Completion report of

Project Title: Ambient noise assisted microzonation of Tezpur and neighboring region of Assam, NER, India with simultaneous analysis of shear waves

Date of Sanction & No: MoES/PO/Seismo/1(214)/2014

Submitted by

Dr. Rajib Biswas

Principal Investigator
Department of Physics
Tezpur University
Tezpur -784028

PROJECT COMPLETION REPORT

- Title of the project: **Ambient noise assisted microzonation of Tezpur and neighboring region of Assam, NER, India with simultaneous analysis of shear waves**
- Name of the PI/Co-PI: **Dr. M.K. Das**
- Implementing Institute: **Tezpur University**
  - Other Collaborating Institutes: **NGRI, Hyderabad, NCS, New Delhi**
- Acknowledgements (Financial help from MoES to be duly acknowledged):
- Date of Sanction & No: **MoES/PO/Seismo/1(214)/2014**
- Duration of Project : **3 years and Six Months**
- Probable date of completion (PDC)
  - Original : **12/12/2017**
    - (as per sanction letter)
  - Revised (if applicable): **13/06/2018**
    - (give details of all revisions to date along with reasons for delay separately for each revision)
- Name of JRF/SRF/RA recruited under the project: **Mr. Nilutpal Bora**
- Total Project Cost : **10.68 Lacs**
- Total Expenditure : **10.44 Lacs**
- Index/table of contents

- Executive Summary

Single station ambient noise measurement in campaign mode has of late gained a huge popularity among geo-scientists. Herein, we present results of ambient vibration analysis, executed in a highly populated urban area covering 47 survey points. The resonance frequency estimates range from 0.5 to 3 Hz, as found from H/V. Taking H/V curve as input for retrieving subsurface information, we deploy diffuse field assumption theory. The obtained shear wave velocity from the inversion of H/V curve through DFA approach provides evidence of the complex nature of the subsurface geological structures. Identifying six characteristic 2D cross-sections of the entire area, we attain prevalence of a low-velocity intermediate layer with velocity ranging from 128-192 m/s. On the contrary, a relatively high-velocity layer is also obtained (279-471 m/s) which can be treated as sedimentary deposits (may be for some sites as basin basement). The attained results, when extended to a 3D shear wave

profile, tally excellently with estimated frequency distribution and its corresponding links with depth wise strata, accompanied by a topographical profile of the surveyed locations. All findings are comprehensively analyzed and interpreted as a proof of concept of implementation of DFA approach towards retrieving subsurface information.

- Introduction

Geotechnical site characterization is of prime importance so far seismic hazard is concerned. It becomes crucial for a region exhibiting active seismicity. Northeast India is characterized by active seismotectonics. It has already witnessed two devastating earthquakes. In the past recent years, there has been a rise in the no of felt tremors which has become a potential challenge for geoscientists, seismologists so far the earthquake hazard is concerned. There has been report of damage of property. It is a matter of concern that most of the populous cities of Assam are actually located in alluvial sediments and river banks. This year (2013), there has been instrumental records of twenty five felt earthquakes in Assam having magnitudes of 3.1 to 5.4 (Mw) till now. Tezpur, the proposed study area, is a small township in Assam, being a commercial hub and a tourist spot with a considerable population density. During last ten years, more than seventy moderate earthquakes had jolted Tezpur and its vicinity. Of late, there has been a considerable rise in the no. of earth tremors. Out of that, more than five earthquakes had its epicenter in and around Tezpur, having the highest magnitude of 4.5. All of them were felt earthquakes. Very recently, a 5.4 (Mw) earthquake jolted Tezpur and its vicinity on November 6, 2013. The epicenters of the earthquakes were merely 80 km from it. There were reports that it caused damages to buildings. Looking at this recent rise of small to moderate felt ground motions, it is customary to look into the hazard aspect. Because, it is already established potential threat in the context of damage occurs when there is a prolonged duration of ground shaking regardless of small magnitude of earthquakes.

Particularly, settlements where there is a predominance of Holocene sediments are largely influenced by ground motion compared to more competent bedrock strata. The proposed study area is no exception. Over the years, the city has expanded tremendously. As a matter of fact, more

settlements are growing due to rising population. There is a need to make an assessment of this rapidly growing city in terms geotechnical parameters such as predominant frequency, shear wave velocity etc. which will pave the way for other scientific research. Moreover, with assistance from civil engineering department, site classification can also be accomplished with special emphasis on building codes.

