding to T_G

Table 12: Estimation of site amplification factor corresponding to T_G

Borehole Site	Natural Period of Ground Site, T_G (s)	Site Amplification Factor (corresponding to T_G)
BH-P1	0.24	2.90
BH-P2	0.23	3.65
BH-P3	0.17	1.69
BH-P4	0.22	2.10
BH-P5	0.22	1.07
BH-P6	0.24	3.34
BH-T-2B7C	0.77	0.17
BH-T-2B9C	0.73	0.79
BH-SC	0.37	2.54
BH-S1B	0.24	1.46
BH-T-1B1A	0.22	1.48
BH-T-1B3A	0.26	1.43
BH-T-1B4A	0.29	1.66
BH-T-1B5A	0.27	1.37
BH-T-1B6A	0.34	3.09
BH-T-1B7A	0.27	1.73
BH-SA	0.34	2.30
BH-S2B	0.27	1.74
BH-T-2B1C	0.28	1.86
BH-T-2B5C	0.30	1.40
BH-T-2B6C	0.29	1.31

ii) *Maximum site amplification in the range of predominant time period of ground response*

Site amplification can also be estimated considering the predominant time period of the ground response as shown in Fig. 15. In this case, a range of predominant time period is determined assuming an allowable site amplification value. In this report, the allowable site amplification value has been taken as 1.5 (SA =1.5). In this approach, if the structural time period is within the predominant time period range, maximum value of site amplification could be used for design purpose. If the structural time period is out of the predominant time period range, allowable value of site amplification or amplification corresponding to structural period can be used. Based on this approach, site amplification of 21 borehole sites has been estimated as shown in Table 13.

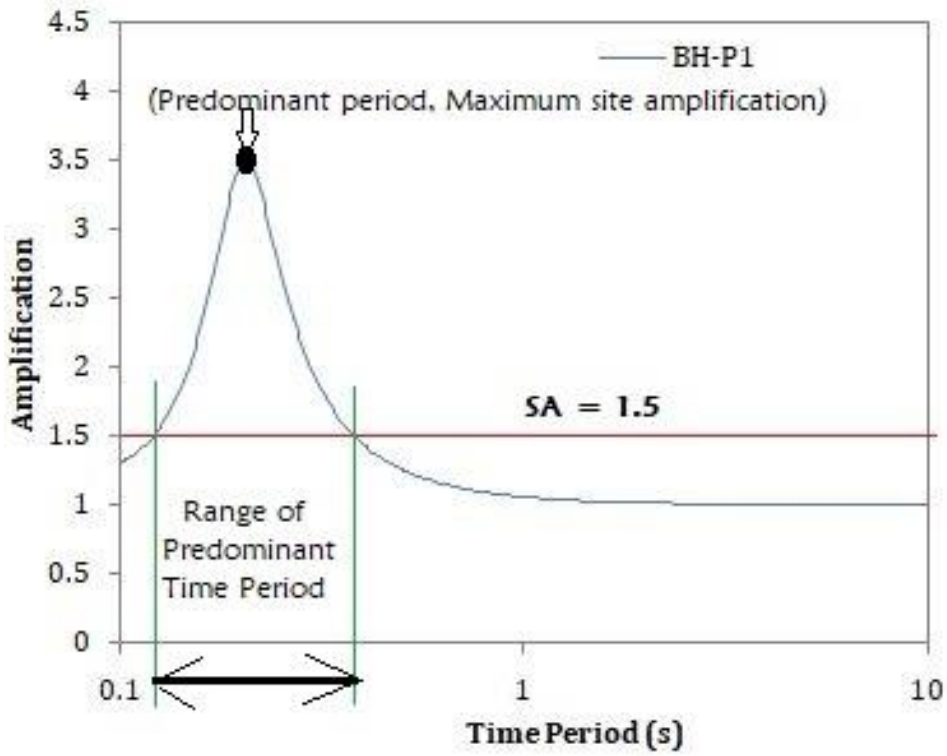


Fig. 15: Estimation of site amplification of the borehole sites considering the range of predominant time period

Table 13: Estimation of site amplification factor considering the range of predominant time period

Borehole Site	Range of predominant time period	Predominant time period	Maximum site amplification
BH-P1	0.12-0.38	0.20	3.49
BH-P2	0.10-0.41	0.22	3.72
BH-P3	0.04-0.20	0.12	2.24
BH-P4	0.19-0.47	0.28	3.15
BH-P5	0.25-0.54	0.33	2.59
BH-P6	0.12-0.49	0.27	3.70
BH-T-2B7C	1.83-4.97	2.78	3.24
BH-T-2B9C	1.85-4.23	2.56	2.92
BH-SC	0.30-0.77	0.44	3.28
BH-S1B	0.00-0.23	0.05	1.99
BH-T-1B1A	0.15-0.21	0.18	1.55
BH-T-1B3A	0.05-0.24	0.08	4.18
BH-T-1B4A	0.04-0.33	0.09	2.80
BH-T-1B5A	0.04-0.23	0.08	2.33
BH-T-1B6A	0.11-0.56	0.28	4.12
BH-T-1B7A	0.06-0.32	0.15	4.04
BH-SA	0.09-0.48	0.24	3.89
BH-S2B	0.06-0.34	0.10	2.09
BH-T-2B1C	0.08-0.35	0.21	2.25
BH-T-2B5C	0.09-0.23	0.11	1.78
BH-T-2B6C	0.07-0.24	0.11	3.90

