# GROUND INVESTIGATION AND RESPONSE OF JHILMIL RESIDENTIAL TOWN PROJECT

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**ABSTRACT**

In Bangladesh many low laying areas which remained under water are developing for residential and commercial purposes by sand filling. These areas are developing by different government and non-government organization by naming different projects. Such a project is Jhilmil Project of RAJUK (RajdhaniUnnayanKartipalha) located near the Dhaka city. Subsoil investigation was carried out in sixteen locations of the project. This paper represents the subsoil investigation reports and the ground response analysis of subsoil of Jhilmil project. SPT N values of sixteen boreholes were collected from Standard Penetration Test. Shear wavevelocity was determined by using universal correlation. The site response analysis was performed using DEEPSOIL (Hashash et al., 2011) V5.1. Equivalentlinear analysis was performed and the response spectrum, the PGA andthe amplification factor was determined and represented in this paper.

Keywords: SPT N; shear wave velocity; DEEPSOIL; PSA; PGA; amplification factor.

## INTRODUCTION

Many historical earthquakes like Mexico earthquake (1985), Edgecumbe Earthquake (1987), San Francisco earthquake (1989), LosAngeles earthquake (1995) have established that local site conditions has significant role in the amplification of ground motion. In case of Bangladesh,April 2015 Nepal earthquake with a magnitude of 7.8, which is one of the strongest earthquake in the world killed 8857 in Nepal and about 600 in the region of Bangladesh and India and affected almost the whole of Bangladesh. For this reason accurate and proper soil investigation of a site has become an essential concern to grasp precise knowledge about site response and as well as seismic hazard. A geotechnical investigation was carried out at Jhilmil residential area, Keranigonj, Dhaka by the detailed sub-surface investigation program which includes sixteen (16) borings, execution of standard penetration test (SPT). Using the SPT N value, shear wave velocity was determined from empirical correlation equation and Equivalent linear site response analysis of the investigated area under a given earthquake motion was performed using program DEEPSOIL.

## SITE INFORMATION

The study area “JhilmilResidential Town Project” is a ongoing project of RAJUK (RajdhaniUnnayanKartipakha) located near to the Dhaka city having latitude 23°40′N and longitude 90° 23′ E (Fig. 1). The soil profile of Jhilmil residential area is consists of an upper non-cohesive deposit of very loose sandy silt and silty fine sand. Occasional deposit of soft to medium stiff clay and clayey silt mixed with varying amount of fine sand upto the maximum depth of about 14.0 m from the existing ground surface. The deposit below upto the depth of exploration consists of non-cohesive deposit of medium dense to very dense silty fine sand mixed with trace amount of mica.

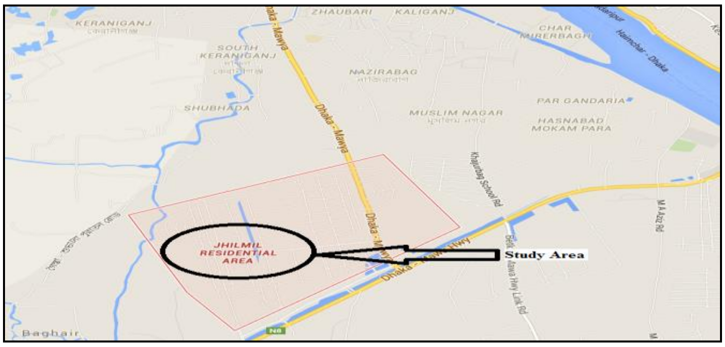


Fig. 1 Location map of the study area (Google map)

## SUB SOIL INVESTIGATION

The field investigation was carried out by Dhaka Soil and the execution of total of sixteen borings which is up to maximum depth of 21 m from existing ground surface. Fig. 2 shows points of SPT Tests. Holes were made by driving the casing of 10cm (4”) diameter up to 1.83 m (6’-0”) depth. The distributed samples were collected at an interval of 1.5 m (5’) depth. Besides, The samples were collected by driving split spoon sampler which is of 3.15 cm (1-3/8”) inner diameter with a hammer of 63.5 kg (140 lbs.) weight falling freely at a height of about 76.2 cm (30”) in average and on the other hand, the number of blows required to drive the sampler for every 0.15 m (6”) penetration over 0.45 m 1.5 ft) depth was recorded to measure the standard penetration resistance-N per 0.30 m. Moreover, Shelby tubes are used for collecting the undisturbed samples having 7.62 cm (3”) diameter. In this case, the ground water table was recorded 24 hours after completion of each hole. The SPT N values with respect to depth of sixteen sites is shown in Fig. 3.