Basically, shear wave velocity is a function of frequency which is dispersive in nature. The dispersive character of which can be efficiently exploited to reveal underlying one dimensional velocity model pertaining to a study area. Estimation of shear wave velocity profile at a particular site is the imminent requirement towards assessment of seismic hazard. Utilization of the data obtained from the ambient noise survey with an array of sensors towards estimations of shear wave velocity, has drawn attention among the researchers. Simultaneously, subsoil structure could also be assessed while estimating shear wave velocity profile.

Seeing the rise in the no. of felt tremors in this seismically active region, a systematic and comprehensive survey of geo-hazards is a must in order to quantify hazards. Although we cannot avert or predict natural calamities in the form of earthquakes, flash floods; but, the hazards can be mitigated with a well defined strategy up to a considerable extent.

In view of these facts, it is proposed to execute a detailed microzonation study for Tezpur and its adjoining areas which would include ambient noise survey as per equispaced formulation, array noise survey with incorporation of multi channel analysis of shear waves and amalgamation of these findings with available geophysical geotechnical data.

- Review of literature & rationale for study

  India has witnessed most disastrous earthquakes (M 8.7), Kangra 1905(M8.6), Bihar-Nepal 1934 (M 8.4), Assam-Tibet 1950(M 8.7), Uttarkashi 1991 (M 6.5), Latur 1993(M 6.4), Jabalpur (M 6.0), Chamoli 1999(M6.8), Bhuj 2001(M7.6) and Kashmir 2005(M7.4) in the recent past. In accordance with the zonation map of India (BIS-1983, 2002), entire country is categorized into four seismic zones of various expected probable intensities of earthquake occurrence based

on effective PGA values as comprehensive intensity scale (CIS-64)(BIS-1893, 2002). In 1992, the Global Seismic Hazard Assessment program was launched with the objective of preparing a global seismic hazard map in a harmonized and in a regionally coordinated fashion and having a strategy of establishing regional centers, which were responsible for the coordination and realization of the four basic elements of seismic hazard analysis. The GSHAP has classified the Indian peninsula into several seismogenic zones based on the seismicity and tectonic group. Bhtia et al., 1999 under GSHAP program estimated the seismic hazard for the Indian region using probabilistic approach.

After Gujarat was badly hit by 2001 earthquake, stress was laid out on seismic microzonation which slowly gained its importance as guiding tool in land use planning and safe construction practices to avoid the loss from future earthquakes. As a result of this, seismic microzoonation of various urban areas, like Delhi, Chennai, Bangalore, Lucknow, Ahmendabad etc., are being carried out by different researchers in the country. Severity of shaking is closely related to local site conditions. Basin effect generally influences long-period wave energy and cause amplified motion in high-rise building and multi-span bridges. Scattering alters the short-period wave energy that affects shorter structures. Impedance contrast affects the amplitude and phase of both short and long period wave. Detailed analysis of macroseismic data of past earthquakes, if available, with reference to topographic and geotechnical maps may lead to qualitative appraisal of most hazardous zone. As a part of National effort, Department of Science & Technology had initiated a mandate for implementation of micro-zoning project at capital cities of India. As a result of this, broad seismic microzonation was carried out in Guwahati, the capital city of Assam and full report with relation to this was prepared which provide as a basic information kit for structuring buildings. Likewise, the proposed work is also an attempt to bring out a detailed report entailing all possible aspects of microzoation work.

The first attempt of seismic microzonation of any urban area i.e. an industrial as well having higher population density was carried out in city of Yokohama, Japan in 1954 taking into account various zones,

corresponding soil conditions and design seismic coefficients for different types of structures located in that different zones. In the light of immense usefulness of it, microzonation work was conducted in earthquake prone areas of the World (Marcellini et al., 1998; Chavez-Garcia and Cuenca, 1998; Lungu et al., 2000; Faccioli and Pessina, 2001; Fäh et al., 2001; Alfaro et al., 2001; Ansal et al., 2004). Slob et al. (2002) proposed a technique for microzonation for the city of Armenia in Colombia exploiting a 3D layer model in GIS, amalgamated with a 1D calculation of seismic response using SHAKE to get the spatial variation in seismic response. After checking this with the damage assessment of Armenia, they inferred higher amplification in the range of 5 Hz for two storied buildings which proved correct after earthquake where more occurred in case of low rise buildings relative to high rise ones. Besides, Topal et al. (2003) considered various parameters for microzonation such as geological, geotechnical, seismo-tectonic and hydro-geological conditions and on the basis of these, four different zones was proposed for the Yeneshir an urban area in Turkey. Similarly, Ansal et al., (2004) adopted a probabilistic approach in a microzonation study for the city of Siliviri, Turkey and estimated the local geological and geotechnical on the basis of the available borehole data and laboratory test result. For site characterization the average shear wave velocity was used, that was determined from seismic refraction tests.

