Report on

"Critical Analysis of the seismic Microzonation work of Guwahati City"

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GENERAL ASPECTS

As a 1st order seismic microzonation, the study is useful. However, the work needs more detailed investigations. For many important aspects only the final step is given without giving the intermediate steps. One example is assumption of Engineering Bed Rock. Second example is that no detail of input motion is given which is used for estimating the strong motion at surface. Without such details it is not possible to verify the results. The major aspects which have not been done but should have been done are as follows:

1. Assigning bed rock level and its shear wave velocity.
2. Drilling to about 100m in 100 boreholes with PS logging.
3. MASW and Micro tremor surveys close to all boreholes.
4. Soil Modeling.
5. Estimation of input motion at bed rock level using finite fault source assumption.
6. Estimation of response spectra and design basis Spectra at 500m grid.
7. Estimation of landslide and liquefaction potential.

The short comings chapter and item wise are described in the following sections:

Chapter wise Comments:

CHAPTER-2 (Analysis of Seismicity in Northeast India)

The Probabilistic analysis on the basis of area source is conducted in the Guwahati and surrounding area. The study based on Fault source is also suggested in the area.

CHAPTER-3 (Site Response Analysis from Geotechnical and Strong Ground Motion Data) Annexure III

i. Fig. 5.5 shows a bedrock depth of up to 200 meters based on GSI work whose authenticity is to be identified.

ii. a.) N-value has been used. It is determined in SPT test. Number of hammering required to penetrate sampler spoon to three depths of 15 cm each called N_1, N_2 and N_3. The total hammering for N_2 and N_3 gives N-value which represents soil strength.

    b.) During SPT test in number of boreholes there is refusal for N2 and N3 but Ncr is given. The methodology adopted for Ncr calculation is not mentioned in the report. Without N2 and N3, Ncr calculation is not possible. Hence Ncr values are suspect.

Suggestion: Some time it is needed to change the wrong N-Values based on Vs values. The best method is to estimate Vs values through Geophysical surveys, Prepare Vs-N relationship and then give final N-Values.

Annexure IV

1. Borehole Ids (83.1, 72.1 …….) given for soil test are different than the borehole nos. given for physical and shear parameters. Hence we are not sure whether the work has been done correctly and it is not possible to check major part of work.
2. Bulk density, dry densities are given but wet density is not given which is required to calculate the overburden pressure. The value of Moisture content in not mentioned in the table. Due to this reason it may be difficult to estimate liquefaction potential.
3. The percentage of Sand, Silt, Clay is not mentioned which is must for true soil modeling.

** The Soil modeling in an area is important aspect in estimating the seismic hazard. It is also a very good crosscheck of soil analysis from borehole samples.

Annexure V & VI

1. The velocity at large depth intervals of 6m is useless as one can miss the major layers in between. The given velocity estimation derived from N-values is very crude and not reliable.

Table 3.1

1. Shear wave velocity estimation from N-values using international relations may not be valid for Guwahati.
2. The Site response/ amplification is calculated on the basis of Boore (2003) relationship at 131 sites out of 141 sites at which Microtremor survey was conducted using Shear wave velocity. The shear wave velocity used in this process is estimated from Vs-N relationships. The discussion on the adoption of Vs-N relation is not presented in the report therefore; it is difficult to rely upon site response values.

CHAPTER 4: Strong Ground Motion Syntheses and Seismic Scenario in the Guwahati Region

4.3 Wave Number integration Method:

The Accelerograms are computed at bedrock level of 205 sites using wave number integration method.The methodology is based on generation of synthetic seismograms using point source assumption and this assumption over simplifies.

4.4 Computation of Response Spectra for Single Degree of Freedom (SDOF):

The Ground Response analysis is carried out by using synthesized acceleration time histories for scenario earthquake of Mw 8.7 Shilliong earthquake from wave number integration method at 200 borehole locations and five strong motion stations as input at rock level. The WESHAKE91 program is used for calculating the response spectra at the surface. The damping of the response spectra is not mentioned (2%, 5% etc.). It is mentioned that degradation curves for sand and rock are used. The G/Gmax vs Strain and damping vs Strain Curves used in the Analysis are not shown in figures. The soil also contains clay. It is not clear whether curves for clay are used or not. The general practice is as follows:

a.) **For Sand-** on the basis of Effective overburden pressure

b.) **For Clay-** on the basis of plasticity Index

Therefore, these curves have importance and need to be mentioned.

4.4.1 Input (Object) Motions: The description about recorded strong earthquakes which were used for site response and other mentioned studies are not given.