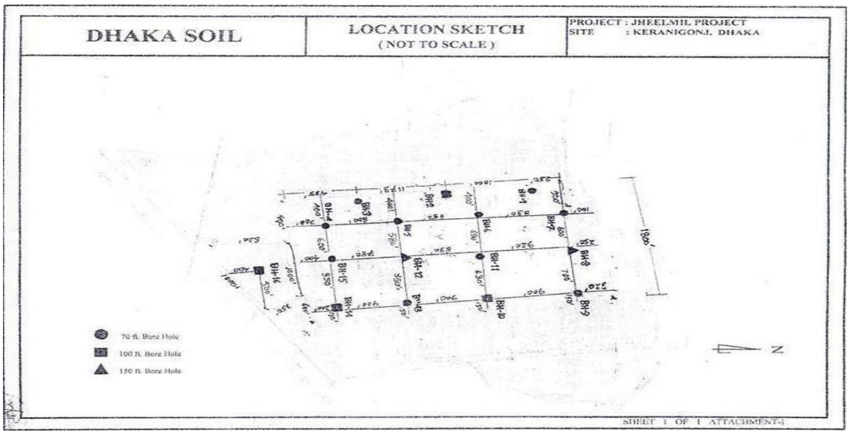


Fig. 2: Location Map of SPT Test points

Various samples of different depths were collected from different sites. They are visually examined and all undisturbed and representative disturbed samples are being selected for necessary testing. The following tests were performed on the selected samples.

- Natural Moisture Content.
- Liquid & Plastic Limit.
- Specific Gravity.
- Grain Size Analysis.
- Wet & Dry Density Test.
- Unconfined Compression Test.
- Consolidation Test.
- Direct Shear Test

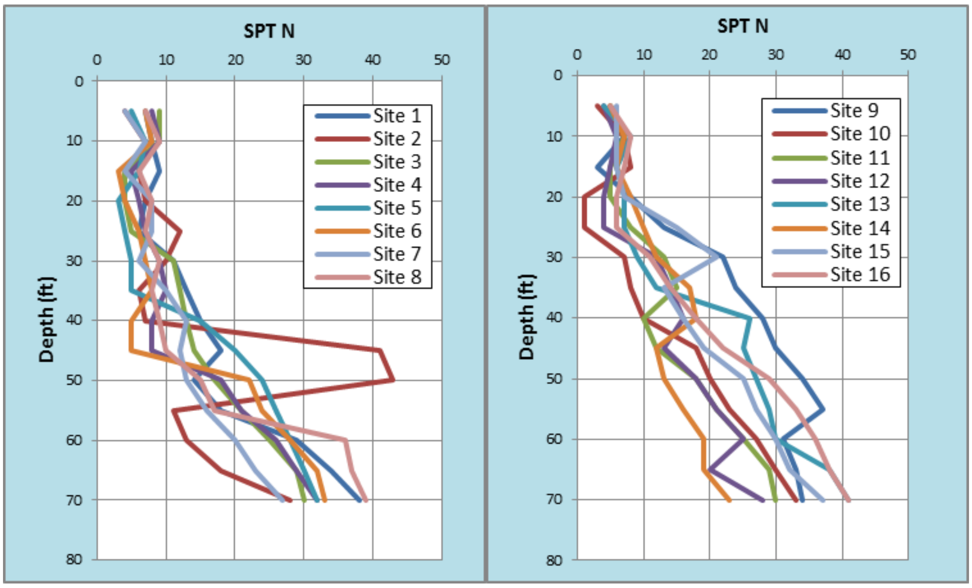


Fig. 3: SPT N Values with respect to depth

The results for different sites for different tests are represented in table 1 and table 2:

Table 1 Summary of laboratory test results (BH-1 to BH-7)

| Bore Hole no. | | 1 | | | 2 | | 3 | | | 4 | | 5 | | | 6 | | 7 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (m) | | 1.50 to 1.95 | 7.50 to 7.95 | 12.00 to 12.95 | 9.00 to 9.45 | 21.00 to 21.45 | 4.50 to 4.95 | 5.55 to 6.00 | 15.00 to 15.45 | 6.00 to 6.45 | 16.50 to 16.95 | 5.55 to 6.00 | 7.50 to 7.95 | 12.00 to 12.45 | 4.50 to 4.95 | 18.00 to 18.45 | 5.55 to 6.00 | 6.00 to 6.45 | 21.00 to 21.45 |
| Natural Moisture Content (%) | | | | | | | 27.6 | 28.8 | | | | 30.8 | 27.8 | | | | 25.7 | 25.2 | |
| Specific Gravity | | | | | | | | 2.670 | | | | | | | | | | | |
| Atterberg Limits | Liquid Limit (LL) | | | | | | 30 | | | | | 41 | | | | | 38 | | |
| | Plastic Limit (PL) | | | | | | 26 | | | | | 23 | | | | | 27 | | |
| Density | Wet (P.C.F) | | | | | | | 18.12 | | | 17.84 | | | | | | 18.57 | | |
| | Dry (P.C.F) | | | | | | | 14.07 | | | 13.64 | | | | | | 14.77 | | |
| | Sand (%) | 72 | 45 | 82 | 77 | 88 | 21 | | 85 | 73 | 87 | | 8 | 83 | 67 | 86 | | 15 | 88 |
| | Silt (%) | 28 | 52 | 18 | 23 | 12 | 74 | | 15 | 27 | 13 | | 72 | 17 | 33 | 14 | | 77 | 12 |
| | Clay (%) | 0 | 3 | 0 | 0 | 0 | 5 | | 0 | 0 | 0 | | 20 | 0 | 0 | 0 | | 8 | 0 |
| Consolidation Tests | Natural Void Ratio, Co | | | | | | | 0.868 | | | | | | | | | | | |
| | Compression Index, Cc | | | | | | | 0.250 | | | | | | | | | | | |
| Unconfined Compression Tests | Strain at failure (%) | | | | | | | 14.0 | | | | 18.0 | | | | | 12.0 | | |
| | Stress undist (P.S.I) | | | | | | | 54.6 | | | | 42.6 | | | | | 98.2 | | |
| Direct Shear Tests | (I) Degree | | | 30.0 | | | | | | | | | | 32.0 | | | | | |
| | C (PSI) | | | 0 | | | | | | | | | | 0 | | | | | |

Table 2 Summary of laboratory test results (BH-8 to BH-16)

| Bore Hole no. | | 8 | | | 9 | | 10 | | 11 | | 12 | | | 13 | | 14 | | 15 | | 16 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth in meter | | 3.00 to 3.45 | 15.00 to 15.45 | 30.00 to 30.45 | 9.00 to 9.45 | 18.00 to 18.45 | 6.00 to 6.45 | 24.00 to 24.45 | 12.00 to 12.45 | 19.50 to 19.95 | 6.00 to 6.45 | 5.55 to 6.00 | 15.00 to 15.45 | 12.00 to 12.45 | 18.00 to 18.45 | 9.00 to 9.45 | 21.00 to 21.45 | 4.50 to 4.95 | 10.50 to 10.95 | 7.05 to 7.50 | 21.00 to 21.45 |
| Natural Moisture Content (%) | | | | | | | | | | | 28.2 | 28.7 | | | | | | | | | |
| Specific Gravity | | | | | | | | | | | | 2.675 | | | | | | | | | |
| Atterberg Limits | Liquid Limit (LL) | | | | | | | | | | 42 | | | | | | | | | | |
| | Plastic Limit (PL) | | | | | | | | | | 23 | | | | | | | | | | |
| Density | Wet (P.C.F) | | | | | | | | | | | 18.17 | | | | | | | | 18.30 | |
| | Dry (P.C.F) | | | | | | | | | | | 14.11 | | | | | | | | 14.43 | |
| | Sand (%) | 72 | 85 | 92 | 87 | 89 | 47 | 93 | 78 | 86 | 8 | | 88 | 82 | 88 | 81 | 91 | 83 | 84 | | 84 |
| | Silt (%) | 28 | 18 | 8 | 13 | 11 | 51 | 7 | 22 | 14 | 75 | | 12 | 18 | 12 | 19 | 9 | 17 | 16 | | 16 |
| | Clay (%) | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 17 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Consolidation Tests | Natural Void Ratio, Co | | | | | | | | | | | 0.855 | | | | | | | | | |
| | Compression Index, Cc | | | | | | | | | | | 0.215 | | | | | | | | | |
| Unconfined Compression Tests | Strain at failure (%) | | | | | | | | | | | 16.0 | | | | | | | | 14.0 | |
| | Stress undist (P.S.I) | | | | | | | | | | | 53.2 | | | | | | | | 78.5 | |
| Direct Shear Tests | (I) Degree | | 30.0 | | | | | 35.0 | | | | | 31.0 | | | | | | | | 36.0 |
| | C (PSI) | | 0 | | | | | 0 | | | | | 0 | | | | | | | | 0 |