Recently, microzonation through ambient vibrations or microseisms survey has recently got vast attention amongst geoscientist's community. There is obvious reason too. Actually, if micro-zoning of a region is accomplished through recording of earthquakes, it requires a lot of time and become very expensive too so far equipment and manpower are concerned. In contrast to this, the zonation can be very rapidly done by exploitation of omnipresent ambient noise. Besides, ambient noise survey provide quick access to the amplification behavior and other associated parameters which enable one to map one area at a faster rate compared to earthquake survey due to rapid data acquisition and interpretation. As a matter of fact, after the classic work of Nakamura, 1989, as modified by Bard et al, 1999, microtremors were recognized globally as an effective tool for

microzonation. In 2004, a European research project WP12-Deliverable d23.12 named SESAME (Site Effects Assessment using Ambient noise excitation) was implemented wherein the utility of ambient vibrations towards computation of several component parameters was exercised leading to estimation of site response. Subsequent to SESAME, 2004 project, lot of research works (Wathelet, 2004, Wathelet et al., 2005; Ohnberger et al., 2004 a,b;Guillier et al., 2007, Soriau et al., 2007, Lombardo et al., 2007, Raptakis et al., 2010, Mundepi and Mahajan, 2010; Nath et al., 2010) was executed in many parts of the world using ambient vibrations with different approaches in order to evaluation of site response complementing microzonation. With advent of technology advancement in terms of seismic instrumentation, the seismic microzonation work has witnessed inclusion of many additional aspects, assisted refraction survey, more sophisticated geological probes. With incorporation of geotechnical and geological inputs, the ambient noise assisted microzonation approach for an urban area has become very robust and widely applied everywhere in the international scenario.

- Aims & Objectives (Objectives as approved/Deviation made from original objectives if any, while implementing the project and reasons thereof).

  - ✓ *Site survey.*
  - ✓ *Gridding of the study area through equispacced points.*
  - ✓ *Determining the predominant frequency by adopting Nakamura Technique.*
  - ✓ *Collection as much as borehole points and geotechnical report.*
  - ✓ *Setting up of temporary array at neighboring points of the borehole.*
  - ✓ *Determination of shear wave velocity profile.*
  - ✓ *Subsoil profile delineation through multichannel analysis of shear waves.*
  - ✓ *Preparation of hazard map (inclusive of land-use planning and vulnerability) of the studied area.*

    As per the objectives stated above, subsoil profile delineation through multichannel analysis could not be executed. During the approval of the project, MASW was approved. As per equipments concerned, nothing was approved. All the instruments were provided from

National Geophysical Research Institute, Hyderabad for duration of six months.

- Methodology (Giving full details of study design, methods adopted, data collected supported).
    - ✓ *With the help of Modified Nakamuras' Technique (as Modified by Bard et al., 1999), predominant frequencies would be determined from ambient noise records accrued at the proposed area as per grid formulation*
    - ✓ *Subsequent estimation of H/V ellipticity from the estimates of predominant frequency*
    - ✓ *Through Modified Spatial Autocorrelation and Frequency Wavenumber Technique, derivation of velocity dispersion curves from array noise data gathered at selective locations of the study area.*
    - ✓ *Inversion of dispersion curves in order to arrive at the best shear wave velocity models through Neighborhood Algorithm(Sambridge, 1999)*
    - ✓ *Exploration of consistency of the obtained models with MASW experimental data.*
    - ✓ *Further validation through geological, morphological and geotechnical input to be accrued from different Govt. Agencies.*
    - ✓ *Preparation of Hazard Map/Land use Map with inclusion of all these estimated parameters.*

- Summary of the result (Detailed analysis of results indicating contributions made towards increasing the state of knowledge in the subject).