4.4.2 Ground Response Analysis: The synthesized acceleration time histories for scenario earthquake of Mw 8.7 Shilliong earthquake are used as bed rock motion for simulation of response spectra through WESHAKE 91. The bedrock velocity considered is not mentioned here. In view of this the ground motion estimation may be only a crude estimation. The bedrock shear wave velocity at which ground motion is simulated should be matched with the shear wave velocity of the base of the soil column.

Therefore:

1. Bedrock and its depth-velocity description at different locations are necessary.
2. Soil Modeling is also important based on Shear wave velocity from PS- logging and MASW data.

Suggestion: It is suggested to use finite source based simulation technique to estimate motion at bedrock/ Engineering bedrock/ Engineering seismic bedrock/ Engineering bed layer.

The response spectra are estimated at 200 Borehole sites and 5 strong motion sites. Twelve "Absolute Spectral Acceleration response spectra" at three velocity classifications III A (200 - 240 m/sec), III B (240 -280), III C (280 -320) m/sec are displayed but it was not discussed whether the response spectra are for average of the velocity ranges or at what velocity. The Pseudo response acceleration (spectral displacement times the square of natural frequency) is the true measure of the response acceleration for the analysis of response for designing the structures. It is also declared that these will be used for seismic design code. Therefore the plot should be plotted with pseudo response spectra (at certain damping like 5% for concrete) with period. Without that the results are not usable by civil engineers.

Suggestions:

1. Take Mean of the response spectra at a particular damping in every velocity class
2. Calculate Mean + σ

   Then prepare the Period wise maps for 0.1, 0.2, 0.3 etc for every velocity class and also the design spectra for NEHRP/UBC method.

4.5 Site Specific Attenuation Relationships in the Guwahati region:

The attenuation relationship for the area is also prepared. However,

1. The process of preparation of attenuation relationship is not mentioned in the section.
2. The need of preparation of attenuation relationship of such type is not given.
3. Why this relationship is not used in Probabilistic Seismic Hazard Assessment.
4. The relationship is not plotted with the recorded dataset for comparison; however it is compared with simulated data (Fig. 4.17)

Suggestion:

Compare the attenuation relationship with the recorded dataset. If recorded on rock then take the help of standardized amplification factors for comparing the data.

CHAPTER 5: GIS Based Thematic Mapping

5.2 Landuse:

The methodology adopted for preparation of the Landuse and Base map has considered data from Survey of India Toposheets, Satellite Imageries (LISS& PAN Scenes) and then GPS survey and Ground Check. The adopted methodology is correct and the prepared maps are reliable.

5.4 Basement Configuration and Thickness of Valley Fill: The Bedrock profiles are mentioned in the report in Fig. 5.4, Fig. 5.5 and Fig. 5.6 based on the resistivity and drilling data. The points are:

1. The locations at which resistivity survey was conducted is not given.
2. The electrode configuration used for the study is not mentioned. Normally GSI does the resistivity survey with depth of investigation upto about 30m. Hence, the bedrock

information to 200m depth appears to be on the basis of some deep boreholes for which also details are not given.

3. The basement was not defined with the shear wave velocity value. In the absence of the above mentioned raw information, the validity of the bedrock cannot be justified.

Suggestions:

1. Take the resistivity Imaging sections/ profiles with DC resistivity meters or Time Domain Electromagnetic Method to establish the major starategraphic Units.
2. The Array Mictrotremor survey is also a good tool for such study.

For the active Fault study, the following points need to be considered:

5.4 Basement Configuration and Thickness of Valley Fill: There is N number of NW-SE and NE-SW conjugate structures in the area. The area needs proper active fault mapping. The faults dimensions and style of deformation (normal, strike slip, dip slip) is not mentioned which is required. Trenching on faults is suggested.

Fig 5.8: The basement map clearly shows presence of deep linear structures and structural high in the area. The surface geological condition also shows strong structural control. It seems that these features were active in recent-past. The matter prepares a strong base for active fault study in the region.

Fig 5.9: shows presence of eight N-S, NE-SW and ENE-WSW oriented faults in Guwahati area. The focal mechanism shows thrust and strike slip motion of these faults. Putting faults and earthquake location is not sufficient database for microzonation. Identification of active faults and their capability for producing earthquakes in near future is important task for Microzonation work.

5.6 Landslide Hazard Zonation: The area is vulnerable for various mass movements either due to anthropogenic activity or due to active fault movement. For landslide study it is necessary to measure orientation of all the joint plain, density of fractures filling of fractures (material).The intersections of the joint planes to be analyzed must be exposed in the slope faces, the plunge of intersection must be less than the dip angle of the slope face and greater than the friction angle of the joint planes. No details are given. Liquefaction is an important issue which has not been addressed at all.