## GROUND RESPONSE ANALYSIS

Equivalent Linear Site amplification was performed using the DEEPSOIL (Hashash, Y.M.A. et al., 2011). As input parameter in the deep soil, soil type, unit weight and the shear wave velocity according to depth were given. Shear wave velocity $V_S$ was calculated from the SPT-N value using the following universal correlation equation (Ohta and Goto, 1978).

$$\mathbf{V_S = 85.35\ N^{0.348}} \quad (1)$$

The equation was chosen because it can be used for all types of soil (clay, fine sand, medium sand, coarse sand, sand and gravel, and gravel) and easy to use. The shear wave velocities of different sites along with depth are shown in table 3 below.

*Table 3 Shear wave velocity with respect to depth*

| **Depth (ft)** | **Shear wave velocities (ft/S)** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Site 6** | **Site 7** | **Site 8** | **Site 9** | **Site 10** | **Site 11** | **Site 12** | **Site 13** | **Site 14** | **Site 15** | **Site 16** |
| **5** | 168 | 135 | 179 | 172 | 146 | 164 | 135 | 168 | 149 | 125 | 149 | 138 | 138 | 149 | 159 | 149 |
| **10** | 176 | 164 | 179 | 179 | 164 | 172 | 164 | 183 | 168 | 168 | 168 | 159 | 176 | 168 | 159 | 176 |
| **15** | 183 | 155 | 135 | 146 | 155 | 122 | 135 | 159 | 125 | 176 | 149 | 149 | 159 | 159 | 159 | 168 |
| **20** | 168 | 164 | 135 | 155 | 122 | 135 | 172 | 176 | 176 | 85 | 149 | 138 | 168 | 176 | 168 | 159 |
| **25** | 159 | 198 | 146 | 164 | 135 | 155 | 172 | 168 | 208 | 85 | 176 | 138 | 168 | 190 | 219 | 159 |
| **30** | 197 | 186 | 192 | 179 | 146 | 164 | 155 | 183 | 250 | 168 | 208 | 203 | 183 | 203 | 246 | 197 |
| **35** | 208 | 155 | 198 | 186 | 146 | 172 | 186 | 176 | 258 | 176 | 219 | 214 | 203 | 229 | 208 | 214 |
| **40** | 219 | 164 | 203 | 172 | 214 | 146 | 203 | 183 | 272 | 190 | 190 | 224 | 265 | 233 | 224 | 233 |
| **45** | 233 | 303 | 209 | 172 | 236 | 146 | 198 | 190 | 279 | 233 | 203 | 208 | 262 | 203 | 238 | 250 |
| **50** | 214 | 309 | 223 | 228 | 252 | 244 | 203 | 219 | 291 | 242 | 233 | 233 | 269 | 208 | 262 | 275 |
| **55** | 233 | 192 | 240 | 240 | 259 | 252 | 219 | 229 | 300 | 254 | 246 | 246 | 275 | 224 | 269 | 288 |
| **60** | 275 | 203 | 255 | 259 | 266 | 266 | 236 | 297 | 282 | 269 | 262 | 262 | 279 | 238 | 279 | 297 |
| **65** | 291 | 228 | 269 | 269 | 272 | 278 | 248 | 300 | 288 | 279 | 275 | 242 | 303 | 238 | 285 | 303 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **70** | 303 | 266 | 272 | 278 | 278 | 281 | 262 | 305 | 291 | 288 | 279 | 272 | 311 | 254 | 300 | 311 |

As input motion, Kobe Earthquake was selected.Kobe Earthquake occurred on Tuesday, January 17th 1995 an earthquake of magnitude 7.2 on the Richter Scale struck the Kobe region of south-central Japan. The ground shook for only about 20 seconds but in that short time, over 5,000 people died, over 300,000 people became homeless and damage worth an estimated £100 billion was caused to roads, houses, factories and infrastructure. The time history of Kobe earthquake is shown in the fig. 4.