    - ✓ *The proposed work envisages preparing a hazard map for Tezpur City in the context of land-use pattern and other socio-economic parameters which will act as future reference for town planning. Furthermore, the vulnerability assessment that would be covered by this work would help identify risk factor during building construction. Likewise, the overall mapping of the study area in the light of fundamental frequency help plan the high-rise structures which are more prone to ground motion.*

- Achievements and how the deliverables have contributed in the overall programmes of the Ministry

  During the execution of the project, the following deliverables have been achieved.

  a) A total of 70 sites in and around Tezpur City have been surveyed.

  b) Array analysis was conducted at these locations just in the immediate neighborhood of borehole.

  c) Post survey, the fundamental frequencies are assessed for the study region.

  d) Apart from this, the attenuation profile of Kopili region is exclusively detailed.

e) Through proper amalgamation of ambient noise measurements and earthquakes data, the shear wave velocity profiles are evaluated through diffuse field concept.
f) Again, DFA theory has been applied successively ti invert H/V curves to arrive at the underneath layers.
All these achievements made through project will prove beneficial for other ground work in microzonation. Even the vulnerability mapping will act as a valuable input for proper planning.

- Scope for future:
  The proposed work envisages preparing a hazard map for Tezpur City in the context of land-use pattern and other socio-economic parameters which will act as future reference for town planning. Furthermore, the vulnerability assessment that would be covered by this work would help identify risk factor during building construction. Likewise, the overall mapping of the study area in the light of fundamental frequency help plan the high-rise structures which are more prone to ground motion.

- Publication of results/presentation of papers (to be clearly mentioned that MoES is not responsible for any result interpretations expressed in the report):
  The interpretations of result in the published works do not make MoES responsible.
  - ✓ N. Bora, **R. Biswas**, Quantifying Regional Body Wave Attenuation in a Seismic Prone Zone of Northeast India, Pure and Applied Geophysics, 2017, (174), 1953-1963.
  - ✓ N. Bora, **R. Biswas** and D. Bora, *Assessing attenuation characteristics prevailing in a seismic prone area of NER India*, IOP: Journal of Geophysics and Engineering, 2017, (14) 1368–1381
  - ✓ N. Bora, **R. Biswas** and A. Dobrynina**,** *Regional variation of coda Q along Kopili fault and its implications***,** Tectonophysics, 722, 235-248, 2018.
  - ✓ N. Bora *and* **R. Biswas**, *Delineation of subsurface profiles beneath the Kopili fault zone in northeast India utilizing coda portion*, Journal of Asian Earth Sciences, doi: 10.1016/j.jseaes.2019.01.023
  - ✓ N. Bora and **R. Biswas**, *P- and S- wave attenuation in Kopli region of northeast India*, Annals of Geophysics
- Capacity Building - No. of B.Tech/M.Tech/Ph.D.s etc. out of the project- **One Ph. D.**
- No. of Workshops conducted if any, related to the project along with date & name of the workshop- **NIL**
- Abstract in 300 words for possible publication on MoES Newsletter/Website.
  Single station ambient noise measurement in campaign mode has of late gained a huge popularity among geo-scientists. Through this work, ambient vibration analysis has been executed in a highly populated urban area covering 47 survey points. In total, data accrued in 71 locations which was also inclusive of three array noise measurements. The resonance frequency estimates range from 0.5 to 3 Hz, as found from

H/V. Taking H/V curve as input for retrieving subsurface information, we deploy diffuse field assumption theory. The obtained shear wave velocity from the inversion of H/V curve through DFA approach provides evidence of the complex nature of the subsurface geological structures. Identifying six characteristic 2D cross-sections of the entire area, we attain prevalence of a low-velocity intermediate layer with velocity ranging from 128-192 m/s. On the contrary, a relatively high-velocity layer is also obtained (279-471 m/s) which can be treated as sedimentary deposits (may be for some sites as basin basement). The attained results, when extended to a 3D shear wave profile, tally excellently with estimated frequency distribution and its corresponding links with depth wise strata, accompanied by a topographical profile of the surveyed locations. All findings are comprehensively analyzed and interpreted as a proof of concept of implementation of DFA approach towards retrieving subsurface information. Apart from this, the quality factors have been deciphered for Kopili and its' neighboring region, assisted shear wave velocity profiling of the underneath region.