Suggestion: Calculate the safety factor of each and every land-slide using the formula given by Markland (1972).This will give the correct picture of activeness of landslides.

5.7 Shear Wave Velocity (Vs30): There are no. of Vs-N relations available worldwide. In the Guwahati Microzonation **Vs** is derived from **Vs-N** relationships which are given by (Mentioned at Page 47) two methods:

(i) Fumal and Tinslay (1985) for Los Angeles in California, USA of soil type clay and silty clay types (equation 3.7)

(ii) Tonouchi, et al. (1983), the area and soil types are not mentioned for this relationship

However, in Annexure-V it is mentioned that Vs values are calculated from Fumal and Tinslay (1985) relationships for different soil classes. The two statements are confusing. The Hard rock is generally considered at N~100 but in this study it is written that hard rock is considered at N> 50. Therefore, in the absence of the above mentioned justifications one cannot rely upon the VS values.

Suggestions:

(i) Acquire the VS values from MASW and PS-Logging then prepare Vs-N relationship.

(ii) The relationship should be prepared for different soil types (Sand, Silt &Gravel etc.)

5.8 Predominant Frequency: The predominant frequency map prepared through microtremor survey is reliable.

5.9 Site Response: Comments are given in chapter 4 for site response analysis.

5.10 Factor of Safety: No methodology/detail is given for load calculation.

5.12 Peak Ground Acceleration: PGA from F-K method at bedrock and at surface by WESHAKE91 is given. The shear wave velocity of bedrock is not mentioned.

CHAPTER 6: Seismic Microzonation on GIS Platform

6.3 GIS Integration and Microzonation Model:

Geological and Seismological themes are provided and weightages based on their importance for seismic hazard is given:

The PGA is the outcome of

a. Tectonic setting
b. Fault parameters
c. Basement depth
d. Magnitude potential
e. Path and attenuation &
f. Soil conditions

Once we derived the PGA or Response spectra, predominant frequency etc. from all the parameters given above from **(a)** to **(f),** then weightage in itself loses its significance. The output is the final weightage and should be given weightage 1. One can be biased for assigning weightages to different classes. PGA map or Response spectra map/values are sufficient and real representative of seismic hazard once calculated through a reliable process.

Seismic vulnerability is subject of Chapter8 and should go there.

Seismic zonation map based on some themes and on the basis of formula in equation (6.2) is something over complicated. The PGA, PGV, PGD and PSA are the outcome of the process mentioned from (a) to (f). Therefore the final Hazard map should be based on out of these (PGA, PGV, PGD and PSA) values.

CHAPTER 7: Generation of Strong Motion Data for Greater Guwahati City Region

Report has itself suggested for taking all possible earthquakes scenarios along different faults around greater Guwahati City for seismic hazard assessment.

The finite–fault consideration for strong motion simulation should be taken for seismic Microzonation work e.g. Stochastic Finite Fault Modeling technique (Motazedian and Atkinson, 2005).

CHAPTER 8: Seismic Vulnerability of buildings for Guwahati

They have prepared rapid visual screening map based on survey done with a Performa which has insufficient details. Screening map should be more detailed. The sample Performa used by ISR is attached.

RAPID VISUAL SURVEY OF BUILDINGS FOR EARTHQUAKE SAFETY			CALCULATION SHEET RC FRAME	
Falling Hazard Identifier 'F'			Seismic Zone	Base Score
Marquees/Hoardings/Roof Signs		Stories	V	
AC Units/Grillework		1 or 2	100	100
Elaborate parapets		3	90	
Heavy elevation features		4	75	
Heavy Canopies		5	65	
Substantial Balconies		> 5	60	
Heavy Cladding				
Structural Glazing				