4. Assessment of Site Classification

Site Classification of boreholes is done by the guidelines provided in section 2.5.3.2 by BNBC 2020 (2021). Classification has been done in accordance with Table 6.2.13 of BNBC 2020 (2021) based on the soil properties of upper 30 meters of the site profile as shown in Table 14. As only SPT values are provided in the soil report of the project site, average soil properties are determined using average SPT value ($\bar{N}$) as given in the following eqn. (4).

$$\bar{N} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{N_i}} \tag{4}$$

Where,

n = Number of soil layers in upper 30m
d_i = Thickness of layer i
N_i = Field (uncorrected) SPT Value for layer i
$\bar{N}$ = Average SPT value of soil layers

Table 14: Soil Types and Properties

Site Classification	Description of Soil Profile	Average SPT value, $\bar{N}$
SA	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	-
SB	Deposits of very dense sand, gravel, or very stiff clay, at least several 10m in thickness, characterized by a gradual increase of mechanical properties with depth.	> 50
SC	Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	15-50
SD	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 15
SE	A soil profile consisting of a surface alluvium layer with Vs values of type SC or SD and thickness varying between about 5 m and 20 m, underlain by stiffer material with Vs > 800 m/s.	-
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content.	-
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types SA to SE or S_1.	-

Field (uncorrected) SPT Value for layer i (N_i) are provided in the soil report supplied by the client as shown in Table 15. In this report, the site classification has been done using average SPT value, $\overline{N}$ as shown in Table 16.

Table 15: Field (uncorrected) SPT values (N_i) of boreholes at project site

Depth (m)	Field (uncorrected) SPT values (N_i)										
	BH-P1	BH-P2	BH-P3	BH-P4	BH-P5	BH-P6	BH-T-2B7C	BH-T-2B9C	BH-SC	BH-S1B	BH-T-1B1A
1.0	3	1	15	4	3	1	1	20	1	39	100
2.0	3	4	24	2	8	3	0	2	1	100	200
3.0	9	9	50	6	2	4	0	1	2	150	200
4.0	27	13	29	13	67	67	7	0	150	300	200
5.0	92	200	85	120	100	100	9	0	85	150	300
6.0	100	150	100	120	100	85	7	0	120	200	200
7.5	150	150	150	150	100	100	2	7	120	300	300
9.0	150	150	120	200	120	120	0	2	150	300	100
10.5	150	200	300	300	150	150	3	1	300	300	200
12.0	172	150	200	300	200	200	2	2	300	300	300
13.5	150	-	-	-	-	-	2	6	200	300	300
15.0	200	-	-	-	-	-	4	2	200	300	300
16.5	-	-	-	-	-	-	4	3	200	300	200
18.0	-	-	-	-	-	-	10	120	300	400	240
19.5	-	-	-	-	-	-	120	300	300	600	300
21.0	-	-	-	-	-	-	150	300	300	400	300
22.5	-	-	-	-	-	-	200	200	300	600	600
24.0	-	-	-	-	-	-	150	200	300	200	300
25.5	-	-	-	-	-	-	150	300	300	600	400
27.0	-	-	-	-	-	-	120	200	300	600	-
28.5	-	-	-	-	-	-	150	300	300	600	-
30.0	-	-	-	-	-	-	300	300	300	-	-

Depth (m)	**Field (uncorrected) SPT values (N_i)**									
	BH-T-1B3A	BH-T-1B4A	BH-T-1B5A	BH-T-1B6A	BH-T-1B7A	BH-SA	BH-S2B	BH-T-2B1C	BH-T-2B5C	BH-T-2B6C
1.0	3	5	14	4	2	2	66	26	50	2
2.0	60	85	44	5	12	4	85	50	60	12
3.0	300	100	55	8	12	7	150	150	66	100
4.0	200	100	100	85	100	10	66	50	66	150
5.0	300	110	100	50	200	300	150	75	66	200
6.0	200	120	150	32	150	150	100	120	85	200
7.5	300	120	200	55	120	120	150	100	85	150
9.0	300	135	200	50	200	150	200	66	150	150
10.5	300	300	200	200	300	200	150	300	200	300
12.0	300	200	200	300	300	300	200	75	150	300
13.5	600	300	200	200	400	300	300	300	151	300
15.0	600	200	300	200	200	300	200	600	152	300
16.5	600	300	240	200	300	200	200	200	153	300
18.0	600	200	300	200	300	300	200	400	154	300
19.5	600	300	200	300	240	300	200	70	155	300
21.0	300	200	300	600	300	300	300	600	156	600
22.5	600	200	600	300	300	300	300	600	157	600
24.0	300	300	600	300	-	300	200	600	158	300
25.5	600	300	600	200	-	300	300	600	159	300
27.0	600	400	400	300	-	300	200	600	160	600
28.5	600	400	300	600	-	300	200	600	161	200
30.0	600	600	-	600	-	300	600	600	162	-

Table 16: Site classification of borehole sites based on average SPT value, $\bar{N}$

Borehole Site	$\bar{N}$	Site Classification		Borehole Site	$\bar{N}$	Site Classification
BH-P1	17	SC		BH-T-1B3A	71	SB
BH-P2	8	SD		BH-T-1B4A	86	SB
BH-P3	55	SB		BH-T-1B5A	129	SB
BH-P4	12	SD		BH-T-1B6A	39	SC
BH-P5	12	SD		BH-T-1B7A	30	SC
BH-P6	7	SD		BH-SA	27	SC
BH-T-2B7C	1	SD		BH-S2B	171	SB
BH-T-2B9C	1	SD		BH-T-2B1C	132	SB
BH-SC	11	SD		BH-T-2B5C	118	SB
BH-S1B	238	SB		BH-T-2B6C	41	SC
BH-T-1B1A	230	SB				

Reference

ATC-40 (1996), Seismic Evaluation and Retrofit of Concrete Buildings, *Report No. ATC-40*, Applied Technology Council, Redwood City, CA, USA.