(22/04/2019)
Dr. Rajib Biswas
Name and signature with date
(Principal Investigator)

UTILISATION CERTIFICATE

(For the financial year: 1st April 2018 to 13th June 2018)

1. **Title of the Project/ Scheme: Ambient noise assisted micro zonation of Tezpur area and its neighboring regions, Assam, NER, India with simultaneous multi-channel analysis of shear waves.**

2. **Name of the Institution :Tezpur University**

3. **Principal Investigator :Dr. Rajib Biswas**

4. **Ministry of Earth Sciences sanction order No & date sanctioning the project:** **MoES/P.O. (Seismo)/1(214)/2014 Dtd 13/12/2014**

5. **Amount brought forward from the previous Financial year quoting MoES letter no & date of sanction order showing the amount paid**

i. Amount:	**Rs. 61,609/-**
ii. Letter/Order No.	MoES/P.O. (Seismo)/1(214)/2014
iii. Date:	28/08/2018

6. **Amount received during the financial year (Please give MoES letter/order no and date)**

i. Amount:	**NIL**
ii. Letter/Order No.	--
iii. Date:	--

7. **Other receipts/interest earned, if any on MoES grants : NIL**
8. **Total amount that was available for expenditure : Rs. 61,609/- Incurred during the financial year (S. No 5, 6 and 7)**

9. **Actual expenditure (excluding commitments) incurring during the financial year : Rs. 43,455/- (1st April '18 to 13th June,'18) (Statement of expenditure is enclosed)**

10. **Unspent balance to be refunded, if any (please give details of cheque no etc) : Rs. 18,154/-**
10. **Balance amount available at the end of the financial year (13th June,'18) : Rs. 18,154/-**

12. **Amount to be carried forward to the next financial year (if applicable) : Rs. 18,154/-**

18/9/18

Finance Officer
Tezpur University

1. **Certified that the amount of Rs. 43,455/- mentioned against col. 9 has been utilized on the project/scheme for the purpose for which it was sanctioned and that the balance of Rs. 18,154/- remaining unutilized at the end of the year will be adjusted toward the grants in aid payable during next year.**

2. **Certified that rules under GFR have been followed for procuring the equipments under the project.**

3. **Certified that I have satisfied myself that the condition on which the grants in aid was sanctioned have been duly fulfilled /are being fulfilled and for procuring the equipments under the project, rules under GFR are followed and that I have exercised the following checks to see that money was actually utilized for the purpose for which it was sanctioned.**

Kinds of checked exercised:

1
2
3
4
5

Date:

Signature of Project Investigator

Signature of Head of the Institute
Registrar
Tezpur University

Signature of Finance Officer
18/4/18
Finance Officer
Tezpur University

(To be counter signed by MoES officer-in charge)

TEZPUR UNIVERSITY

NAPAAM,SONITPUR, ASSAM-784028

HEADWISE REPORT

PROJECT

FROM DATE:- 01-APR-2018 TO DATE:- 27-DEC-2018

HEAD NAME: MOES-DR. RAJIB BISWAS- "AMBIENT NOISE ASSISTED MICROZONATION.....ANALYSIS OF SHEAR WAVES

PARTICULARS	DEBIT(IN RS.)	CREDIT(IN RS.)
OPENING BALANCE	**0.00**	**61609.00**
CONSUMABLES	30853.00	0.00
INTEREST ON BANK(P-III)	0.00	6772.00
TRAVEL	12602.00	0.00
TOTAL:	**43455.00**	**6772.00**
CLOSING BALANCE:	**24926.00**	**0.00**
GRAND TOTAL:	**68381.00**	**68381.00**

Dr. Rajib Biswas
Department of Physics
Phone: +91-3712-275564(o)
+91-99543139709(m)
Email id: rajib@tezu.ernet.in

Tezpur University
(A central University)
Phone : +91-3712-267007/8/9
Fax: +91-3712-267005/6
Napaam, Tezpur, Assam, India, Pin - 784 028

Date 08/02/2019

To
The Joint Registrar (Finance)
TU

Sub: Return of Balanced Amount to Ministry of Earth Sciences

Sir,

Refer to the subject cited above.

It is for your kind information that the MoES Project [Sanction order no- **MoES/P.O.(Seismo)/1(214)/2014** Date of Sanction **13/12/2014**] has been completed and there is an unspent balance of Rs 24926/-(Rs 18154 +Rs. 6772).

In view of that, you are requested kindly to issue a demand draft of those unspent balance favoring DDO, MoES, New Delhi

Thanking you in anticipation,

With regards

(Dr. Rajib Biswas)

Assistant Professor
Dept. of Physics
Tezpur University

Duration of Project: 13/12/2014 to 13/06/2018

Copy to Dean R & D

Enclosure:
a) Unspent disclosure
b) Mail received from MoES