Number of storeys	1 or 2	3	4	5	> 5	Vulnerability Score Modifiers	
Vulnerability Scores (VS)						(VSM)	(VS X VSM)
Soft Story	0	-15	-20	-25	-30	Doesn't exist=0 Exists=1	
Vertical irregularities Setbacks Buildings on Slopes	-10	-10	-10	-10	-10	Doesn't exist=0 Exists=1	-10
Plan irregularities	-5	-5	-5	-5	-5	None=0 Moderate=1 Extreme=2	0
Heavy Overhangs	-5	-10	-10	-15	-15	Doesn't exist=0 Exists=1	-5
Apparent quality	-5	-10	-10	-15	-15	Good=0 Moderate=1 Poor=2	-10
Short columns	-5	-5	-5	-5	-5	Doesn't exist=0 Exists=1	—
Pounding	0	-2	-3	-3	-3	Doesn't exist=0 Unaligned floors=2 Poor apparent quality of adjacent building=2	—
Soil Condition	10	10	10	10	10	Medium=0 Hard=1 Soft=-1	0
Frame Action	10	10	10	10	10	Doesn't exist=-1 Exists=1 Not sure=0	10
Water tank at roof capacity	0	-3	-4	-5	-5	Doesn't exist = 0 Capacity < 5000 lit = 0.5 Capacity > 5000 lit = 1	—
Location of water tank	0	-3	-4	-5	-5	Symmetric = 0 Unsymmetrical = 1	[illegible]
Basement - Full or Partial	0	3	4	5	5	Doesn't exist = 0 Exist = 1	—
						∑ [(VSM) x (VS)]	-15
Performance Score= (BS) - ∑ [(VSM) x (VS)] where VSM represents the vulnerability score modifiers and VS represents the Vulnerability Score that is multiplied with VSM to obtain the actual modifier to be applied to the Basic Score (BS).						Performance Score	85

Field Survey by: bendIP	Reviewed by: [illegible]	Approved by:
Date: 12/5/08	Date: 12/5/08	Date:

Form 2-B: Proforma for Reinforced Concrete Buildings (Second Page)

A Sample of Rapid Visual Screening Map

Suggestions for incorporating features of Seismic Microzonation Study of Guwahati City in its Master Plan:

Land use Zoning Plan 2025 of Guwahati City has shown three new areas in Guwahati city (Fig.1):

(1) New Town 1 & special scheme area in the north of the Guwahati

(2) New Town 2 in the western part of the Guwahati city

(3) New Town 3 & SEZ area in the South western part of the Guwahati city.