BNBC 2020 (2021), Bangladesh National Building Code, Ministry of Housing and Public Works, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Cornell CA, Banon H & Shakal AF (1979), Seismic motion and response prediction alternatives, Earthquake Engineering & Structural Dynamics, 7(4), 295–315. https://doi.org/10.1002/eqe.4290070402

GEM (2018), Global Earthquake Hazard Map (version 2018.1), Global Earthquake Model, https://www.globalquakemodel.org/gem-maps/global-earthquake-hazard-map [Accessed July 13, 2021].

Hossain ASFM and Ansary MA (2015), Shear Wave Velocity as a Function of Standard Penetration Number and Depth in Dhaka City, Bangladesh, *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 12(3): 31-39.

International Seismological Centre (2018), ISC-GEM Earthquake Catalogue, https://doi.org/10.31905/d808b825 (Accessed on December 2018)

JRA (2002), Specifications for Highway Bridges - Part V: Seismic design, *Japan Road Association*, Tokyo, Japan.

NDMA (2010) Development of probabilistic seismic hazard map of India, *National Disaster Management Authority*, India, New Delhi.

Rahman MZ, Siddiqua S and Kamal ASMM (2020), Seismic source modeling and probabilistic seismic hazard analysis for Bangladesh, *Natural Hazards*, 103: 2489-2532, https://doi.org/10.1007/s11069-020-04094-6 .

USGS (2021) United States Geological Survey, Earthquake Catalog https://www.usgs.gov/natural-hazards/earthquake-hazards/earthquakes (Accessed on June 2021)

Annex-1: Provided Soil Borehole Data

Soil Bore Hole with in Accessories Building & Parking Area (Station A):

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- P1	1.0	3	0.45	1.00	1.00	0.75	1.68	1.69	2.84
	2.0	3	0.45	1.00	1.00	0.75	1.54	1.69	2.60
	3.0	9	0.45	1.00	1.00	0.75	1.29	5.06	6.51
	4.0	27	0.45	1.00	1.00	0.75	1.17	15.19	17.82
	5.0	92	0.45	1.00	1.00	0.85	1.11	58.65	64.83
	6.0	100	0.45	1.00	1.00	0.85	1.06	63.75	67.75
	7.5	150	0.45	1.00	1.00	0.95	1.02	106.88	108.84
	9.0	150	0.45	1.00	1.00	0.95	0.97	106.88	104.16
	10.5	150	0.45	1.00	1.00	1.00	0.97	112.50	108.96
	12.0	172	0.45	1.00	1.00	1.00	1	129.00	128.94
	13.5	150	0.45	1.00	1.00	1.00	1.01	112.50	113.95
	15.0	200	0.45	1.00	1.00	1.00	1.03	150.00	154.00

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- P2	1.0	1	0.45	1.00	1.00	0.75	1.61	0.56	0.91
	2.0	4	0.45	1.00	1.00	0.75	1.47	2.25	3.30
	3.0	9	0.45	1.00	1.00	0.75	1.21	5.06	6.14
	4.0	13	0.45	1.00	1.00	0.75	1.11	7.31	8.09
	5.0	200	0.45	1.00	1.00	0.85	1.04	127.50	132.76
	6.0	150	0.45	1.00	1.00	0.85	1.00	95.63	95.82
	7.5	150	0.45	1.00	1.00	0.95	0.96	106.88	103.04
	9.0	150	0.45	1.00	1.00	0.95	0.93	106.88	99.16
	10.5	200	0.45	1.00	1.00	1.00	0.92	150.00	138.56
	12.0	150	0.45	1.00	1.00	1.00	0.95	112.50	106.96

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- P3	1.0	15	0.45	1.00	1.00	0.75	1.71	8.44	14.42
	2.0	24	0.45	1.00	1.00	0.75	1.57	13.50	21.18
	3.0	50	0.45	1.00	1.00	0.75	1.33	28.13	37.27
	4.0	29	0.45	1.00	1.00	0.75	1.22	16.31	19.92
	5.0	85	0.45	1.00	1.00	0.85	1.16	54.19	62.63
	6.0	100	0.45	1.00	1.00	0.85	1.12	63.75	71.24
	7.5	150	0.45	1.00	1.00	0.95	1.07	106.88	114.77
	9.0	120	0.45	1.00	1.00	0.95	1.02	85.50	87.61
	10.5	300	0.45	1.00	1.00	1.00	1.02	225.00	229.09
	12.0	200	0.45	1.00	1.00	1.00	1.05	150.00	158.17

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- P4	1.0	4	0.45	1.00	1.00	0.75	1.59	2.25	3.57
	2.0	2	0.45	1.00	1.00	0.75	1.45	1.13	1.63
	3.0	6	0.45	1.00	1.00	0.75	1.22	3.38	4.12
	4.0	13	0.45	1.00	1.00	0.75	1.13	7.31	8.24
	5.0	120	0.45	1.00	1.00	0.85	1.07	76.50	81.80
	6.0	120	0.45	1.00	1.00	0.85	1.03	76.50	78.57
	7.5	150	0.45	1.00	1.00	0.95	0.99	106.88	105.47
	9.0	200	0.45	1.00	1.00	0.95	0.95	142.50	135.29
	10.5	300	0.45	1.00	1.00	1.00	0.91	225.00	205.55
	12.0	300	0.45	1.00	1.00	1.00	0.91	225.00	204.41