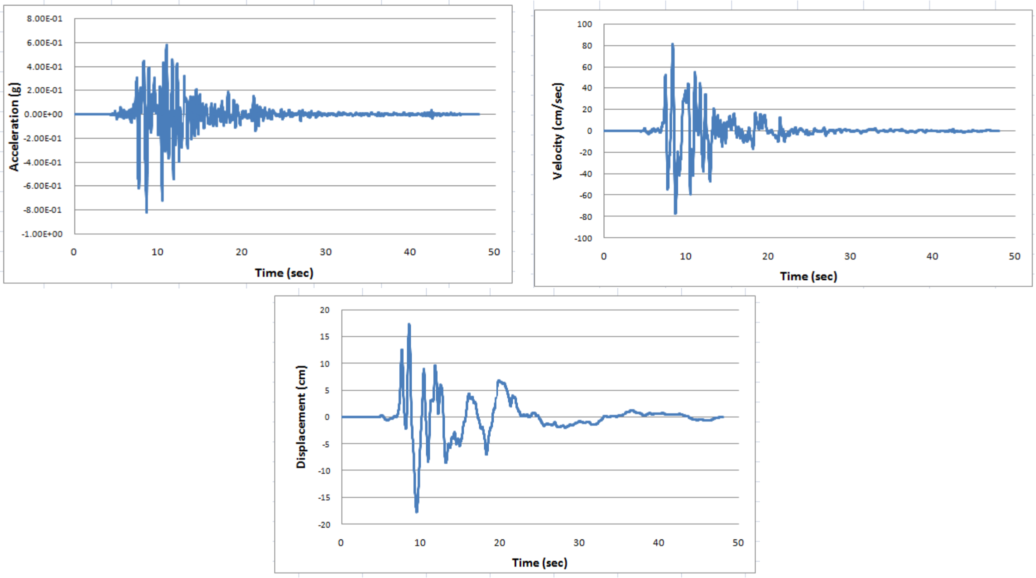


*Fig. 4 Time history of Kobe earthquake*

## GROUND RESPONSE RESULTS

Response Spectrum of input motion and 16 bore holes are shown in fig.5. From the 16sites,site 9 and site 15 produce highest (0.28g) peak spectral acceleration (PSA) and site 10 producesthelowest (0.06g) peak spectral acceleration (PSA). It was observed that surface response in all locations were less than the response of Kobe.

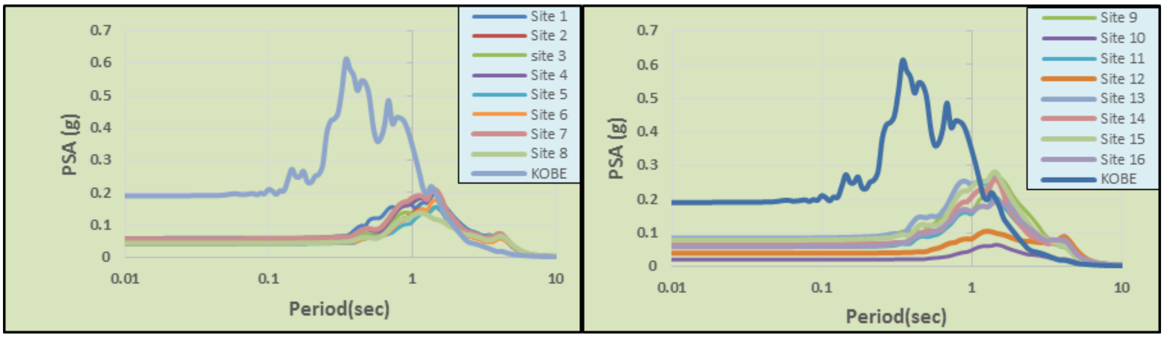


*Fig. 5 Response Spectrum of different Sites*

Peak Ground Acceleration (PGA) of different sites is represented in fig.6. PGA at surface and that at bedrock is obtained from the analysis. The peak ground acceleration values at surface are observed to be in the range of 0.002g (Site 10) to 0.008g (Site 13) and that of the bed rock were observed to be in the range of 0.08g (Site 12) to 0.17g (Site 15). The values were within the value of zone co efficient 0.15g of Dhaka city.