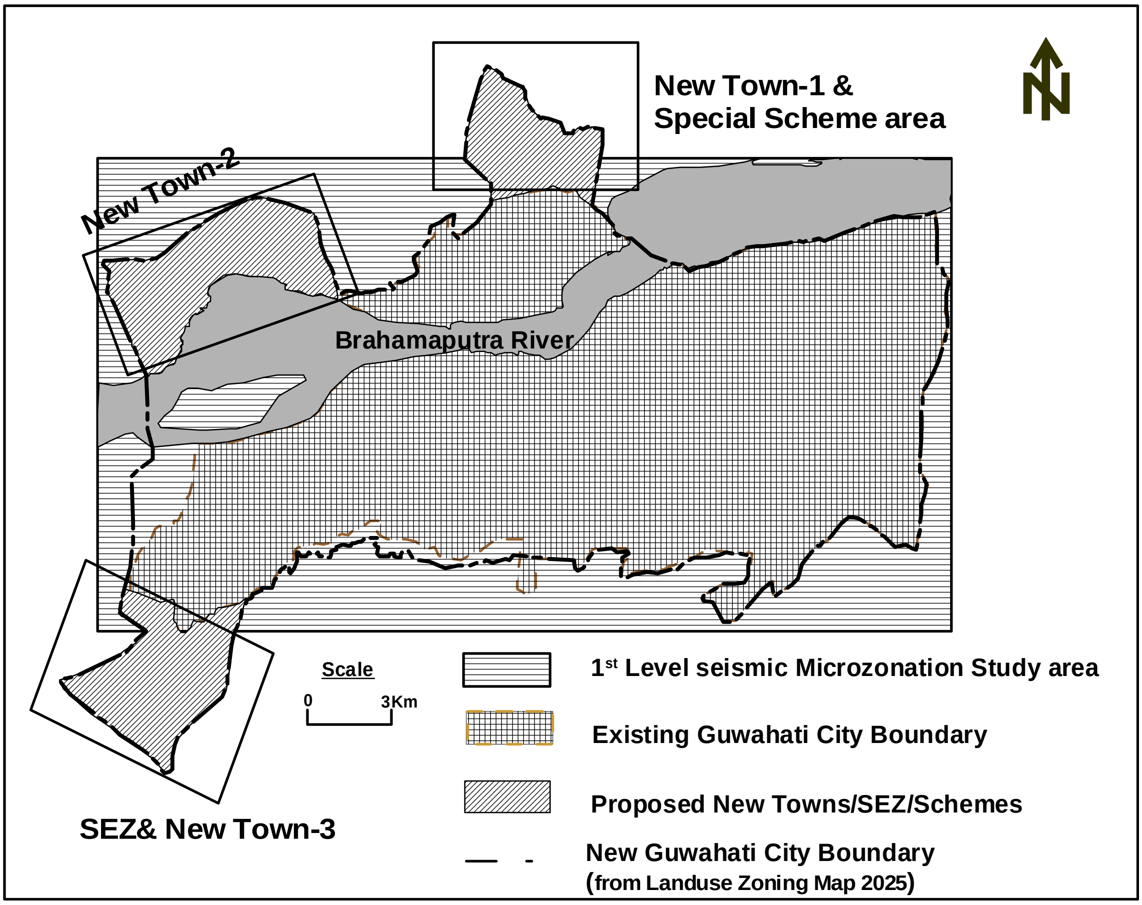

Fig.1: Guwahati city Boundary (existing and proposed in Landuse Plan 2025).

Pending suggested detailed investigation as mentioned in our report we are providing here some generalized opinion on the basis of the report on Seismic Microzonation study of Guwahati City by Department of Science and Technology, New Delhi. The points are as follws on which we broadly agree:

(1) New Town 1 & Special Scheme Area:
(i) Most of the area falls outside DST Seismic microzonation study.

(ii) The area is relatively more suitable for development than New Town-2 & New Town-3.

(iii) Although most of the area is out of the DST study area but still chances of ground acceleration of the order of 0.15 to 0.3g is expected based on the value estimated in part of the area. However, the prescribed ground acceleration for MCE is 0.36 as per the existing earthquake code and the same is in implementation by the competent development authority already.

2. New Town 2:
(i) Although the area is covered in DST Seismic microzonation study but only one borehole (no. 163) is drilled in this part. Hence it is not a well studied zone.
(ii) The area is situated on Quaternary alluvium (Bordang surface) and shown a PGA of the order of 0.3 to 0.75g (0.3-0.45g in the northeastern and eastern part, 0.45 to 0.60g in the central part while 0.6 to 0.75g in the western and southwestern part of the area. The PGA values are amplified PGA values due to site response characteristics expected in this area. These PGA values are not to be used directly for design force calculations. What is important is the micro-level mapping of predominant frequency in this area to advise on the risk level associated with type of structures. It can be advised to build structures with height restrictions so that the natural frequencies of these structures (having heights in certain range) will be isolated from the predominant frequencies at which amplifications are predicted in microzonation.
(iii) Site response/amplification of the order of 2.5 to 4.5 is mentioned in this part of the area (Chapter 3, Fig 3.9).
(iv) The area is very close to the river hence highest flood level should be checked. The Chances of Liquefaction will be high in this zone as the area is situated on Quaternary soil and on the Bank of Brahmaputra River. Liquefaction analysis is a must for any development in this area and the foundation design has to be done extremely carefully. In addition the area is susceptible to erosion so the township should be carefully planned.

3. SEZ & New Town3:
(i) The area is the south-west of the Guwahati city and most of the area falls outside DST Seismic microzonation study.

(ii) From the Geomorphological Map (Chapter 5, Fig 5.3), this area falls on Quaternary alluvium. The site amplification of 3(average from extrapolation of results (Chapter3, Fig 3.9)) is expected.

(iii) The area falls 30-50km east of the epicenter of Mw 8.7, 1897 Assam earthquake. From the present study (on extrapolation) one can expect a PGA of the order of 0.6 to 0.75g. The PGA values should be considered while designing structures in this area.

Existing Guwahati City:

The PGA in the Guwahati city is varying from 0.11g to 0.81g (Chapter5, Fig.5.20). The PGA is high in the western part 0.52g to 0.75g. While 0.15g to 0.3g is in the eastern part of the Guwahati city. In the central part of the Guwahati city, it is varying from 0.3g to 0.45g with a small patch of 0.45g to 0.6g. The western part is under high hazard. During design of structures, the PGA values of Guwahati city mentioned in the DST Seismic Microzonation report should be considered. The average normalized spectra due to recorded earthquakes at strong motion stations up to magnitude M_w 5.7 are given from Fig. 7.12 to 7.19. These spectra show Sa/g values of ~3 in the period range of 0.1 to 0.3 sec, which is higher than the Bureau of Indian Standard (BIS) suggested Sa/g value of 2.5. The Sa/g values form these given spectra should be considered for calculating the Design horizontal seismic coefficient (A_h) near the strong motion stations.

Landslide hazard should also be considered seriously in the new master plan (Landslide Hazard Zonation map is given in Chapter 5, fig 5.10 of DST seismic microzonation report) of Guwahati City.