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- P5	1.0	3	0.45	1.00	1.00	0.75	1.68	1.69	2.84
	2.0	8	0.45	1.00	1.00	0.75	1.54	4.50	6.92
	3.0	2	0.45	1.00	1.00	0.75	1.27	1.13	1.43
	4.0	67	0.45	1.00	1.00	0.75	1.16	37.69	43.59
	5.0	100	0.45	1.00	1.00	0.85	1.09	63.75	69.40
	6.0	100	0.45	1.00	1.00	0.85	1.05	63.75	66.65
	7.5	100	0.45	1.00	1.00	0.95	1.01	71.25	71.78
	9.0	120	0.45	1.00	1.00	0.95	0.97	85.50	83.01
	10.5	150	0.45	1.00	1.00	1.00	0.97	112.50	108.67
	12.0	200	0.45	1.00	1.00	1.00	1.00	150.00	149.52

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- P6	1.0	1	0.45	1.00	1.00	0.75	1.58	0.56	0.89
	2.0	3	0.45	1.00	1.00	0.75	1.45	1.69	2.44
	3.0	4	0.45	1.00	1.00	0.75	1.21	2.25	2.72
	4.0	67	0.45	1.00	1.00	0.75	1.11	37.69	41.75
	5.0	100	0.45	1.00	1.00	0.85	1.05	63.75	66.81
	6.0	85	0.45	1.00	1.00	0.85	1.01	54.19	54.92
	7.5	100	0.45	1.00	1.00	0.95	0.98	71.25	69.67
	9.0	120	0.45	1.00	1.00	0.95	0.94	85.50	80.45
	10.5	150	0.45	1.00	1.00	1.00	0.91	112.50	101.88
	12.0	200	0.45	1.00	1.00	1.00	0.90	150.00	135.09

Soil Bore Hole near Naf River (Station C):

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H. T-2B7C	1.0	1	0.45	1.00	1.00	0.75	1.62	0.56	0.91
	2.0	0	0.45	1.00	1.00	0.75	1.48	0.00	0.00
	3.0	0	0.45	1.00	1.00	0.75	1.24	0.00	0.00
	4.0	7	0.45	1.00	1.00	0.75	1.14	3.94	4.47
	5.0	9	0.45	1.00	1.00	0.85	1.07	5.74	6.16
	6.0	7	0.45	1.00	1.00	0.85	1.03	4.46	4.61
	7.5	2	0.45	1.00	1.00	0.95	0.99	1.43	1.41
	9.0	0	0.45	1.00	1.00	0.95	0.95	0.00	0.00
	10.5	3	0.45	1.00	1.00	1.00	0.95	2.25	2.13
	12.0	2	0.45	1.00	1.00	1.00	0.98	1.50	1.46
	13.5	2	0.45	1.00	1.00	1.00	0.99	1.50	1.48
	15.0	4	0.45	1.00	1.00	1.00	1.00	3.00	3.00
	16.5	4	0.45	1.00	1.00	1.00	1.01	3.00	3.04
	18.0	10	0.45	1.00	1.00	1.00	1.03	7.50	7.71
	19.5	120	0.45	1.00	1.00	1.00	1.04	90.00	93.77
	21.0	150	0.45	1.00	1.00	1.00	1.06	112.50	118.91
	22.5	200	0.45	1.00	1.00	1.00	1.07	150.00	160.92
	24.0	150	0.45	1.00	1.00	1.00	1.09	112.50	122.56
	25.5	150	0.45	1.00	1.00	1.00	1.11	112.50	124.53
	27.0	120	0.45	1.00	1.00	1.00	1.13	90.00	101.28
	28.5	150	0.45	1.00	1.00	1.00	1.14	112.50	128.80
	30.0	300	0.45	1.00	1.00	1.00	1.17	225.00	262.26

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H. T-2B9C	1.0	20	0.45	1.00	1.00	0.75	1.58	11.25	17.82
	2.0	2	0.45	1.00	1.00	0.75	1.45	1.13	1.63
	3.0	1	0.45	1.00	1.00	0.75	1.20	0.56	0.68
	4.0	0	0.45	1.00	1.00	0.75	1.10	0.00	0.00
	5.0	0	0.45	1.00	1.00	0.85	1.04	0.00	0.00
	6.0	0	0.45	1.00	1.00	0.85	0.99	0.00	0.00
	7.5	7	0.45	1.00	1.00	0.95	0.95	4.99	4.75
	9.0	2	0.45	1.00	1.00	0.95	0.92	1.43	1.31
	10.5	1	0.45	1.00	1.00	1.00	0.91	0.75	0.68
	12.0	2	0.45	1.00	1.00	1.00	0.94	1.50	1.41
	13.5	6	0.45	1.00	1.00	1.00	0.95	4.50	4.27
	15.0	2	0.45	1.00	1.00	1.00	0.96	1.50	1.44
	16.5	3	0.45	1.00	1.00	1.00	0.97	2.25	2.19
	18.0	120	0.45	1.00	1.00	1.00	0.98	90.00	88.61
	19.5	300	0.45	1.00	1.00	1.00	1.00	225.00	224.39
	21.0	300	0.45	1.00	1.00	1.00	1.01	225.00	227.36
	22.5	200	0.45	1.00	1.00	1.00	1.02	150.00	153.63
	24	200	0.45	1.00	1.00	1.00	1.04	150.00	155.78
	25.5	300	0.45	1.00	1.00	1.00	1.05	225.00	237.03
	27	200	0.45	1.00	1.00	1.00	1.07	150.00	160.37
	28.5	300	0.45	1.00	1.00	1.00	1.09	225.00	244.26
	30	300	0.45	1.00	1.00	1.00	1.10	225.00	248.14