Site amplification factors at sub surface layers are used to measure the ground response. The amplification factor is the ratio of peak ground acceleration at surface to that of acceleration at hard rock.

Amplification Factor = PGA recorded at ground surface / PGA recorded at hard rock

The amplification factors of different sites are represented in the bar chart in fig. 7.The amplification factor ranges from 0.12 (site 10) to 0.52 (site 9).

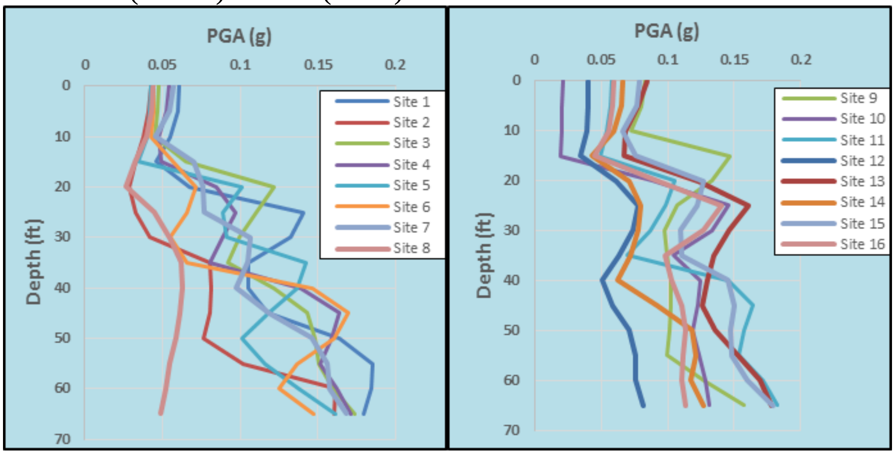


*Fig. 6 Peak Ground Acceleration of different locations*

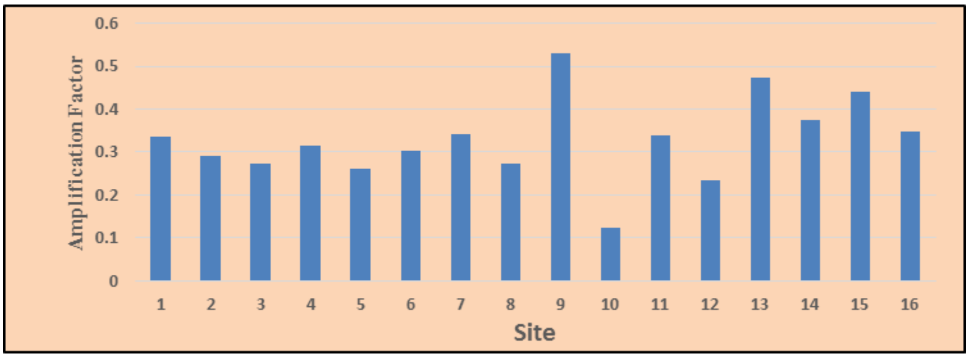


*Fig. 7Amplification Factor of different locations*

## CONCLUSION

Jhilmil residential area covers 381.11 acres land is a new project which is taken by RAJUK. It will become an important place in Dhaka city as it was proposed to development with various infrastructures. Therefore the ground response analysis was performed for the area. The surface soil response was less than the input motion of the area. The PGA values were not too much high. The amplification factor of all locations was less than one. So the surface soil is not much vulnerable for earthquake like Kobe. It can be predicted that damage in this area will not so strong but anything can be happened. Thus deeper analysis is needed. Shear wave velocity should be measured using geophysical tests and using the values, site response analysis should be estimated.

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