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- S.C	1.0	1	0.45	1.00	1.00	0.75	1.64	0.56	0.92
	2.0	1	0.45	1.00	1.00	0.75	1.51	0.56	0.85
	3.0	2	0.45	1.00	1.00	0.75	1.26	1.13	1.42
	4.0	150	0.45	1.00	1.00	0.75	1.15	84.38	97.02
	5.0	85	0.45	1.00	1.00	0.85	1.07	54.19	58.17
	6.0	120	0.45	1.00	1.00	0.85	1.02	76.50	78.24
	7.5	120	0.45	1.00	1.00	0.95	0.98	85.50	83.63
	9.0	150	0.45	1.00	1.00	0.95	0.94	106.88	100.22
	10.5	300	0.45	1.00	1.00	1.00	0.90	225.00	202.89
	12.0	300	0.45	1.00	1.00	1.00	0.90	225.00	201.79
	13.5	200	0.45	1.00	1.00	1.00	0.89	150.00	134.23
	15.0	200	0.45	1.00	1.00	1.00	0.89	150.00	133.94
	16.5	200	0.45	1.00	1.00	1.00	0.90	150.00	135.38
	18.0	300	0.45	1.00	1.00	1.00	0.91	225.00	205.30
	19.5	300	0.45	1.00	1.00	1.00	0.92	225.00	207.59
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	209.96
	22.5	300	0.45	1.00	1.00	1.00	0.94	225.00	212.40
	24	300	0.45	1.00	1.00	1.00	0.96	225.00	214.92
	25.5	300	0.45	1.00	1.00	1.00	0.97	225.00	217.53
	27	300	0.45	1.00	1.00	1.00	0.98	225.00	220.24
	28.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.04
	30	300	0.45	1.00	1.00	1.00	1.00	225.00	225.96

Soil Bore Hole from Path : Station-A to Station-B:

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-S1B	1.0	39	0.45	1.00	1.00	0.75	1.68	21.94	36.88
	2.0	100	0.45	1.00	1.00	0.75	1.55	56.25	86.94
	3.0	150	0.45	1.00	1.00	0.75	1.30	84.38	110.03
	4.0	300	0.45	1.00	1.00	0.75	1.20	168.75	202.34
	5.0	150	0.45	1.00	1.00	0.85	1.14	95.63	108.96
	6.0	200	0.45	1.00	1.00	0.85	1.11	127.50	141.48
	7.5	300	0.45	1.00	1.00	0.95	1.08	213.75	229.97
	9.0	300	0.45	1.00	1.00	0.95	1.03	213.75	221.10
	10.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.11
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	300	0.45	1.00	1.00	1.00	0.92	225.00	207.84
	16.5	300	0.45	1.00	1.00	1.00	0.91	225.00	204.79
	18.0	400	0.45	1.00	1.00	1.00	0.91	300.00	272.49
	19.5	600	0.45	1.00	1.00	1.00	0.92	450.00	413.27
	21.0	400	0.45	1.00	1.00	1.00	0.93	300.00	278.62
	22.5	600	0.45	1.00	1.00	1.00	0.94	450.00	422.75
	24.0	200	0.45	1.00	1.00	1.00	0.95	150.00	142.58
	25.5	600	0.45	1.00	1.00	1.00	0.96	450.00	432.88
	27.0	600	0.45	1.00	1.00	1.00	0.97	450.00	438.21
	28.5	600	0.45	1.00	1.00	1.00	0.99	450.00	443.73

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-1B1A	1.0	100	0.45	1.00	1.00	0.75	1.68	56.25	94.57
	2.0	200	0.45	1.00	1.00	0.75	1.55	112.50	173.88
	3.0	200	0.45	1.00	1.00	0.75	1.30	112.50	146.70
	4.0	200	0.45	1.00	1.00	0.75	1.20	112.50	134.90
	5.0	300	0.45	1.00	1.00	0.85	1.14	191.25	217.92
	6.0	200	0.45	1.00	1.00	0.85	1.11	127.50	141.48
	7.5	300	0.45	1.00	1.00	0.95	1.08	213.75	229.97
	9.0	100	0.45	1.00	1.00	0.95	1.03	71.25	73.70
	10.5	200	0.45	1.00	1.00	1.00	0.99	150.00	148.74
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	300	0.45	1.00	1.00	1.00	0.92	225.00	207.84
	16.5	200	0.45	1.00	1.00	1.00	0.91	150.00	136.53
	18.0	240	0.45	1.00	1.00	1.00	0.91	180.00	163.50
	19.5	300	0.45	1.00	1.00	1.00	0.92	225.00	206.63
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	208.97
	22.5	600	0.45	1.00	1.00	1.00	0.94	450.00	422.75
	24.0	300	0.45	1.00	1.00	1.00	0.95	225.00	213.87
	25.5	400	0.45	1.00	1.00	1.00	0.96	300.00	288.59

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-1B3A	1.0	3	0.45	1.00	1.00	0.75	1.68	1.69	2.84
	2.0	60	0.45	1.00	1.00	0.75	1.55	33.75	52.17
	3.0	300	0.45	1.00	1.00	0.75	1.30	168.75	220.06
	4.0	200	0.45	1.00	1.00	0.75	1.20	112.50	134.90
	5.0	300	0.45	1.00	1.00	0.85	1.14	191.25	217.92
	6.0	200	0.45	1.00	1.00	0.85	1.11	127.50	141.48
	7.5	300	0.45	1.00	1.00	0.95	1.08	213.75	229.97
	9.0	300	0.45	1.00	1.00	0.95	1.03	213.75	221.10
	10.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.11
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	600	0.45	1.00	1.00	1.00	0.94	450.00	421.85
	15.0	600	0.45	1.00	1.00	1.00	0.92	450.00	415.68
	16.5	600	0.45	1.00	1.00	1.00	0.91	450.00	409.58
	18.0	600	0.45	1.00	1.00	1.00	0.91	450.00	408.74
	19.5	600	0.45	1.00	1.00	1.00	0.92	450.00	413.27
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	208.97
	22.5	600	0.45	1.00	1.00	1.00	0.94	450.00	422.75
	24.0	300	0.45	1.00	1.00	1.00	0.95	225.00	213.87
	25.5	600	0.45	1.00	1.00	1.00	0.96	450.00	432.88
	27.0	600	0.45	1.00	1.00	1.00	0.97	450.00	438.21
	28.5	600	0.45	1.00	1.00	1.00	0.99	450.00	443.73
	30.0	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-1B4A	1.0	5	0.45	1.00	1.00	0.75	1.68	2.81	4.73
	2.0	85	0.45	1.00	1.00	0.75	1.55	47.81	73.90
	3.0	100	0.45	1.00	1.00	0.75	1.30	56.25	73.35
	4.0	100	0.45	1.00	1.00	0.75	1.20	56.25	67.45
	5.0	110	0.45	1.00	1.00	0.85	1.14	70.13	79.90
	6.0	120	0.45	1.00	1.00	0.85	1.11	76.50	84.89
	7.5	120	0.45	1.00	1.00	0.95	1.08	85.50	91.99
	9.0	135	0.45	1.00	1.00	0.95	1.03	96.19	99.49
	10.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.11
	12.0	200	0.45	1.00	1.00	1.00	0.95	150.00	142.79
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	200	0.45	1.00	1.00	1.00	0.92	150.00	138.56
	16.5	300	0.45	1.00	1.00	1.00	0.91	225.00	204.79
	18.0	200	0.45	1.00	1.00	1.00	0.91	150.00	136.25
	19.5	300	0.45	1.00	1.00	1.00	0.92	225.00	206.63
	21.0	200	0.45	1.00	1.00	1.00	0.93	150.00	139.31
	22.5	200	0.45	1.00	1.00	1.00	0.94	150.00	140.92
	24.0	300	0.45	1.00	1.00	1.00	0.95	225.00	213.87
	25.5	300	0.45	1.00	1.00	1.00	0.96	225.00	216.44
	27.0	400	0.45	1.00	1.00	1.00	0.97	300.00	292.14
	28.5	400	0.45	1.00	1.00	1.00	0.99	300.00	295.82
	30.0	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-1B5A	1.0	14	0.45	1.00	1.00	0.75	1.68	7.88	13.24
	2.0	44	0.45	1.00	1.00	0.75	1.55	24.75	38.25
	3.0	55	0.45	1.00	1.00	0.75	1.30	30.94	40.34
	4.0	100	0.45	1.00	1.00	0.75	1.20	56.25	67.45
	5.0	100	0.45	1.00	1.00	0.85	1.14	63.75	72.64
	6.0	150	0.45	1.00	1.00	0.85	1.11	95.63	106.11
	7.5	200	0.45	1.00	1.00	0.95	1.08	142.50	153.32
	9.0	200	0.45	1.00	1.00	0.95	1.03	142.50	147.40
	10.5	200	0.45	1.00	1.00	1.00	0.99	150.00	148.74
	12.0	200	0.45	1.00	1.00	1.00	0.95	150.00	142.79
	13.5	200	0.45	1.00	1.00	1.00	0.94	150.00	140.62
	15.0	300	0.45	1.00	1.00	1.00	0.92	225.00	207.84
	16.5	240	0.45	1.00	1.00	1.00	0.91	180.00	163.83
	18.0	300	0.45	1.00	1.00	1.00	0.91	225.00	204.37
	19.5	200	0.45	1.00	1.00	1.00	0.92	150.00	137.76
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	208.97
	22.5	600	0.45	1.00	1.00	1.00	0.94	450.00	422.75
	24.0	600	0.45	1.00	1.00	1.00	0.95	450.00	427.73
	25.5	600	0.45	1.00	1.00	1.00	0.96	450.00	432.88
	27.0	400	0.45	1.00	1.00	1.00	0.97	300.00	292.14
	28.5	300	0.45	1.00	1.00	1.00	0.99	225.00	221.87

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-1B6A	1.0	4	0.45	1.00	1.00	0.75	1.68	2.25	3.78
	2.0	5	0.45	1.00	1.00	0.75	1.55	2.81	4.35
	3.0	8	0.45	1.00	1.00	0.75	1.30	4.50	5.87
	4.0	85	0.45	1.00	1.00	0.75	1.20	47.81	57.33
	5.0	50	0.45	1.00	1.00	0.85	1.14	31.88	36.32
	6.0	32	0.45	1.00	1.00	0.85	1.11	20.40	22.64
	7.5	55	0.45	1.00	1.00	0.95	1.08	39.19	42.16
	9.0	50	0.45	1.00	1.00	0.95	1.03	35.63	36.85
	10.5	200	0.45	1.00	1.00	1.00	0.99	150.00	148.74
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	200	0.45	1.00	1.00	1.00	0.94	150.00	140.62
	15.0	200	0.45	1.00	1.00	1.00	0.92	150.00	138.56
	16.5	200	0.45	1.00	1.00	1.00	0.91	150.00	136.53
	18.0	200	0.45	1.00	1.00	1.00	0.91	150.00	136.25
	19.5	300	0.45	1.00	1.00	1.00	0.92	225.00	206.63
	21.0	600	0.45	1.00	1.00	1.00	0.93	450.00	417.94
	22.5	300	0.45	1.00	1.00	1.00	0.94	225.00	211.38
	24.0	300	0.45	1.00	1.00	1.00	0.95	225.00	213.87
	25.5	200	0.45	1.00	1.00	1.00	0.96	150.00	144.29
	27.0	300	0.45	1.00	1.00	1.00	0.97	225.00	219.10
	28.5	600	0.45	1.00	1.00	1.00	0.99	450.00	443.73
	30.0	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-1B7A	1.0	2	0.45	1.00	1.00	0.75	1.68	1.13	1.89
	2.0	12	0.45	1.00	1.00	0.75	1.55	6.75	10.43
	3.0	12	0.45	1.00	1.00	0.75	1.30	6.75	8.80
	4.0	100	0.45	1.00	1.00	0.75	1.20	56.25	67.45
	5.0	200	0.45	1.00	1.00	0.85	1.14	127.50	145.28
	6.0	150	0.45	1.00	1.00	0.85	1.11	95.63	106.11
	7.5	120	0.45	1.00	1.00	0.95	1.08	85.50	91.99
	9.0	200	0.45	1.00	1.00	0.95	1.03	142.50	147.40
	10.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.11
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	400	0.45	1.00	1.00	1.00	0.94	300.00	281.23
	15.0	200	0.45	1.00	1.00	1.00	0.92	150.00	138.56
	16.5	300	0.45	1.00	1.00	1.00	0.91	225.00	204.79
	18.0	300	0.45	1.00	1.00	1.00	0.91	225.00	204.37
	19.5	240	0.45	1.00	1.00	1.00	0.92	180.00	165.31
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	208.97
	22.5	300	0.45	1.00	1.00	1.00	0.94	225.00	211.38

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.- S.A	1.0	2	0.45	1.00	1.00	0.75	1.68	1.13	1.89
	2.0	4	0.45	1.00	1.00	0.75	1.55	2.25	3.48
	3.0	7	0.45	1.00	1.00	0.75	1.30	3.94	5.13
	4.0	10	0.45	1.00	1.00	0.75	1.20	5.63	6.74
	5.0	300	0.45	1.00	1.00	0.85	1.14	191.25	217.92
	6.0	150	0.45	1.00	1.00	0.85	1.11	95.63	106.11
	7.5	120	0.45	1.00	1.00	0.95	1.08	85.50	91.99
	9.0	150	0.45	1.00	1.00	0.95	1.03	106.88	110.55
	10.5	200	0.45	1.00	1.00	1.00	0.99	150.00	148.74
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	300	0.45	1.00	1.00	1.00	0.92	225.00	207.84
	16.5	200	0.45	1.00	1.00	1.00	0.91	150.00	136.53
	18.0	300	0.45	1.00	1.00	1.00	0.91	225.00	204.37
	19.5	300	0.45	1.00	1.00	1.00	0.92	225.00	206.63
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	208.97
	22.5	300	0.45	1.00	1.00	1.00	0.94	225.00	211.38
	24.0	300	0.45	1.00	1.00	1.00	0.95	225.00	213.87
	25.5	300	0.45	1.00	1.00	1.00	0.96	225.00	216.44
	27.0	300	0.45	1.00	1.00	1.00	0.97	225.00	219.10
	28.5	300	0.45	1.00	1.00	1.00	0.99	225.00	221.87
	30.0	300	0.45	1.00	1.00	1.00	1.00	225.00	224.73
	31.50	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47
	33.00	300	0.45	1.00	1.00	1.00	1.00	225.00	224.73
	34.50	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47
	36.00	300	0.45	1.00	1.00	1.00	1.00	225.00	224.73
	37.50	300	0.45	1.00	1.00	1.00	1.00	225.00	224.73
	39.00	300	0.45	1.00	1.00	1.00	1.00	225.00	224.73

Soil Bore Hole from Path : Station-B to Station-C:

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-S2B	1.0	66	0.45	1.00	1.00	0.75	1.68	37.13	62.42
	2.0	85	0.45	1.00	1.00	0.75	1.55	47.81	73.90
	3.0	150	0.45	1.00	1.00	0.75	1.30	84.38	110.03
	4.0	66	0.45	1.00	1.00	0.75	1.20	37.13	44.52
	5.0	150	0.45	1.00	1.00	0.85	1.14	95.63	108.96
	6.0	100	0.45	1.00	1.00	0.85	1.11	63.75	70.74
	7.5	150	0.45	1.00	1.00	0.95	1.08	106.88	114.99
	9.0	200	0.45	1.00	1.00	0.95	1.03	142.50	147.40
	10.5	150	0.45	1.00	1.00	1.00	0.99	112.50	111.56
	12.0	200	0.45	1.00	1.00	1.00	0.95	150.00	142.79
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	200	0.45	1.00	1.00	1.00	0.92	150.00	138.56
	16.5	200	0.45	1.00	1.00	1.00	0.91	150.00	136.53
	18.0	200	0.45	1.00	1.00	1.00	0.91	150.00	136.25
	19.5	200	0.45	1.00	1.00	1.00	0.92	150.00	137.76
	21.0	300	0.45	1.00	1.00	1.00	0.93	225.00	208.97
	22.5	300	0.45	1.00	1.00	1.00	0.94	225.00	211.38
	24.0	200	0.45	1.00	1.00	1.00	0.95	150.00	142.58
	25.5	300	0.45	1.00	1.00	1.00	0.96	225.00	216.44
	27.0	200	0.45	1.00	1.00	1.00	0.97	150.00	146.07
	28.5	200	0.45	1.00	1.00	1.00	0.99	150.00	147.91
	30.0	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-2B1C	1.0	26	0.45	1.00	1.00	0.75	1.68	14.63	24.59
	2.0	50	0.45	1.00	1.00	0.75	1.55	28.13	43.47
	3.0	150	0.45	1.00	1.00	0.75	1.30	84.38	110.03
	4.0	50	0.45	1.00	1.00	0.75	1.20	28.13	33.72
	5.0	75	0.45	1.00	1.00	0.85	1.14	47.81	54.48
	6.0	120	0.45	1.00	1.00	0.85	1.11	76.50	84.89
	7.5	100	0.45	1.00	1.00	0.95	1.08	71.25	76.66
	9.0	66	0.45	1.00	1.00	0.95	1.03	47.03	48.64
	10.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.11
	12.0	75	0.45	1.00	1.00	1.00	0.95	56.25	53.55
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	600	0.45	1.00	1.00	1.00	0.92	450.00	415.68
	16.5	200	0.45	1.00	1.00	1.00	0.91	150.00	136.53
	18.0	400	0.45	1.00	1.00	1.00	0.91	300.00	272.49
	19.5	70	0.45	1.00	1.00	1.00	0.92	52.50	48.21
	21.0	600	0.45	1.00	1.00	1.00	0.93	450.00	417.94
	22.5	600	0.45	1.00	1.00	1.00	0.94	450.00	422.75
	24.0	600	0.45	1.00	1.00	1.00	0.95	450.00	427.73
	25.5	600	0.45	1.00	1.00	1.00	0.96	450.00	432.88
	27.0	600	0.45	1.00	1.00	1.00	0.97	450.00	438.21
	28.5	600	0.45	1.00	1.00	1.00	0.99	450.00	443.73
	30.0	600	0.45	1.00	1.00	1.00	1.00	450.00	449.47

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-2B5C	1.0	50	0.45	1.00	1.00	0.75	1.68	28.13	47.28
	2.0	60	0.45	1.00	1.00	0.75	1.55	33.75	52.17
	3.0	66	0.45	1.00	1.00	0.75	1.30	37.13	48.41
	4.0	66	0.45	1.00	1.00	0.75	1.20	37.13	44.52
	5.0	66	0.45	1.00	1.00	0.85	1.14	42.08	47.94
	6.0	85	0.45	1.00	1.00	0.85	1.11	54.19	60.13
	7.5	85	0.45	1.00	1.00	0.95	1.08	60.56	65.16
	9.0	150	0.45	1.00	1.00	0.95	1.03	106.88	110.55
	10.5	200	0.45	1.00	1.00	1.00	0.99	150.00	148.74
	12.0	150	0.45	1.00	1.00	1.00	0.95	112.50	107.09
	13.5	151	0.45	1.00	1.00	1.00	0.94	113.25	106.17
	15.0	152	0.45	1.00	1.00	1.00	0.92	114.00	105.31
	16.5	153	0.45	1.00	1.00	1.00	0.91	114.75	104.44
	18.0	154	0.45	1.00	1.00	1.00	0.91	115.50	104.91
	19.5	155	0.45	1.00	1.00	1.00	0.92	116.25	106.76
	21.0	156	0.45	1.00	1.00	1.00	0.93	117.00	108.66
	22.5	157	0.45	1.00	1.00	1.00	0.94	117.75	110.62
	24.0	158	0.45	1.00	1.00	1.00	0.95	118.50	112.64
	25.5	159	0.45	1.00	1.00	1.00	0.96	119.25	114.71
	27.0	160	0.45	1.00	1.00	1.00	0.97	120.00	116.86
	28.5	161	0.45	1.00	1.00	1.00	0.99	120.75	119.07
	30.0	162	0.45	1.00	1.00	1.00	1.00	121.50	121.36

B.H. No	Depth m	SPT Value	E_H	C_B	C_S	C_R	C_N	N_{60}	N'_{60}
B.H.-T-B6C	1.0	2	0.45	1.00	1.00	0.75	1.68	1.13	1.89
	2.0	12	0.45	1.00	1.00	0.75	1.55	6.75	10.43
	3.0	100	0.45	1.00	1.00	0.75	1.30	56.25	73.35
	4.0	150	0.45	1.00	1.00	0.75	1.20	84.38	101.17
	5.0	200	0.45	1.00	1.00	0.85	1.14	127.50	145.28
	6.0	200	0.45	1.00	1.00	0.85	1.11	127.50	141.48
	7.5	150	0.45	1.00	1.00	0.95	1.08	106.88	114.99
	9.0	150	0.45	1.00	1.00	0.95	1.03	106.88	110.55
	10.5	300	0.45	1.00	1.00	1.00	0.99	225.00	223.11
	12.0	300	0.45	1.00	1.00	1.00	0.95	225.00	214.18
	13.5	300	0.45	1.00	1.00	1.00	0.94	225.00	210.93
	15.0	300	0.45	1.00	1.00	1.00	0.92	225.00	207.84
	16.5	300	0.45	1.00	1.00	1.00	0.91	225.00	204.79
	18.0	300	0.45	1.00	1.00	1.00	0.91	225.00	204.37
	19.5	300	0.45	1.00	1.00	1.00	0.92	225.00	206.63
	21.0	600	0.45	1.00	1.00	1.00	0.93	450.00	417.94
	22.5	600	0.45	1.00	1.00	1.00	0.94	450.00	422.75
	24.0	300	0.45	1.00	1.00	1.00	0.95	225.00	213.87
	25.5	300	0.45	1.00	1.00	1.00	0.96	225.00	216.44
	27.0	600	0.45	1.00	1.00	1.00	0.97	450.00	438.21
	28.5	200	0.45	1.00	1.00	1.00	0.99	150.00	147.91